А.В. Гоберман

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МЕЖДУНАРОДНЫЙ
ГЕОЛОГИЧЕСКИЙ
КОНГРЕСС

ТЕЗИСЫ
ABSTRACTS

Volume IX, Part 1

SPECIAL SESSION
OF THE INTERNATIONAL
"LITHOSPHERE" PROGRAMME

COLLOQUIA 01 to 06

PLENARY MEETING
"GEOLOGICAL ASPECTS OF
ENVIRONMENTAL PROTECTION"

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"METALLOGENESIS AND
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ИЗДАТЕЛЬСТВО «НАУКА»
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Том 1X, часть 1 тезисов, представленных к 27-му Международному геологическому конгрессу включает специальную сессию по Международной программе "Литосфера", Коллоквиумы 01-06, пленарное заседание "Геологические проблемы охраны окружающей среды" и специальный симпозиум "Металлогения и месторождения урана". Тезисы, представленные ведущими учеными-геологами из разных стран мира, отражают вопросы теоретической и прикладной геологии.

Volume 1X, part 1 of abstracts presented for the 27th International Geological Congress includes Special Session of the International "Lithosphere" Programme, Colloquia 01 to 06, Plenary Meeting "Geological Aspects of Environmental Protection" and Special Symposium "Metallogenesis and Uranium Deposits". The abstracts submitted by leading scientists from various countries of all over the world cover problems of theoretical and applied geology.

Ответственный редактор

Н.А.БОГДАНОВ

П Р Е Д И С Л О В И Е

Тезисы, представленные к 27-му Международному геологическому конгрессу, распределяются по 22 секциям и 6 коллоквиумам. Кроме того, в их число включены тезисы докладов к пленарному заседанию "Геологические аспекты охраны окружающей среды", к специальной сессии по Международной программе "Литосфера" и к симпозиуму "Металлогения и месторождения урана".

Все тезисы опубликованы в десяти томах и распределены следующим образом:

том 1 - секции 01-03
том П - секции 04-05
том Ш - секции 06-07
том 1У - секции 08-09
том У - секции 10-11
том У1 - секция 12
том УП - секции 13-16
том УШ - секции 17-22
том 1Х - пленарное заседание "Геологические проблемы охраны окружающей среды", коллоквиумы 01-06, программа "Литосфера", симпозиум "Металлогения и месторождения урана", а также тезисы, присланные в Оргкомитет после 1 ноября 1983 года
том Х - авторский указатель.

Следует отметить, что в каждой секции и коллоквиуме тезисы расположены в алфавитном порядке (латинском) по фамилии авторов.

Н.А.БОГДАНОВ
Генеральный секретарь
Оргкомитета

P R E F A C E

Abstracts presented for the 27th International Geological Congress are divided up into twenty two sections and six colloquies. On top of this we have added the abstracts submitted for the Plenary Meeting "Geological Aspects of Environmental Protection", for the Special Session of the International "Lithosphere" Programme and for the Special Symposium "Metallogenesis and Uranium Deposits".

The whole is published in ten volumes divided up in the following way:

volume I - Sections 01 to 03,
volume II - Sections 04 to 05,
volume III - Sections 06 to 07,
volume IV - Sections 08 to 09,
volume V - Sections 10 to 11,
volume VI - Section 12,
volume VII - Sections 13 to 16,
volume VIII - Sections 17 to 22,
volume IX - Plenary Meeting "Geological Aspects of Environmental Protection", Colloquies 01 to 06, Special Session of the International "Lithosphere" Programme and Special Symposium "Metallogenesis and Uranium Deposits" as well as abstracts received by the Organizing Committee after November 1, 1983.
volume X - General authors index.

Lastly, for each section and colloquium, the abstracts are classified in alphabetical order of the authors.

N.A.BOGDANOV

General Secretary
of the Organizing
Committee

СПЕЦИАЛЬНАЯ НАУЧНАЯ СЕССИЯ ПО МЕЖДУНАРОДНОЙ ПРОГРАММЕ "ЛИТОСФЕРА"

SPECIAL SCIENTIFIC SESSION OF THE INTERNATIONAL "LITHOSPHERE" PROGRAMME

L.01. Эволюция осадочных бассейнов и их минеральные и энергетические ресурсы

Evolution of Sedimentary Basins and their Mineral and Energy Resources

L.02. Тихоокеанское складчатое кольцо и эволюция Тихоокеанского бассейна

Circum-Pacific Orogenic Belts abd Evolution of the Pacific Ocean Basin

L.03. Архейская литосфера и эволюция коры на ранней стадии истории Земли

Archaean Lithosphere and Early Crustal Evolution

L.04. Современные и четвертичные движения плит

Recent and Quaternary Plate Motions

L.06. Геохимическое и геофизическое моделирование тектоники плит

Geochemical and Geophysical Modelling of Plate Tectonics

L.07. Геологические, геофизические и геохимические параметры глубинных структур континентов и океанических бассейнов

Geological, Geophysical and Geochemical Constraints on the Deep Structure of the Continents and Ocèan Basins

L.08. Сверхглубокое бурение на континентах

Deep Continental Drilling

L.09. Поиски и освоение подземных вод в полупустынных зонах

Groundwater Exploration and Development in Semi-Arid Zones

L.10. Динамика земной коры в протерозое и эволюция литосферы

Proterozoic Crustal Dynamics and Lithospheric Evolution

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MECHANISM OF FORMATION OF DEEP BASINS ON THE CONTINENTAL CRUST

Formation of large deep basins on continental crust is usually explained by stretching. This phenomenon produces large deformations in the upper crust that are observed in some rift valleys. Many past basins on continental crust were strongly folded. The structure of their sedimentary cover was well studied in numerous sections. There are no deformations typical of stretching in the predominant part of the sections. Hence in most cases formation of the above basins was not caused by stretching.
There are two main types of large deep basins on continental crust. The basins of the first type are formed in cratonic areas by large magnitude subsidence in a few m.y. Rapid subsidence without significant stretching in cool areas may be explained by gabbro to eclogite transformation in the lover crust. Rapid transformation can arise under the upwelling to the crust of a hydrous low-velocity mantle of moderate temperature $T \sim 800°C$. Sinking of dense eclogite into the mantle strongly attenuates the crust and lithosphere. That is why strong crustal shortening often occurs in such basins.

The basins of the second type are deep cratonic sedimentary basins formed by compensated subsidence during the period of time of several hyndred m.y. of more. Their formation can be attributed to slow eclogitization in the lowermost crust within the lithospheric layer of a high thickness $\gtrsim 100$ km. Intense crustual shortening does not take place in such basins, until rapid subsidence occurs in them.
The basins of the above two types cover mush wider area than narrow continental rift valleys - typical structures produced by stretching. Basic mechanisms for the continental crust subsidence premit to determine geodynamic for the formation of hydrocarbon basins.

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МЕХАНИЗМ ОБРАЗОВАНИЯ ГЛУБОКИХ ПРОГИБОВ НА КОНТИНЕНТАЛЬНОЙ КОРЕ

Образование крупных глубоких прогибов на континентальной коре большинство исследователей объясняет растяжением. Сильное растяжение приводит к большим деформациям в верхней части коры, которые наблюдаются в ряде рифтовых впадин.

Многие древние прогибы на континентальной коре были вовлечены в интенсивную складчатость. Строение их осадочного чехла хорошо изучено в многочисленных разрезах основных фанерозойских складчатых поясов: Альпийского, Уральского, Верхоянского, Аппалачей, Северо-Американских Кордильер, каледонид и герцинид Западной Европы. В подавляющем большинстве случаев в нём отсутствуют деформации, характерные для сильного растяжения. Следовательно, образование таких прогибов, как правило, не было обусловлено растяжением.

Выделяются два основных типа глубоких прогибов на континентальной коре. Прогибы первого типа формируются на платформах за несколько млн. лет в результате погружений большой амплитуды. Такие быстрые погружения без сильного растяжения в холодных областях можно объяснить переходом габбро в эклогит в нижней части коры. Быстрый переход возникает при подходе к коре водосодержащей аномальной мантии с умеренной температурой $T \sim 800^{\circ}C$. Последующий отрыв и погружение тяжелого эклогита в мантию сильно утоняет кору и литосферу. Поэтому большинство таких прогибов в дальнейшем вовлекается в сильное сжатие.

Прогибы второго типа это глубокие платформенные осадочные бассейны, образованные компенсированным прогибанием за время в сотни млн.лет и более. Их формирование можно связать с медленной эклогитизацией в нижней части коры, протекающей в пределах литосферы большой мощности $\gtrsim 100$ км. Такие прогибы не вовлекаются в сильное сжатие до тех пор, пока в их пределах не происходит быстрого погружения, характерного для прогибов первого типа.

Прогибы описанных типов покрывают в сумме много большую площадь, чем узкие континентальные рифтовые впадины - типичные структуры, образованные растяжением.

Знание основных механизмов погружений континентальной коры позволяет определить геодинамические условия образования нефтегазоносных бассейнов.

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APPALACHIAN THRUSTING, LITHOSPHERIC FLEXURE AND THE PALEOZOIC STRATIGRAPHY OF THE EASTERN INTERIOR OF NORTH AMERICA

The Appalachian Basin is interpreted to be a multistage foreland basin developed by lithospheric downwarp under the loads of successive Taconic, Acadian and Alleghanian overthrusts in the adjacent Appalachian Mountains. By quantifying this model we show how the stratigraphic record of the foreland basin can be used to constrain the timing, areal distribution and thickness of the orogenic overthrusts. The cumulative present-day thickness of these allochthonous units is suggested to range from 4 to 18 km. We suggest that, for reasons of isostatic balance, these thick overthrusts are likely to rest on the old Cambro-Ordovician continental margin, a conclusion also in keeping with, but independent of, COCORP results. The distribution of model loads is qualitatively correlative with observed patterns of regional Bouguer gravity anomalies.

Flexural interactions between the Appalachian Basin and the contemporaneous intracratonic Michigan and Illinois Basins produced the interbasinal Kankakee, Findlay-Algonquin and Cincinnati Arches as well as the Jessamine and Nashville Domes. These arches and domes fluctuated between submergent and emergent conditions, alternately yoking together and decoupling the foreland basin and one or both of the intracratonic basins. The location and magnitude of Appalachian overthrusting and the lithosphere's rheological behaviour are the primary controls on arch development. The most satisfactory stratigraphic results are achieved using a lithospheric model with a temperature dependent Maxwell viscoelastic rheology.

We propose no explanation for the initiation of subsidence in the intracratonic Michigan and Illinois Basins. Nevertheless, we show that the sediment record of these basins is likely to have been substantially modified by the influence of Appalachian overthrusts. This influence should be removed before attempting to interpret the sedimentary record of the intracratonic basins in terms of a basin initiating mechanism.

Viscoelastic relaxation is shown to provide a natural explanation for the unconformities that bound Sloss' sedimentary sequences in those parts of the basins well removed from the overthrusts. Sloss' sequences are seen as marking intervals of major orogenic overthrusting in the Appalachians.

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PROBLEMES DE LA RECHERCHE DES ACCUMULATIONS D'HYDROCARBURES SOUS LES TRAPPS

Les Trapps sont largement répandus dans les aires continentales. On les connait d'âges divers, affleurant ou ensevelis. Dans certaines régions, ils surmontent les formations à hydrocarbures. Les principaux problèmes qui se posent à la recherche du pétrole et du gaz sous les trapps sont: 1 - Origine, migration et accumulation des hydrocarbures - 2 - Répartition et type de pièges - 3 - Etancheité des Trapps. Le Sahara algérien est une région unique au monde à possèder de nombreux gisements de pétrole découverts sous les Trapps. Ces Trapps d'âge Triasique, composés de basaltes et de dolérites ophitiques à faciés tholeitique, transformés en partie en spillites ont été traversés par 150 puits à une profondeur variant entre

1500 m et 3500 m. Ces Trapps couvrent une superficie d'environ 60 000 km^2 avec une épaisseur de 40 m en moyenne. L'épaisseur maximum enregistrée est de 140m. Ces Trapps renferment jusqu'à 10 nappes éruptives superposées. leur apparition est dûe à la fracturation de la Pangée au début du secondaire, accompagnée d'émissions rythmiques de magma basique le long des failles d'orientation Nord-Est. Les Trapps surmontent la discordance hercynienne et la série inférieure Triasique polygène (alluviale, deltaïque et lagunaire) qui renferment 14 accumulations d'hydrocarbures du type anticlinal et stratigraphique *écranisées parfois* par des Trapps. On a relevé également du pétrole accumulé entre les nappes éruptives. Le pétrole est venu du Primaire, dont les assises le renferment encore en partie. Les zônes faillées à *gradient géothermique élevé ont favorisé la formation* et la migration verticale des hydrocarbures.
Les reconstructions paléotectoniques et paléogéographiques, l'analyse séquentielle, la sismique, les prospections gravimétrique et magnétométrique sont utilisées pour la reconnaissance des formations sous-trapps.
Ces formations présentent un intérêt pétrogazifère en Sibérie orientale et occidentale, en Algérie de l'Ouest et Sud, dans la zône Est de l'Amérique du Sud etc.

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STRUCTURAL DEVELOPMENT AND REGIONAL SETTING OF THE BASS BASIN, S E AUSTRALIA

In 1982 the Bureau of Mineral Resources carried out a 3200 km, high quality seismic reflection survey in Bass Strait, between mainland Australia and Tasmania. The survey was centred on the Bass Basin, but was tied to the adjacent Gippsland and Otway Basins and continental margins. The superior quality of information on the Cretaceous-Palaeocene rift-stage of these basins has led to a new interpretation of the development of the Bass Basin and its regional setting. During the early Cretaceous, the Bass, Gippsland and Otway Basins developed as parallel, extensional basins with major rotational normal faults trending about 290°. A series of transform-like wrench faults connected the main basin segments. Kinematic reconstructions of the major normal faults in the Bass Basin indicate extension during the Early Cretaceous with $\simeq$ 1.7.
The published structural interpretations of the region have overemphasised younger structures that are superimposed on/the major Cre-

taceous faults. For example, the north-easterly trending structures evident in the onshore Cretaceous (including the Mornington-King Island rise) are late Tertiary to Recent, and the east-west wrench faults that dominate the Gippsland Basin are post-Eocene. The parallelism of the Cretaceous rift trends in the three basins casts doubt on the various triple-junction and aulacogen interpretations previously favoured for the region. An alternative kinematic model will be presented.

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THE EARLY PALEOZOIC HISTORY OF AUSTRALIA

A recent compilation of continent-wide Australian palaeogeographic data clarifies the nature and extent of climatic, sea-level and sedimentological changes during the Cambro-Ordovician. A total of ten time slices distinguished on the basis of major time breaks, or fundamental changes in the style of sedimentation are used as the time framework for the paleogeographic maps. Through these maps it is possible to relate features such as occurrence of phosphorites and organic rich sediments to high sea-level stands during the Cambro-Ordovician. The development of a transcratonic seaway in the middle Cambrian, and again in the Ordovician was also a very important feature in the extension of nutrient-rich conditions far onto the craton. Some difficulty was experienced in relating cratonic and "geosynclinal" events because of the lack of good biostratigraphic control in some parts of the sequence. Despite this, an attempt has been made to present an integrated palaeogeographic picture throughout the Cambro-Ordovician for all parts of the continent. Inevitably this is model-dependent in the "geosyncline". The palaeogeographic maps are useful not only for elucidating the history of the continent but also for establishing the known and inferred distribution of sedimentary mineral deposits and fossil fuels and the reasons for that distribution.

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THE KEWEENAWAN RIFT (PROTEROZOIC) OF NORTH AMERICA: BASINS AND RESOURCES

The Keweenawan province defines an intraplate rift that extends from Kansas northeastward to Lake Superior where it trends eastward and then southeastward into lower Michigan. The belt of Keweenawan rocks is 2000 km long, is typically 150 km wide, and lies maily discordant to the structural grain in older Precambrian rocks. Age limits are poorly known, but most Keweenawan rocks fall in the 1300-1000 m.y. range. The Keweenawan Supergroup consists of a lower clastic sedimentary unit (100 m), a middle volcanic unit (10 km), and an upper sedimentary unit (8 km). The Keweenawan belt forms a crustal syncline, locally asymmetric, with an axial horst along much of its length. Near western Lake Superior the northwestern limb dips gently but the southeastern limb quite steeply. The tectonic evolution can be divided into three stages: 1) crustal extension with subsidence, eruption, and deposition; 2) crustal shortening with steepening of one limb of the syncline; and 3) uplift of axial horst with deposition in flanking basins. Keweenawan volcanic and sedimentary rocks contain important copper deposits, and metal sulfides occur in some mafic intrusive rocks. Paleozoic basins overlie the Keweenawan rift, but their origin is enigmatic. One of these, the Michigan basin, has important oil and evaporite resources.

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EVOLUTIONARY SIMILARITIES AND DIFFERENCES BETWEEN COAL BASINS OF THE EQUATORIAL EURAMERICAN COAL BELT OF THE CARBONIFEROUS

During the Carboniferous three genetically different basin types developed in the equatorial zone of Laurussian (foredeep, intermontane intracratonic). They provided ample opportunities for the development of peat swamps in wetlands of coastal, deltaic and alluvial plains. Uniform climate and lack of separating major oceans led for a basically global tropical plant community. Much drier conditions evolved around the Westphalian/Stephanian boundary, probably because of northward drift and possibly mountain building. Sediment accumulation rates differed by an order of magnitude between intracratonic basins on the one hand and foredeep and intermontane basins on the other, enhancing the chances of deeper burial in the latter basin types. This, combined with higher than normal temperature gradients produced high-rank coals. Sediment depot centers migrated outward from the emerging orogens, almost perpendicular to the Variscans, diagonally to the Appalachians, and along the trend in the Saar-Nahe Basin. No clear migration pattern is recognizable in the Illinois Basin. The depositional systems differ greatly between the basin types. The great Michigan River carried its sediments from far away northeast into shallow seas of the Illinois Basin, building many thin deltas next and on top of each other. The most common setting of coals was on top of delta platforms, in a typical cyclothemic rock sequence. In the foredeep basins alluvial plain and lacustrine settings are only occasionally interrupted by marine ingressions. Meandering rivers are common. The intermontane Saar-Nahe Basin was landlocked. Sediments came from nearby borderlands and include many conglomerates. Alluvial fans, braided river systems, extensive lakes and peat swamps in alluvial flood plains and other wetlands are thought to have prevailed much of the time, but details of depositional environments are still poorly understood.

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TYPES OF SEDIMENTARY BASINS AND THEIR OIL-GAS POTENTIAL

Sedimentary basins (SB) form destructive evolution-tectonic structure sequence. Destruction manifested in extension, crushing and stoping of the lithosphere results in the formation of tectonic depressions with intensive sedimentation and, hence, with a drastic oil generation. SB formation occur in the main in two stages: rift (spreading) and plate ones. Generally, they succeed regularly in time. According to tectonic position SB of the rift genesis can be related to the intracontinental (intraplatform and epiorogenic), and pericontinental, as well as to mid-oceanic ones. They are characterized by a high mobility; permeability which is the way of the mantle degazation; intensive heat flow which is manifested in deep hot (up to 350°C)gas currents bearing water steam, hydrogen, methane, as well as sulphides and hydroxides of metals; effusive magmatism. These SB under the conditions of arid climate are non-compensated, with evaporite and carbonate sedimentation, and under humid climate conditions they are mainly filled with terrigene and terrigene-carbonaceous formations up to 10 km in thickness. Plate stage is characterized by wide settling of rift areas, which causes the formation of syneclise within the platforms and of pericratonic trough and pericontinental near-oceanic subsidences - in their peripheral parts. Foredeeps appear on the boundaries with folded structures, and intermontane troughs-within them. Particular type of SB is represented by troughs with suboceanic Earth crust (labigene and mergegene structures) like the Precaspian one, this of inland seas of the Mediterranean zone and others. The formation of oil-gas-bearing SB occurs under the following circumstances: a high rate of formation of subaqueous oil-gas-generating series (40-80 m/million years and over) and their considerable thickness, geothermal gradient over 3-3.5°C/100 m, deep-seated fractured zones which appear under the extension conditions. All these factors contribute to the transformation of SB into the oil-gas-bearing ones.

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ТИПЫ ОСАДОЧНЫХ БАССЕЙНОВ И ИХ НЕФТЕГАЗОНОСНОСТЬ

Осадочные бассейны (ОБ) образуют деструктивный эволюционно-тектонический ряд структур. Деструкция, выражающаяся в растяжении, дроблении и обрушении литосферы, приводит к формированию тектонических депрессий с интенсивным осадконакоплением и, как следствие этого, с энергичным нефтеобразованием. Формирование ОБ в основном протекает в два этапа: рифтовый (спрединговый) и плитный. Обычно они закономерно сменяют друг друга во времени. По тектоническому положению ОБ рифтового генезиса могут относиться к внутриконтинентальным (внутриплатформенным и эпиорогенным), межконтинентальным и периконтинентальным, а также срединно-океанским. Для них характерны высокая подвижность; большая проницаемость, служащая путями дегазации мантии; интенсивный тепловой поток, который находит свое выражение и в глубинных горячих (до 350°С) газовых струях, несущих пары воды, водород, сероводород, углекислый газ, метан, а также сульфиды и гидроокислы металлов; эффузивный магматизм. Эти ОБ в условиях аридного климата являются некомпенсированными с эвапоритовой и карбонатной седиментацией, а в условиях гумидного климата заполняются преимущественно терригенными и терригенно-карбонатными формациями мощностью до 10 км. Плитный этап характерен широким погружением рифтовых областей, что вызывает формирование внутри платформ синеклиз, а по их периферии - перикратонных прогибов, периконтинентальных приокеанических опусканий. На границе со складчатыми сооружениями возникают краевые прогибы, а внутри них - межгорные. Особый тип ОБ - впадины с субокеанической земной корой (лабигенные или мергегенные структуры) такие, как Прикаспийская, внутренних морей Средиземноморского пояса и др. Формирование нефтегазоносных ОБ протекает при высокой скорости образования субаквальных нефтегазогенерационных толщ (40-80 м/млн. лет и более) и их значительной мощности, геотермическом градиенте свыше 3-3,5°С/100 м, глубинных зонах трещиноватости, возникающих в обстановке растяжения. Все это способствует превращению ОБ в нефтегазоносные.

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SEISMOSTRATIGRAPHY AND SEISMOFACIES OF THE PRIPYAT TROUGH

Platform mantle of the Pripyat trough up to 5000-6000 m in thickness is subdivided into a number of seismostratigraphic complexes (SSC) according to the data of seismic prospecting by methods of common-depth-point shooting (CDP), vertical seismic profiling, refraction shooting, as well as to the results of lithology and biostratigraphy. These seismostratigraphic complexes are represented by strata enclosed between two adjacent reflective or refractive seismic boundaries and having characteristic seismic parameters. They are named according to their position relatively to two (Frasnian and Famennian) salt-bearing formations: lower subsalt, upper subsalt, lower saline, intersaline, underlying upper saline, overlying upper saline and supersalt ones. Seismic boundaries coincide generally with these of lithological formations, sometimes - with unconformity surfaces, which are in both cases stratigraphic boundaries. Every SSC can be subdivided into a number of subcomplexes, as the quality of seismic data is improved. Seismic facies (SF) have been distinguished within the most of SSC for the Devonian part of the trough platform mantle. The principle of SF separation is determined by the character of seismic recording of wave field, in particular of such parameters as tracing, interposition, amplitude and frequency of reflected waves. Ten main varieties of seismic recording are generally used: thick-bedded, thin-bedded, clinoform, chaotic, poorly bedded, diffractive converging, continuous, interrupted, continuous-interrupted, interrupted-continuous ones, all being in conformity with their lithofacial analogues (facies of terrigene and carbonaceous shelfs, depression, volcanogenic, reef ones and other facies) which were determined according to the boring data. Noted SSC which are confidently traced on CDP profiles are used for seismofacial mapping during searching for non-anticlinal traps of gas and oil (in particular for organogenous structures) in the platform mantle of the Pripyat trough. Seismostratigraphic and seismofacies methods are widely adopted in the intersalt SSC (the Zadonsk-Yeletsk deposits) study.

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СЕЙСМОСТРАТИГРАФИЯ И СЕЙСМОФАЦИИ ПРИПЯТСКОГО ПРОГИБА

Платформенный чехол Припятского прогиба мощностью до 5-6 тыс.м подразделен на ряд сейсмостратиграфических комплексов (ССК) на основе данных сейсморазведки (ОГТ, ВСП, КМПВ), литологии и биостратиграфии.

Выделенные ССК представляют собой толщи, обладающие характерными сейсмическими параметрами и заключенные между двумя соседними отражающими или преломляющими сейсмическими границами. Они названы в соответствии с их положением относительно двух (франской и фаменской) соленосных толщ: подсолевой нижний, подсолевой верхний, нижнесолевой межсолевой, верхнесолевой нижний, верхнесолевой верхний и надсолевой. Сейсмические границы совпадают в основном с границами литологических толщ, иногда с поверхностями несогласий, являющимися в обоих случаях стратиграфическими границами. Каждый ССК по мере повышения качества сейсмического материала может быть подразделен на ряд подкомплексов. Для девонской части платформенного чехла Припятского прогиба в границах большинства ССК выделены сейсмофации (СФ).

Принцип выделения СФ связан с характером сейсмической записи волнового поля, в частности таких его параметров, как прослеживаемость, взаимное положение, амплитуда и частота отраженных волн. Всего используется 10 основных типов сейсмических записей (толстослоистая, тонкослоистая, клиноформенная, хаотичная, неяснослоистая, дифракционно-сходящаяся, непрерывная, прерывистая, непрерывно-прерывистая, прерывисто-непрерывная), хорошо согласующихся с их литолого-фациальными аналогами (фации терригенного и карбонатного шельфов, депрессионные, вулканогенные, рифогенные и др.), которые установлены по данным бурения.

Выделенные ССК, уверенно прослеживаемые на профилях ОГТ, используются для сейсмофациального картирования при поисках неантиклинальных ловушек нефти и газа (в частности, органогенных построек) в платформенном чехле Припятского прогиба. Наибольшее применение сейсмостратиграфический и сейсмофациальный методы получили в межсолевом ССК (задонско-елецкие отложения).

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CLINOFORMS OF SEDIMENTARY BASINS

The sedimentary mantle of deep sea basins usually consists of three rock complexes: thin depressional, thick filling and lateral accretion inpersistent along lateral accretion. The depressional complex is composed of carbonate-clay sediments which on flanks of basins via direct clinoforms (carbonate steps) are replaced for synchronous shallow water biogerm carbonates. The complex of filling is composed of terrigenous or evaporite sediments. On flanks of basins via inverse clinoforms they transit to synchronous, relatively thin deposits with similar composition or are subjected to insetting (adjoining) to underlying substratum and do not escape its boundaries. The complex of filling fills deep sea basins of internal and marginal seas, upto hundreds of kilometers in diameter. Within internal regions of oceanic basins, 1000 and more kilometers from the source areas, this complex is thinning out at the expense of lack of terrigenous geological bodies (progradational clinoforms) of avalanche sedimentation, quickly wedging out (dozens of kilometers) along the strike and dip. Usually they occupy peripheral part of deep sea basin. However there are cases when its bodies cover the whole territery of basin (Neocomian progradational clinoforms of West Siberian plate). Geological bodies of lateral accretion extend in parallel to the basin slope or can go deep inside it (debris cone).

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КЛИНОФОРМЫ ОСАДОЧНЫХ БАССЕЙНОВ

Осадочный чехол глубоководных бассейнов обычно состоит из трех комплексов пород: маломощного депрессионного, мощного заполнения и невыдержанного по латерали бокового наращивания. Депрессионный комплекс слагают карбонатно-глинистые осадки, которые на бортах бассейнов через прямые клиноформы (карбонатные уступы) сменяются одновозрастными мощными мелководными биогермными карбонатами. В строении комплекса заполнения участвуют терригенные или эвапоритовые осадки. На бортах бассейнов они через обратные клиноформы переходят в одновозрастные мелководные, близкого состава, относительно маломощные отложения или испытывают прислонение (прилегание) к подстилающему субстрату и не выходят за его пределы. Комплекс заполнения выполняет глубоководные бассейны внутренних и краевых морей, достигающих в поперечнике сотен километров. Во внутренних районах океанических глубоководных бассейнов на расстоянии в 1000 километров и более от источников сноса комплекс заполнения начинает утоняться за счет нехватки терригенного обломочного материала. Комплекс бокового наращивания состоит из терригенных геологических тел (проградационные клиноформы) лавинной седиментации, быстро выклинивающихся (десятки километров) по падению и восстанию. Обычно он занимает периферию глубоководного бассейна. Но известны случаи, когда его тела покрывают весь бассейн (неокомские проградационные клиноформы Западно-Сибирской плиты). Геологические тела бокового наращивания протягиваются параллельно склону бассейна или могут уходить вглубь него (конуса выноса).

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TECTONIC EVOLUTION OF CENOZOIC BASINS IN BOHAI BAY REGION OF NORTH CHINA

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Over 40 basins have developed in Bohai Bay region of Noth China since Eocene time. Most of them are half grabens, distributed around the central Bohai sea. However, as a whole they trend NNE. They are fault bounded and accompanied by multiphase tholieiitic basalt eruptions. The crustal extension is mainly in NW direction with a maximum amount of about 20% in the middle segment of this region. Several NW-striking transversal fault zones adjusted the different extension between adjacent parts.

The crust and lithosphere beneath this region are lateral heterogeneous and thinner than the surroundings. The low resistivity and low velocity layers are widespread in the crust of this region. The possible cause is that the crust was heated by heat pulses from the lower mantle. Most of the listric faults terminated on top of these layers, which shows that the rocks above are essentially brittle and those below are ductile.

Finite element method is utilized to model the taphrogenic process. Results indicate that the thermal creep dictate the extensional tectonics. A thermal uplift zone with NNE-striking long-axis was formed centering in Bohai sea in the early Cenozoic. Normal faults and basins developed where the horizontal rheological velocities were large enough. As the thermal creep continued rifting propagated towards the central Bohai sea. At the end of Oligocene regional thermal creep began to decay because of decaying of thermal energy, followed by cooling and subsidence.

The seismicity related to the formation of the basins are discussed.

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ROLE OF HALOKINESIS IN THE TECTONIC EVOLUTION OF A TEXAS AULACOGEN*

The East Texas Basin, an aulacogenic embayment of the Gulf of Mexico, evolved from a Triassic rift basin. Halokinetic flow of Middle Jurassic Louann Salt was responsible for the deformation of the 6-km-thick overburden in the basin. Salt structures constitute four provinces: a central belt of diapirs is surrounded by two zones of salt pillows, which, in turn, are surrounded by an undeformed salt wedge. Lithofacies and thickness variations in Upper Jurassic and Lower Cretaceous deltaic sediments controlled the pattern of halokinesis. Structural analysis of salt-deformed cover allows reconstruction of the original Jurassic salt ridges from which the diapirs budded; ridge wavelength was remarkably constant, with a mean of 18 km. Salt structures grew for similar durations (10-30 Ma) while in the pillow stage of growth and in the subsequent diapir stage. Peak growth rates in the Early Cretaceous ranged from 150 to 530 m/Ma, declining in the Early Tertiary to less than 30 m/Ma. Peak growth rates are equivalent to steady-state strain rates of 2×10^{-15}/s, corresponding to slower forms of orogenic strain and contrasting with rates of 10^{-9} to 10^{-11}/s calculated for Iranian salt glaciers, whose extrusion is promoted by Zagros folding. Original thickness of Louann Salt in the basin center is calculated to have been 1500-2100 m. The entire basin has lost about 40% of its original salt, maximum loss being in the diapir province where about 70% was lost after being raised by diapirs from the deep source layer to surface. About 800 km^3 were lost by subsurface dissolution and about 2400 km^3 were lost by extrusion and erosion. In the basin center loss of 2000 m of salt by diapir tapping accounts for one third of the total basin subsidence.
*Publication authorized by Director, Bur. Econ. Geol., UT-Austin.

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EVOLUTION OF SALT-DOME SEDIMENTARY BASINS OF OLD PLATFORMS

Salt-dome sedimentary basins of old platforms have been formed under the influence of the interaction of horizontal movements and considerable vertical subsidences. Three-stage succession of their formation including rift, syneclise (perikratogenic) and orogenic stages has been outlined. Areas of helokinesis of intrakratonic and intercontinental rifts were mainly formed in the first stage; areas of halokinesis of pericontinental subsidence zones - in the second one, areas of halokinesis of marginal systems - in the third one. Stages of early syneclise, rift one and that of late (superimposed) syneclise were outlined during the evolution of areas of intrakratonic rift halokinesis. They have been mainly formed in the rift stage, when a block structure and deep noncompensated depressions filled with thick salt-bearing strata were built and saline structures were made up and developed later on, in the stage of late syneclise. A platform mantle of halokinesis areas of intercontinental rifts has been accumulated in the stage of early syneclise, but it was mainly deposited in the rift stage, when the block structure was formed. Thick salt-bearing strata were also accumulated in deep non-compensated depressions and the formation of saline structures begun, which were developed during the following drift stage. Areas of halokinesis of pericontinental subsidence zones were downwarped in the stage of early syneclise. They were intensively developed in the rift stage, when the block structure was formed and thick strata of rifting molassa were accumulated. But mainly they were formed in the perikratogenic stage, at the beginning of which thick salt-bearing strata were accumulated in deep depressions, and salt domes were formed during deposition of thick lenses of carbonaceous and terrigenous sediments over shelfs and slopes. Halokinesis areas of marginal systems were developed in the rift and perikratogenic stages, but they were mainly formed in the orogenic stage. Deep non-compensated depressions filled with thick salt-bearing strata were formed in them in the early-orogenic substage; thick strata of orogenic molassa were accumulated and salt domes were intensively developped in the late-orogenic substage. Salt-dome areas of old platforms form a single evolution-genetic series of structures.

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ЭВОЛЮЦИЯ СОЛЯНОКУПОЛЬНЫХ ОСАДОЧНЫХ БАССЕЙНОВ ДРЕВНИХ ПЛАТФОРМ

Солянокупольные осадочные бассейны древних платформ формировались при взаимодействии горизонтальных движений и значительных вертикальных погружений, при этом намечается трехстадийная последовательность их образования, включающая рифтовую, синеклизную (перикратонную) и орогенную стадии. В первую стадию в основном образовались области галокинеза интракратонных и межконтинентальных рифтов, во вторую - области галокинеза зон периконтинентальных опусканий, в третью - области галокинеза краевых систем. В развитии областей галокинеза интракратонных рифтов намечаются стадии ранней синеклизы, рифтовая и поздней (наложенной) синеклизы. В основном они сформировались в рифтовую стадию, когда образовались блоковая структура и глубокие некомпенсированные депрессии, заполненные мощными соленосными толщами, и сформировались соляные структуры, развивавшиеся затем унаследованно на стадии поздней синеклизы. Платформенный чехол областей галокинеза межконтинентальных рифтов накапливался на стадии ранней синеклизы, но в основном он отложился на рифтовой стадии, когда сформировалась блоковая структура. В глубоких некомпенсированных депрессиях накопились мощные соленосные толщи и начали формироваться соляные структуры, развивавшиеся унаследованно на следующей, дрифтовой стадии. Области галокинеза зон периконтинентальных опусканий прогибались на стадии ранней синеклизы, активно формировались на рифтовой стадии, когда образовалась их блоковая структура и накопились мощные толщи рифтогенной молассы. Но в основном они сформировались на перикратонной стадии, в начале которой в глубоких депрессиях накопились мощные соленосные толщи, а при отложении на шельфе и склоне мощных линз карбонатных и терригенных осадков образовались соляные поднятия. Области галокинеза краевых систем развивались на рифтовой и перикратонной стадиях, но в основном сформировались на орогенной стадии. В раннеорогенную подстадию в них образовались глубокие некомпенсированные депрессии, которые были заполнены мощными соленосными толщами; в позднеорогенную подстадию накапливались мощные толщи орогенной молассы и активно росли соляные поднятия. Солянокупольные области древних платформ образуют единый направленный эволюционно-генетический ряд структур, каждый член которого находится на определенной стадии эволюции.

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SEDIMENTARY BASINS OF DIFFERENT TYPES AND SEISMOSTRATIGRAPHY

1. Prior to drilling seismostratigraphy allows to identify peculiarities of structure and evolution of sedimentary basins as single systems whose development is controlled by tectonic, sedimentary and climatic factors over the sedimentation areas and in the adjacent denudation regions. Quasi-synchronous seismic complexes (QSSC) and seismic facies (SF) are the major objects of seismostratigraphic research which regards them as three-dimensional geological bodies. Sedimentary basins of different types are characterised by specific features of QSSC and SF.

2. At the early stages of study of sedimentary basins, seismostratigraphy allows to reveal the regularities in their filling by the terrigenous continental, coal-bearing, delta shelf, slope, deep-water QSSC, to determine the location of carbonate-chemogenic, organogenic rudaceous, marginal bank, reef, atoll, chemogenic and effu-

sive QSSC and SF. This study provides the basis for quantitative prediction of energy and mineral resources of sedimentary basins on the whole and of their separate zones and QSSC. Reasons are given to justify the necessity of compiling special programs of seismostratigraphical research in sedimentary basins.
3. The possibility for quantitative estimations is emphasised as regards pre-sedimentary, con-sedimentary and post-sedimentary tilts and nonconformities created under the effect of endogenous tectonic, diapirogenic and exogenic factors on the boundaries and inside QSSC and SF. Peculiarities in the indication of tilts and nonconformities are discussed for basins of different types: with uncompensated or with molassic sedimentation, riftogenic, salt dome, and others.
4. Classification of QSSC and SF of several types of sedimentary basins is suggested with special emphasis on classification of clinoforms of sedimentary basins in the western part of the USSR. Examples and different techniques of evaluations of oil-gas-bearing prospects are discussed on the basis of results of seismostratigraphy.

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ОСАДОЧНЫЕ БАССЕЙНЫ РАЗЛИЧНОГО ТИПА И СЕЙСМОСТРАТИГРАФИЯ

I. Использование сейсмостратиграфии позволяет до проведения бурения осветить особенности строения и эволюции осадочных бассейнов как целостных систем, развитие которых контролируется тектоническими седиментационными и климатическими факторами на площадях осадконакопления и в сопряженных ареалах денудации. Главным объектом сейсмостратиграфических исследований являются квазисинхронные сейсмические комплексы (КССК) и сейсмические фации (СФ), рассматриваемые как трехмерные геологические тела. Осадочные бассейны различных типов характеризуются специфическими особенностями КССК и СФ.
2. Сейсмостратиграфия позволяет на ранних стадиях изучения осадочных бассейнов выявить закономерности их выполнения терригенными континентальными, угленосными, дельтовыми, шельфовыми, склоновыми, глубоководными КССК, выяснить размещение карбонатно-хемогенных, органогенных обломочных, окраинных банковых, рифтовых, атолловых, хемогенных и эффузивных КССК и СФ. На этой основе возникает возможность количественного прогнозирования энергетических и минеральных ресурсов осадочных бассейнов в целом, отдельных зон и КССК. Обосновывается необходимость составления специальных программ сейсмостратиграфических исследований осадочных бассейнов.
3. Подчеркивается возможность количественных оценок доседиментационных, конседиментационных и постседиментационных наклонов и несогласий, формирующихся под влиянием эндогенных тектонических, диапиро-

генных и экзогенных факторов на границах и внутри КССК и СФ. Обсуждаются особенности индикации наклонов и несогласий в бассейнах разных типов: с некомпенсированным или с молассовым осадконакоплением, рифтогенных, солянокупольных и иных.

4. Предлагается классификация КССК и СФ различных типов осадочных бассейнов, особое внимание уделяется классификации клиноформ осадочных бассейнов западной части СССР. Обсуждаются примеры и приемы оценки перспектив нефтегазоносности на основе результатов сейсмостратиграфии.

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REEF FORMING OF SEDIMENTARY BASINS

The conditions that promote reef forming of sedimentary basins are the following: the location of the latter in the zone of arid and humid climate, normal salinity of main quantity, limited supply of clastic material, the rate of not compensated downwarping of even a part of a sedimentation basin, which is more than the rate of sedimentation and the presence of a morphologically exposed ledge of a sea bottom. Reef form stretched systems along this ledge which are characterized by a considerable structural geomorphological and facies asymmetry. In geosynclinal areas reef formation is replaced by leptogeosynclinal and black shale formations in the direction of the basin, in platform areas - by domanicoid. The character of the outside sediments of the reef formation is defined by the climate and by the remoteness from the land. Bentogene calcareous, limestone-dolomite, sulphate-dolomitic and terrigene-carbonate formation are located here. Different by the direction and the dimension area displacements of reef systems depend on the ratio of the rate of the reef growth and the tectonic downwarping even in the limits of one basin. Reef formation on different facies border refers to Riphean but asymmetry is poorly developed. Paleozoic and mezocenozoic basins of reef formation differ in depths and in morphology of the part of the basin where the rate of downwarping is more than the rate of sedimentation and in dimension of shallow water basins situated outside the reef formation. The area interconnection of depression deposits enriched by sapropelic organic matter with reef reservoir and reef trap and overlapping of the latter by impermeable clays or evaporites often causes the presence of oil and gas in reef systems.

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РИФОВОЕ ОБРАМЛЕНИЕ ОСАДОЧНЫХ БАССЕЙНОВ

Условиями появления рифов в обрамлении осадочных бассейнов являются: положение последних в зоне аридного или гумидного климата, среднеокеаническая соленость, ограниченный привнос обломочного материала, не компенсированное осадками прогибание хотя бы части бассейна седиментации и наличие морфологически выраженного уступа морского дна. Рифы образуют вытянутые вдоль этого уступа системы, характеризующиеся значительной структурно-геоморфологической и фациальной асимметрией.
В геосинклинальных областях рифовая формация замещается в сторону бассейна лептогеосинклинальными и черносланцевыми формациями, в платформенных - доманикоидными. Характер зарифовых отложений определяется климатом и удаленностью от суши. Здесь развиты бентоногенные известняковые, известняково-доломитовые, сульфатно-доломитовые и терригенно-карбонатные формации.
В зависимости от соотношения скоростей роста рифов и тектонического прогибания даже в пределах одного бассейна происходят различные по направлению и масштабу пространственные смещения рифовых систем.
Зарождение рифов на границе различных фаций относится к рифею, но асимметрия развита слабо. Палеозойские и мезо-кайнозойские бассейны рифообразования различаются по глубине и морфологии некомпенсированной осадками их части и по величине зарифовых мелководных водоемов.
Пространственная взаимосвязь обогащенных сапропелевым органическим веществом депрессионных отложений с высокоемким рифовым резервуаром и рифовой ловушкой, а также перекрытие последних непроницаемыми глинами или эвапоритами нередко обуславливает нефтегазоносность рифовых систем.

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THE EVOLUTION, MINERAL AND ENERGY RESOURCES OF PRECAMBRIAN SEDIMENTARY BASINS

The major types of mineralization and their distributions in Precambrian sedimentary basins will be considered in the light of our knowledge of the early geobiochemical evolution of the Earth.
Most Archaean mineralization formed as a result of the high levels of igneous activity. The limited Archaean environments with relatively high sedimentary components contain local bedded barite deposits and exhalative iron formations, some of the latter being auriferous. The barite formed during the early Archaean in environments

that were tectonically stable compared with those for auriferous BIF. Neither type of mineralization demands extensive oxidation of the hydrosphere not oxygenated atmosphere, and isotopic and other evidence strongly implies sulfate was not present in significant concentration in most of the hydrosphere.

In contrast, the main styles of mineralization in early Proterozoic sequences reflect the importance of epicratonic sedimentation, generally more stable environments and the change to an oxygenous atmosphere. They are: U and Au paleoplacers in quartz-rich clastics; extensive BIF, and U associated with unconformities, carbonaceous matter and chlorite. Less common are Mn associated with carbonates and BIF; clastic-hosted Cu and Pb-Zn deposits; and "coal" of probable algal origin.

The middle Proterozoic saw the formation of giant "shale-hosted" Pb-Zn ores, well above the bases of intracratonic trough sequences, and some Cu deposits. In the late Proterozoic there was major copper accumulation in shale-sandstone sequences near basal unconformities; the earliest oil, gas and phosphorites; and the oldest unpseudomorphed evaporites.

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ORIGIN OF PALEOZOIC CARBONATE-HOSTED LEAD-ZINC DEPOSITS, WITH EXAMPLES FROM THE WESTERN CANADA BASIN

Many sedimentary Paleozoic basins contain showings or deposits of Zn and Pb sulphides within carbonate rock units. Most of these belong to the Mississippi Valley-type (MVT) class. The deposits tend to occur at or close to the margins of basins; most are associated with unconformities; sulphides were emplaced in lithified rocks, not sediments; temperatures of formation were commonly less than 150°C; Zn normally is more abundant than Pb; most deposits have associated organic matter. The range of these deposits is from Proterozoic to late Mesozoic. However, these features are generalizations which do not apply to all deposits. Important differences from deposit to deposit include: tectonic setting, presence or absence of major facies changes such as carbonate-shale transitions; form of deposits, as stratoform or cross cutting; universal association with dolomite but amounts and types of dolomite highly variable; and ores ranging from Zn-rich to less commonly Pb-rich. However, with some exception no systematic or evolutionary changes have been identified for these deposits. The study of MVT deposits requires examination of their spatial and temporal setting within the context of the subsidence and thermal history of the host carbonates, and relationships between deposits and intraplate activity responsible for emergence/erosion and the development of faults, arches and sub-basins. Accordingly, the dating of deposits by radiometric or paleomagnetic means is crucial. Studies of associated organic matter provide an assessment of the thermal/burial history of host rocks/orebodies, and the possible role of organic matter in sulphide precipitation mechanisms. The cratonic platform part of the western Canada Basin contains scattered surface/subsurface Zn-Pb showings in Cambrian through Mississippian carbonates. Studies of Pine Point deposits, hosted by Middle Devonian carbonates, are instructive. Karst control of these deposits is documented. They are provisionally dated paleomagnetically and isotopically as Late Paleozoic, although there is at least a 35 million year discrepancy between the dates obtained by the two methods. With respect to genesis of the sulphides, a compelling case can be made for local derivation of requisite volumes of hydrogen sulphide by organic matter-sulphate reactions, based on physical attributes of unaltered/altered bitumen, atomic hydrogen/carbon ratios, sulphur isotope compositions and its abundances in bitumen.

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EVOLUTION HISTORY OF SEDIMENTARY BASINS OF OLD PLATFORMS AND STAGES OF REEF FORMATION

Reef formation stages occurred under favourable paleogeographical and paleotectonic conditions in any of three main phases of evolution of rift sedimentary basins - initial, principal and final ones. Most of scientists suggesting different tectonic classifications of reef-rock structures distinguish their three main groups: platform, geosynclinal and aulacogene ones (or structures of rift sedimentary basins). According to the character of their development, the latters have features of big platform structures in their initial and final phases, and geosynclines - in the principal phase of evolution. In conformity with this, rift formation in rift sedimentary basins is distinguished by some peculiarities. Bedded reef-rock structures - biostromes, biostrome masses and more seldom bioherm beds - are characteristic of the majority of such basins in initial phase of their evolution irrespective of the rock-forming organism types and sedimentation occurs frequently with overcompensation. Tectonic influence on reef-rock structures in this phase was poor and consisted in consedimentation control of the paleobasin's depth and, correspondingly of zones of reef-builder biocoenoses. In the principal, most active phase of evolution of rift sedimentary basins, being formed reef-rock structures were considerably influenced by consedimentation tectonic movements, which controlled the relief, depth of paleobasin and sedimentary product supply. Intensive descending movements periodically resulted in the basin isolation and determined thereby the aqueous medium mineralization. All these factors influenced, in the end, reef-builder biocoenoses and morphology of reef-rock structures. Noncompensated, compensated and overcompensated sedimentation occurred under conditions of dissected topography of the paleobasin bed and different rate of subsidence of its individual areas. That's why, in the first case depression deposits were accumulated, in the second one - reef-rock structures were formed and in the later one - products of their destruction were deposited. In the final phase of evolution of rift sedimentary basins the rate of descending vertical movements markedly reduces, which results in overconpensation and accumulation of carbonate beds small in thickness with rare bedded reef-rock structures.

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ИСТОРИЯ РАЗВИТИЯ РИФТОВЫХ ОСАДОЧНЫХ БАССЕЙНОВ ДРЕВНИХ ПЛАТФОРМ И ЭТАПЫ РИФООБРАЗОВАНИЯ

Этапы рифообразования имели место при благоприятных палеогеографических и палеотектонических условиях в любую из трех основных фаз развития рифтовых осадочных бассейнов - начальную, главную или завершающую. Большинство авторов тектонических классификаций рифогенных построек рассматривает три их основные группы: платформенные, геосинклинальные и авлакогенные (или рифтовых осадочных бассейнов). По характеру своего развития последние несут в себе в начальной и завершающей фазах черты крупных платформенных структур, а в главную - геосинклинали. В соответствии с этим и рифообразование в рифовых оса - дочных бассейнах имеет отличительные особенности. Для большинства подобных бассейнов в начальную фазу их развития независимо от типов породообразующих организмов характерны пластообразные рифогенные постройки - биостромы, биостромные массивы и реже биогермные пласты, а осадконакопление происходит при частой перекомпенсации. Влияние тектоники на рифогенные постройки в эту фазу было слабым и заключалось лишь в конседиментационном контроле глубины палеобассейна и соответственно зон биоценозов рифостроителей. В главную, наиболее активную фазу развития рифтовых осадочных бассейнов формирующиеся рифогенные постройки подвергались значительному влиянию конседиментационных тектонических движений, которые контролировали рельеф и глубину дна палеобассейна и поступление осадочного материала. Интенсивные нисходящие движения периодически приводили также к изоляции бассейна, определяя тем самым минерализацию водной среды. Все эти факторы в конечном итоге влияли на биоценозы рифостроителей и морфологию рифогенных построек. В условиях расчлененного рельефа дна палеобассейна и различной скорости погружения отдельных его участков имели место некомпенсированное, компенсированное и перекомпенсированное осадконакопление. Поэтому в первом случае накапливались депрессионные отложения, во втором формировались рифогенные постройки, а в последнем - продукты их разрушения. В завершающую фазу развития рифтовых осадочных бассейнов заметно снижается скорость нисходящих вертикальных движений, что приводит к перекомпенсации и накоплению маломощных карбонатных пластов с редкими пластообразными рифогенными постройками.

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TECTONIC PECULIARITIES OF GLOBAL DISTRIBUTION OF HYDROCARBON POTENTIAL RESOURCES

New data on oil and gas potential of World Ocean and continents, on average thickness of tight rocks and specific volumetrical density of potential resources in different types of basins, permitted to make up the conclusion about the global distribution of resources between continents, oceans and different genetic types of basins.

Maximum of resources (60-70%) are located in transitional zones between continents and oceans. About 89% resources of oil and 68% of gas are located in these zones. Intracontinental basins of all types contain as much as 11% of oil resources and that 32% of gas.

Ancient platform basins contain - 20% oil and gas resources, young platform basins - 8%, intramountain basins - 3%, transitional zone basins - 32%, present passive margine basins - 35%.

Paleozoic sediments contain - 17% oil and gas resources, mesozoic - eocene - 68%, oligocene-pleistocene - 15%.

Distribution of hydrocarbon is controlled by types of basins, formed in conditions of considerable litospheric tension.

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ТЕКТОНИЧЕСКИЕ ОСОБЕННОСТИ ГЛОБАЛЬНОГО РАСПРЕДЕЛЕНИЯ ПОТЕНЦИАЛЬНЫХ РЕСУРСОВ УГЛЕВОДОРОДОВ

Новые данные о нефтегазоносности Мирового океана и континентов, средневзвешенной мощности уплотненных пород и удельной объемной плотности потенциальных ресурсов в тектонотипах каждой из групп бассейнов дали основание наметить относительное (в %) глобальное распределение ресурсов: между континентами, океанами и краевыми морями; генетическими группами бассейнов, отождествляемых с мегапровинциями; крупными стратиграфическими комплексами осадочного слоя для Земли в целом и каждой из мегапровинций в частности.

Наибольшая концентрация ресурсов (60-70%) характерна для бассейнов переходной зоны от континентов к океану, что подтверждается сосредоточением в их пределах 89% разведанных запасов нефти и 68% газа против II% нефти и 32% газа во внутриконтинентальных бассейнах всех типов. На долю бассейнов древних платформ приходится порядка 20% ресурсов; бассейнов молодых платформ 8%; межгорных впадин зрелых орогенов около 3%; бассейнов современной активной окраины 2%; переходной зоны к той же окраине до I0%; переходной зоны краевых морей к древней океанической окраине до 22%; современной пассивной окраины порядка 35%. Палеозойский комплекс, пользующийся распространением преимущественно на континентах, содержит около I7%; мезозойско-эоценовый-68% и олигоцен-плейстоценовый-I5% ресурсов.

Главной особенностью распределения запасов оказывается их взаимосвязь с генетическими группами бассейнов, формировавшимися в тектонических условиях существенного растяжения литосферы.

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NEOGENE-ANTHROPOGENE PANNONIAN BASIN - STRUCTURE OF LABIGENIC TYPE

For the last few years, many geologists ascribe the Pannonian basin to be interarc structures resulted from subduction. The data on structure of the sedimentary cover, chemical composition of Cenozoic volcanics and geophysical materials enable us to regard the Pannonian

basin as a structure of a specific type.
The Pre-Neogene basement of the Pannonian basin is represented by different rocks ranging by age from Precambrian up to Paleogene. They are predominantly geosynclinal but also include platform covers of Triassic-Cretaceous, Upper Cretaceous and Paleogene age widespread in some zones.
The Pre-Neogene basement surface forms a number of large structural elements, rather gentle and complicated by fractures, represented predominantly by faults and upthrusts. At the same time, the seismic data established a few overthrusts.
The Neogene-Anthropogene sedimentary cover is subdivided into two structural complexes: the lower - Miocene (up to Sarmatian stage inclusively) and the upper one, including a part of the Upper Miocene (Pannonian and Pontian stages), Pliocene and Anthropogene. Narrow relatively elongated structures are typical for the lower complex. The linear zones composed of andesite and rhyolite volcanites developed synchronously. The upper complex forms very gentle isometric structures. Their formation was accompanied by the widespread basaltic volcanism. The maximum thickness of the lower complex deposits (up to 4-5 km) is associated with marginal structures of the basin, while that of the upper complex (up to 5 km) was found in its central part). The Miocene (up to the Sarmatian) is characterized by conditions of extension, while the time of formation of the upper complex by predominantly vertical negative movements.
The analysis of the structure in the deep-seated part of the Earth crust suggests that its formation began in the Middle Miocene (the main stage - Upper Miocene/Pliocene) due to the uplift of the mantle diapir. The Pannonian basin, as well as basins of the internal seas of the Mediterranean belt, should be ascribed to a peculiar class of labigenic structures.

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НЕОГЕН-АНТРОПОГЕНОВЫЙ ПАННОНСКИЙ БАССЕЙН - СТРУКТУРА ЛАБИГЕННОГО ТИПА

В последние годы Паннонский бассейн многими геологами относится к внутридуговым структурам, возникшим как следствие субдукции. Данные по структуре осадочного чехла, химизму кайнозойских вулканитов и материалы геофизики позволяют выделить Паннонский бассейн как структуру особого типа. Донеогеновый фундамент Паннонского бассейна представлен разнообразными породами с возрастом от докембрия до палеогена. Среди них преобладают геосинклинальные толщи, но есть и платформенные серии. К последним относятся триасово-меловые, верхнемеловые и палеогеновые осадочные чехлы, развитые в отдельных зонах. Поверхность донеогенового фундамента образует ряд крупных структурных форм, достаточно пологих, осложненных разрывными нарушениями. Среди них преобладают сбросы и взбросы. Вместе с тем по материалам сейсморазведки установлены надвиги.

В неоген-антропогеновом осадочном чехле выделено два структурных комплекса. Нижний - миоценовый (до сарматского яруса включительно)-и верхний, включающий часть верхнего миоцена (паннонский и понтический ярусы), плиоцен и антропоген. Для нижнего комплекса характерны узкие относительно вытянутые структуры. Синхронно развивались линейные зоны, сложенные андезитовыми и риолитовыми вулканитами. Верхний комплекс образует очень пологие изометричные структуры. Их формирование сопровождалось разобщенным в плане базальтовым вулканизмом. Максимальные мощности отложений нижнего комплекса (до 4-5 км) приурочены к краевым структурам бассейна, тогда как максимум мощностей верхнего комплекса (до 5 км) расположен в центральной части бассейна.

Для миоцена (до сармата) характерна обстановка растяжения, а для времени верхнего комплекса - преобладание вертикальных отрицательных движений.

Анализ строения глубинной части земной коры позволяет предположить, что она формировалась начиная со среднего миоцена (основной этап - верхний миоцен - плиоцен) за счет поднятия мантийного диапира. Паннонский бассейн, так же как и впадины внутренних морей Средиземноморского пояса, следует относить к особому классу лабигенных структур.

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INTERPRETATION OF THE BOUGUER ANOMALIES IN THE NIGERIAN MIDDLE NIGER BASIN WITH CONSTRAINTS FROM MAGNETIC DATA

The Middle Niger Basin of Nigeria is an elongated trough filled with Upper Cretaceous sediments. It cuts across a zone of approximately north-south trending linear belts of Precambrian metasediments and meta-igneous rocks of generally greenschist and lower amphibolite facies metamorphism.

The Bouguer anomaly map of the south-east segment of the basin is dominated by a broad positive high to the east reaching an absolute amplitude of +17 mGal with a prominent NW-SE trend parallel to the northern margin of the basin; and a N-S trending negative low to the west with an absolute amplitude of -30 mGal which is interpreted as

being caused by relatively thick sedimentary rocks.
Two-dimensional gravity models constrained with preliminary depth-to-basement estimates from aeromagnetic data show that the basin is generally shallow (less than 2.5 km), and that the data are best explained by a combination of moderately thick sediments accompanied or underlain by areas of shallow basement or high density metamorphic basement and schists. A doming of the Moho surface under the basin is indicated by the low-gradient positive anomaly suggesting thinning or stretching of the crust with stresses which might have caused rifting and subsidence similar to those of the Central African rifts.

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DEVELOPMENT OF LEAD-ZINC STRATIFORM MINERALIZATION AS RELATED TO EVOLUTION OF SEDIMENTARY BASINS

The geological correlations between stratiform lead-zinc mineralization and potentially oil and gas generating horizons in the sedimentary basins are rewieved for the USSR ore fields mainly from Siberia region. The obtained results maintain the following conclusions.
The origin of hydrothermal systems which provide the primary sedimentary-diagenetic ore deposition is associated with catagenetic generation of solutions as a result of replacement of montmorillonite by hydromica in strata submerged to the deep levels of the principal oil forming zone. These potential oil and gas producing processes are associated with redistribution of microcomponents and organic matter, thus, enriching confined high pressure solutions. The solution discharge into favourable tectonic structures takes place after filtration along collectors and is accompanied by removal of waters which in the course of postsedimentary transformation of host rocks are also enriched by metals. High salinity of these waters substantially facilitates the increase of their metalliferous properties.
The high temperatures of fluids which facilitate transformation of primary deposits are conditioned by progressive sagging of sedimentary basins and displacement of rocks to deeper areas. These events under even more extreme thermobaric conditions, cause dehydration of hydromica. All these phenomena are facilitated by the strong increase of rise in dynamic load and heat flow during the epochs of intensive tectonic activity.
The principal difference of hydrogeologic conditions in the realiza-

tion of the potential metalliferous capacities in comparison with the oilliferous ones lies in the more exposed forms of discharge. In both cases the discharge is frequently controlled by slopes of consedimentary uplifts

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ФОРМИРОВАНИЕ СТРАТИФОРМНОЙ СВИНЦОВО-ЦИНКОВОЙ МИНЕРАЛИЗАЦИИ КАК РЕЗУЛЬТАТ ЭВОЛЮЦИИ ОСАДОЧНЫХ БАССЕЙНОВ

На примере месторождений СССР, главным образом Сибири, рассматриваются геологические соотношения стратиформной свинцово-цинковой минерализации с потенциально нефтегазопродуцирующими толщами, захороненными в недрах осадочных бассейнов. Полученные результаты позволяют предполагать следующее.

Возникновение гидротермальных систем, обеспечивших первичное осадочно-диагенетическое отложение сульфидов, обусловлено процессами катагенетической генерации растворов в результате гидрослюдизации монтмориллонита глинистых толщ, погруженных на глубинный уровень главной зоны нефтеобразования. Эти потенциально нефтегазообразующие процессы сопровождаются перераспределением микрокомпонентов и органического вещества, обогащающих формирующиеся высоконапорные растворы. Их разгрузка в благоприятные тектонические структуры происходит после фильтрации по породам коллекторов с попутным вытеснением из них вод, также обогащенных металлами в ходе постседиментационных преобразований. Рассольный состав пластовых вод существенно способствует повышению их металлоносности

Высокие температуры флюидов, участвовавших в преобразовании первичных залежей, обусловлены дальнейшим прогибанием осадочных бассейнов, сопровождавшимся перемещением пород в области еще более высоких термобарических условий в глубоких частях этих бассейнов, где идет дегидратация сформированных ранее гидрослюд. Генерации флюидов содействует резкое возрастание динамических нагрузок и теплового потока в эпохи повышенной тектонической активности.

Главное отличие гидрогеологических условий реализации потенциальной металлоносности катагенетических растворов по сравнению с нефтеносностью - более открытые формы разгрузки, в обоих случаях часто приурочиваемой к склонам конседиментационных поднятий.

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HYDRODYNAMICS OF ORE-FORMING FLUID SYSTEMS

Ore-forming fluid systems in sedimentary basins have disseminated input. The main sources of the fluids are relict pore waters and solutions released while compaction and dehydratation of the basin sedimentary strata. As a result of disseminated nature of the source fluids, the hydrodynamic pre-conditions for the system generation play decisive role. The key problem is that how the flow becomes "focused" (W.S.Fyfe, N.J.Price, A.W.Thompson, 1978), that is how initially disseminated fluids come to spatial convergence.

Economic geologists know from experience, that in phenomenon of spatial convergence of hydrothermal fluids major role play structural environment. The structural control of hydrodynamics of the hydrothermal flow is a result of diverse permeability of constituent elements of the geological structure. In accordance with the principle of minimization of energy wastes, the percolating solutions accumulate in the most permeable elements of the geological structure - faults, fracture zones, reservoir beds etc.

In order to examine the influence of structural environments on the hydrodynamics of the hydrothermal streams, an electric-analog modelling of solutions flow had been carried out in the simulated structures representing patterns typical for structural environments of hydrothermal ore-forming systems in the sedimentary basins. The obtained results permitted to outline general principles of hydrothermal flow control by fault and fold structures. The significance of drainage structures was specially emphasized, in particular, for deep penetraining faults and regional reservoir beds. The quantative estimates show the degree of structurally induced hydrodynamic convergence ("focusing") of the flow up to hundreds and thousands of times and even more.

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ГИДРОДИНАМИКА РУДООБРАЗУЮЩИХ ФЛЮИДНЫХ СИСТЕМ

Рудообразующие флюидные системы осадочных бассейнов формируются за счет пространственно рассредоточенных источников растворов. Основными такими источниками являются реликтовые поровые воды и растворы, выделяющиеся при уплотнении и дегидратации заполняющих бассейн осадочных отложений. Вследствие рассредоточенного характера флюидного питания систем вопрос о гидродинамических предпосылках их формирования приобретает решающее значение. Основная проблема заключается в определении того, каким образом происходит "фокусирование" (W.S.Fyfe, N.J.Price, A.W.Thompson, 1978) питающего систему потока, т.е. пространственное сосредоточение исходно рассеянных растворов.

Опыт изучения гидротермальных месторождений показывает, что в формировании пространственно сосредоточенных потоков гидротермальных растворов ведущая роль принадлежит структурным условиям. Структурные условия влияют на гидродинамику гидротермального потока в связи с тем, что образующие геологическую структуру элементы обладают различной проницаемостью для движения гидротермальных растворов. Стремясь к минимизации затрат энергии на процесс движения, растворы сосредоточиваются в наиболее проницаемых элементах геологической структуры - разломах, зонах трещиноватости, пластах-коллекторах и др.

С целью изучения характера влияния структурных условий на гидродинамику гидротермальных потоков произведено электрическое моделирование движения растворов в моделях геологических структур, представляющих типизированные условия формирования рудообразующих флюидных систем осадочных бассейнов. По результатам моделирования определены общие закономерности гидродинамического контроля гидротермальных потоков разрывными и складчатыми структурами. Подчеркнуто значение для формирования рудообразующих флюидных систем дренирующих структур, в частности глубоко проникающих разломов и региональных пластов-коллекторов. Полученные количественные оценки показывают, что степень структурно обусловленного гидродинамического сосредоточения ("фокусирования") потока может достигать сотен, тысяч и более раз.

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CARBONACEOUS-PHOSPHATE DEPOSITS AND THEIR EVOLUTION

Carbonaceous-phosphate rock sequences are the characteristic part of many phosphate basins of the world. Carbonaceous-phosphate deposits can be observed in AR_1, PR_1, R, V, $PZ_{1,3}$. The detail study of carbonaceous-shale rocks of PR_1 of the KMA gave the opportunity to distinguish lithological-facial types of sections. Each of them is characterized by different composition, content in them of C_{free} metasomatic transformation of component rocks, texture features and also in character of phosphate mineralization, the scales of which are growing near the region of volcanic activity. These data and also the information about other regions - the Kola peninsula, Tuva, Podolia etc. prove the existance of specific Pre-Cambrian phosphate basins, where the phosphates are closely connected with high concentration of the products of life activity. As a result the high carbonaceous type appeares with the content of C_{free} up to 40% In PZ carbonaceous-shale rock sequences are the part (or their facial analogues) of the biggest phosphate basins of the world- Hubsugulskoye, Karatau, Georgina, Phospharia. In the process of evolution of the lithosphere the tectonic position of these deposits is changing from protoplatform in PR_1 to geosyncline in R, V, E (Altai-Saiansky basin), myogeosyncline in E (Karatau Basin) and platform in $E_{2,3}$ (Georgina) and in P (Phosphoria). Each phase of carbonaceous-phosphate accumulation is characterized by the different complex of ore elements: for Early Proterozoic and Riphean-Cambrian - the association of P with Mn and Fe. Essential changes in the time and character of dispersed carboniceous substance from sapropelic or bacterial in ancient phosphate basins to mainly humic in P_3; the degree of its graphitization and bituminosity, and the composition of elements are also different.

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УГЛЕРОДИСТО-ФОСФАТОНОСНЫЕ ОТЛОЖЕНИЯ ПРОТЕРОЗОЯ И ИХ ЭВОЛЮЦИЯ

Во многих фосфоритоносных бассейнах мира углеродисто-сланцевые и фосфатоносные толщи находятся в парагенетической ассоциации. Углеродисто-фосфатоносные отложения наблюдаются в архее, раннем протерозое рифее, венде, раннем и позднем палеозое. Детальное изучение углеродисто-фосфатоносной толщи нижнего протерозоя КМА позволило выделить литолого-фациальные типы разрезов, в разной мере удаленные от области синхронного активного вулканизма. Каждый из них отличается своеобразием вещественного состава и метасоматических преобразований слагающих пород, текстурными особенностями, содержаниями в них свободного углерода, а также характером фосфатной минерализации, масштабность которой увеличивается вблизи области вулканической деятельности. Текстуры пород фосфоритоносных интервалов разрезов свидетельствуют о формировании их в условиях повышенной сейсмической активности, связанной с близостью области синхронного вулканизма. Все эти данные, а также материалы по другим районам - Кольскому полуострову, Туве, Подолии и др.- свидетельствуют о существовании своеобразных протерозойских фосфоритоносных бассейнов, где фосфориты тесно связаны с высокими содержаниями продуктов жизнедеятельности, следствием чего является появление высокоуглеродистого типа с содержанием свободного углерода до 40%. В палеозое углеродисто-сланцевые толщи входят в состав фоссерий (или являются их фациальными аналогами) крупнейших фосфоритоносных бассейнов мира - Хубсугульского, Каратауского, Фосфории. В процессе эволюции литосферы меняется геотектоническая позиция этих отложений - от протоплатформенных в раннем протерозое к геосинклинальным в рифее, венде, кембрии (Алтае-Саянский бассейн), миогеосинклинальным в кембрии (Каратауский, Хубсугульский бассейны) и платформенным в среднем, позднем кембрии (Джорджина) и в перми (Фосфория). Каждому этапу углеродисто-фосфатоносного накопления свойственен определенный парагенез фосфора с рудными элементами: для нижнепртерозойского и рифейско-кембрийского с железом и марганцем.

Существенны изменения во времени и в самом характере рассеянного углеродистого вещества - от сапропелевого или бактериального в древних фоссериях к преимущественно гумусовым в верхнепалеозойских; различны степень его графитизации и битуминозности, а также элементарный состав.

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"GRANITELESS" DEPRESSIONS ARE THE LARGEST OIL-GAS BEARING BASINS

The deepest sedimentary depressions can be divided by crustal structure into two types from the evidence of data of geophysical research on continents and on their periphery. In some of them (Caspian) the bottom of the Earth crust, i.e., the Mohorovicic boundary, is relatively lifted, in others (Ferghana) it lies much lower. The thickness of the crust under depressions of the first type is not more than 20-30 km; under depressions of the second type the Mohorovicic boundary subsides to 45-50 km. The thickness and composition of the consolidated crust of these depressions are essentially different: in the former the thickness of the consolidated crust does not exceed 8-12 km and the "granite" layer in it is much thinner or absent; in the latter the consolidated crust is represented by both layers with normal thickness. This means that depressions of the first type are characterised by reverse relation of topographical features of the surface of the consolidated crust and the Mohorovicic boundary and by reverse dependences between the thicknesses of the sedimentary and "granite" layers. This crustal structure is apparently typical of the subsidences with terminated development. On the contrary, depressions which are still growing are characterised by *conform deposition of the surface and bottom of the consolidated* crust. Depressions of the first type, independently of the time of their formation and of their structural type, have many common features in their evolution. Their appearance is the result of endogenous subcrustal processes of one type. In most of them industrial oil-gas fields have been prospected (Dnieper-Donetsk, Mexican). Therefore, the distribution of zones of regional concentration of hydrocarbonates is associated not only with surface tectonic conditions, but with the thickness and composition of the consolidated crust as well.

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"БЕЗГРАНИТНЫЕ" ВПАДИНЫ - КРУПНЕЙШИЕ НЕФТЕГАЗОНОСНЫЕ БАССЕЙНЫ

Геофизическими исследованиями внутри континентов и по их периферии выделены глубочайшие седиментационные впадины, которые по структуре земной коры могут быть разделены на два типа. В одних (Прикаспийская) подошва земной коры - граница Мохоровичича-относительно приподнята, в других (Ферганская) - резко погружена. Мощность коры под впадинами первого типа не превышает 20-30 км, под впадинами второго типа граница Мохоровичича прогнута до 45-50 км. Существенно различны мощность и состав консолидированной коры этих впадин: в первых толщина консолидированной коры не превышает 8-12 км, в ее составе сильно утонен или вообще отсутствует "гранитный" слой, во вторых консолидированная кора представлена обоими слоями нормальной мощности. Т.е. для впадин первого типа характерны обратное соотношение форм рельефа поверхности консолидированной коры и границы Мохоровичича и обратные зависимости между мощностями осадочного и "гранитного" слоев. Такая структура земной коры, по-видимому, характерна для прогибов, прекративших свое развитие. Наоборот, прогибы, продолжающие расти, характеризуются согласным залеганием поверхности и подошвы консолидированной коры. Впадины первого типа, вне зависимости от времени их заложения и структурной принадлежности, обладают сходными чертами развития, их возникновение является результатом однотипных эндогенных подкоровых процессов. В большинстве из них установлена промышленная нефтегазоносность (Днепровско-Донецкая, Мексиканская). Таким образом, размещение зон региональной концентрации углеводородов связано не только с поверхностными тектоническими условиями, но и с мощностью и составом консолидированной коры.

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DETERMINATION OF EUSTATIC SEA LEVEL CHANGES IN SEDIMENTARY BASINS

The record of transgressions and regressions in sedimentary basins throughout the world should provide, if detailed stratigraphic correlations can be made, a means of determining a global eustatic sea-level age curve. The derivation of such a curve requires the development of quantitative basin analysis techniques capable of distinguishing the relative control of tectonic and eustatic factors on the preserved stratigraphic record. We discuss a variety of techniques currently in use for one and multi-dimensional analysis of basin subsidence involving analytical, numerical, graphical and statistical approaches. It is shown that only through the use of different methods in combination, applied to a variety of tectonic settings can a global sea-level curve be approximated. Preliminary sea-level age curves are presented based on an ongoing study of passive margin and interior basin subsidence. Comparison of our results with previous work allows us to examine 1) the use of the Vail et al. (1977) curve as a tool of stratigraphic correlation 2) the geological basis for sudden large amplitude sea-level changes and 3) possible causes for long term changes in the volume of the ocean basins.

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PRECASPIAN DEPRESSION - THE GREATEST SEDIMENTARY BASIN OF THE WORLD

The Precaspian depression is the greatest global sedimentary basin. It covers more than 500,000 sq km, thickness of the sedimentary section in its central part is 20 to 23 km. This depression has a suboceanic type of the crust: geophysical "granite layer" is absent in the central area. Two major structural megaunits have been distinguished within the sedimentary section. The lower unit, a pre-plate, appears to consist of Riphean and Vendian terrigenous and carbonate rocks which have a rather high density and deformation; their thickness is as much as 7 to 10 km, according to geephysical data. The plate megaunit comprises Paleozoic subsalt sediments, soliferous Kungurian and Upper Permian-Cenozoic above-salt strate. The subsalt unit within the margins of the depression is composed of alternating carbonate (300 to 1700 m thick) and terrigenous (50 to 500 m) strate.

Inward the basin, the carbonate deposits are displaced by thin (thickness is limited by tens and a few hundred meters) argillo-carbonate siliceous rocks. Therefore, the thickness of the Paleozoic subsalt sediments on the flanks of the depression exceds their thickness in the central parts. The carbonate rocks form large tectono-sedimentary structures: barrier reefs, both relatively subtle and rugged "carbonate platforms" and single, sometimes high-amplitude reef pinnancles.
Geologic history includes the following stages: aulacogenic or rift stage (Riphean-Vendian, 1000 m.y. duration), epicontinental stage (Early Paleozoic-Early Middle-Devonian, about 200 m.y.), basinal stage (Middle Fransian-Artinskian, 125 m.y.), compensation stage (Kungurian, 10 m.y.), and salt-dome stage (Late Permian-Quarternary, 260 m.y.). The above noted features of structure and development of the Precaspian depression consider it to be highly promising for oil and gas.

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ПРИКАСПИЙСКАЯ ВПАДИНА - КРУПНЕЙШИЙ ОСАДОЧНЫЙ БАССЕЙН ЗЕМЛИ

Прикаспийская впадина представляет собой крупнейший осадочный бассейн Земли. Его площадь более 500 тыс.км^2, мощность осадочного чехла в центральной части 20-23 км^2. Впадина характеризуется субокеаническим типом Земной коры - в ее центральной части отсутствует геофизический "гранитный слой". В разрезе осадочного чехла впадины выделяется два крупных структурных мегакомплекса. Нижний из них - доплитный мегакомплекс, по-видимому, сложен терригенными и карбонатными породами рифея и венда, обладающими повышенной плотностью и дислоцированностью, их мощность по геофизическим данным 7-10 км. Плитный мегакомплекс охватывает подсолевые палеозойские отложения, соленосные породы кунгурского яруса и надсолевую верхнепермскую - кайнозойскую толщу. Подсолевой комплекс в бортовых зонах впадины сложен чередующимися в разрезе карбонатными (мощность 300-1700 м) и терригенными (50-500 м) толщами. Карбонатные отложения к центральным районам впадины замещаются маломощными (десятки и первые сотни метров) глинисто-карбонатно-кремнистыми породами. Поэтому мощность палеозойских подсолевых отложений в бортовых зонах впадины превышает их мощность в центральной части. Карбонатные породы образуют крупные тектоно-седиментационные структуры: барьерные рифы, как относительно плоские, так и расчлененные "карбонатные платформы" и одиночные иногда высокоамплитудные рифовые массивы (пинаклы).

В геологическом развитии Прикаспийской впадины выделяются следующие этапы: авлакогенный или рифтовый (рифей-венд продолжительностью 1000 млн.лет), эпиконтинентальный (ранний палеозой -ранний-средний девон, около 200 млн.лет), глубоководный (среднефранско-артинский, 125 млн.лет), компенсационный (кунгур, 10 млн.лет), солянокупольный (позднепермско-четвертичный, 260 млн.лет). Отмеченные особенности строения и развития впадины предопределяют высокие перспективы ее нефтегазоносности.

С И М П О З И У М / S Y M P O S I U M L.02

ТИХООКЕАНСКОЕ СКЛАДЧАТОЕ КОЛЬЦО И ЭВОЛЮЦИЯ ТИХООКЕАНСКОГО БАССЕЙНА

CIRCUM-PACIFIC OROGENIC BELTS AND EVOLUTION OF THE PACIFIC OCEAN BASIN

Conveners: J.Monger, Yu.A.Kosygin, S.M.Tilman

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OCEANIC PLATEAUS, DISPLACED TERRANES AND OROGENY

Numerous oceanic rises are embedded in the earth's oceanic plates and are fated to be consumed at active margins in the future. These rises, or plateaus, are mid plate features of various origins. Included are extinct arcs, extinct spreading ridges, detached and submerged continental fragments, oceanic island and seamounts including hotspot tracks. Some of these buoyant rises are presently being consumed, causing gaps in active volcanic chains, disordering the normal seismic pattern associated with subduction of oceanic crust, emplacing ophiolites, and possible creating marginal seas. Some past oceanic plateaus have become accreted terranes now found in ancient active margins. They consitute a large portion of the orogenic belts throughout the circum-Pacific region. Similar accreted terranes have been also identified in older orogenic belts. In the circum-Pacific the accretion of the terranes involve extensive orogenic deformation, usually without full continent-continent collision. Many terranes have been accreted with substantial deformation also in the Alpine chain, well before major continent-continent collision. It is suggested, therefore, that the accretion of fragments may be the common process of the deformation phase of mountain building. Subduction of normal oceanic crust may be insufficient for deformation, whereas full continent-continent collision may not be necessary.

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ACCRETIONARY AND INTRAPLATE TECTONICS IN THE EVOLUTION OF THE NORTH AMERICAN CORDILLERA

Although up to 70% of the North American Cordillera is now known to be composed of suspect terranes neither subduction driven Andean nor Himalayan collision models adequately explain the complexity observed.

In most cases the suspect terranes are in stacks of rootless nappes or imbricate slices completely detached from any known basement or original lithosphere. Many terranes are either surrounded or embedded in a deformed matrix of deep marine flysch. Many terrane boundaries are major strike-slip faults with hundreds of kilometers of displacement. Rotations about vertical axes are not uncommon. On the Cordilleran cratonic foreland thin-skinned telescoping and deep-seated crustal thrust faults are widespread.

The majority of the vast telescoping, translations, and rotations took place between Middle Jurassic and Early Tertiary time, but continue in some sectors to the present time. Collisions must have taken place, but they were short-lived and did not produce the deformation observed. Most of the deformation, both within the suspect terranes and on the foreland is the result of prolonged post-collision accretionary intraplate consolidation which must have absorbed a significant percentage of the convergent relative motion between various "Pacific" plates and North America.

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PACIFIC BASIN PLATE MOTIONS, RECONSTRUCTIONS, AND THE DISPLACEMENT OF TERRANES SINCE THE JURASSIC

Available models for the displacement histories between oceanic and continental plates of the Pacific Basin are examined for possible correlations with a variety of geological observations. Some of the important elements derived from analyses of these displacement models for use in comparison with the geological record follow.

(1) Reconstructions of the plates at selected times are shown depicting observable and proposed boundaries between the North American, Eurasian, Pacific, Farallon, Kula, Izanagi, and Phoenix plates. These reconstructions include the times and locations of major plate reorganizations and the migrations of important triple junctions.

(2) Examples are presented that show the effectiveness of the known plates for providing a means for the origin, travel history, and accretion of allochthonous terranes. Relationships between travel histories of terranes and their paleomagnetic record are outlined.

(3) Relative linear velocities are shown as diagrams that depict the azimuth and speed of plates as a function of time at selected points around the Pacific margin. Significant changes in linear velocities offer insights into the mechanisms that control the diversity of tectonic styles found in the geologic record.

(4) The age and bathymetric features of portions of now-consumed oceanic plates are predicted. Bathymetric features result from differences in age across fracture zones and from the development of volcanic edifices associated with the motion of the plates over hotspots.

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A GENERAL VIEW ON THE CHILEAN - ARGENTINIAN ANDES

The Andes are generally thought as a young mountain belt associated to eastward subduction of the Nazca or prexisting oceanic plates beneath the South American plate. However, the Meso-cenozoic Andes are built over a highly complex basement which spans in time from Precambrian to Triassic. Collision of continental blocks might have occurred in the early Palaeozoic in northern and central Argentina and Chile. A well defined Late Palaeozoic subduction complex is present along the coastal ranges South of 30° lat. This is associated to a Carboniferous to Permian pluto-volcanic belt and related marine basins constructed inboard the SW Gondwana continental margin. Paired metamorphic belts with occasional blueschists were developped during the accretion processes. The Meso-cenozoic history is mainly one of pluto-volcanic "accretion" via episodic build ups of narrow, linear, North-South trending, calcalkaline magmatic belts. Those of the Jurassic to Early Cretaceous are related to intra-arc and back-arc ensialic basins which, in southernmost Andes evolved into short lived marginal basin, floored by an oceanic type crust. No subduction complexes of Meso-cenozoic age appear to outcrop subaerially.
Longitudinal changes in the stratigraphy and tectonics along the belt are beginning to be established.They reflect a complex interaction of the coverging palaeoplates which has a present day expression in the volcanic and tectonic segmentation of the Andes. The huge Late Tertiary to Recent volcanic deposits testify the widespread partial melting of subcontinental mantle under the action of the subducting Nazca plate which has maybe scraped off tectonically parts of the Meso-cenozoic fore-arc assemblages. The existance of megafaults, roughtly parallel to the continental margin, one of which is associated to the subducting Chile rises or ridges have been consumed earlier in the geological history of the Andean chain.

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CIRCUM-PACIFIC TECTONOSTRATIGRAPHIC-TERRANE ANALYSES AND THE GROWTH OF CONTINENTS

Since the Paleozoic, the geologic evolution of the continents surrounding the proto-Pacific (=Panthalassa) and modern Pacific basin has been affected by rifting and dispersal of allochthonous terranes, many from equatorial paleolatitudes. Fragments of these rifted terranes are now found plastered onto continental margins around much of the rim of the Pacific basin. The terranes are composed of a wide variety of geologic materials, including scraps of island arcs, seamounts, ocean basins, continental rise prisms, and fragments of continents. The continental fragments are themselves composed of a collage of terranes amalgamated during the Proterozoic and (or) Paleozoic time.

Continental growth by accretion is a global phenomenon, resulting from processes of crustal spreading at ocean ridges and subduction along continental margins. The nearly 60,000 km of ridges, if spreading at 5 cm/yr, would create a surface equal to all the modern oceans in 120 m y. Assuming similar plate-tectonic rates throughout the Phanerozoic, four modern-size world oceans have been subducted, all accompanied by accretion of allochthonous terranes along continental margins. Furthermore, based on the breadth and composition of Proterozoic fold belts (=ancient continental margins), this process has been controlling the growth and shape of continents since the Archean.

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GEOLOGICAL EVOLUTION OF THE NORTHERN AND CENTRAL ANDES BETWEEN THE CARIBBEAN SEA AND 18°S

The several segments of the Andes may be subdivided on the basis of their Mesozoic and early Tertiary evolutions and particularly on the basis of the presence or absence of ophiolitic sutures of this age. Later evolution was similar along most of the Andean orogen. It gave rise both to the main linear physiographic features and to its typical Cenozoic volcanic belts.

The northern Andes s.s. are limited on the north by the northern Sierra de Santa Marta - Barquisimeto WNW-ESE trending thrust-belt, along which the Caribbean belt overrides the structural units of the Central and Eastern Cordilleras of Colombia and of the Merida Andes of Venezuela, and (ii) on the south by the 3°S parallel. The internal, i.e. western, structural units of the northern Andes consist largely of Mesozoic rocks that are: (i) volcanic rocks of tholeiitic to calcalkaline composition locally associated with gabbros and peridotites and (ii) highly siliceous and flysch-type sedimentary rocks. These units are mainly exposed in the Western Cordilleras of Colombia and Ecuador and in an allochtonous westernmost strip of the Central Cordillera of Colombia. They most probably represent slices of island arcs and of intervening oceanic crust that have been accreted to the continent between the Albian and early Tertiary. In sharp contrast with the above units, the external, i.e. eastern, units of the northern Andes were entirely deposited upon continental crust. They consist mainly of continental and shallow marine sedimentary rocks of Mesozoic and Tertiary age with an aggregate thickness of as much as 9 km, that are partly interspersed with calcalkaline volcanic rocks. Much of the shortening and metamorphism of the central Cordillera of Colombia and of the eastern (or Real) Cordillera of Ecuador was probably caused by the accretion of the western units.

South of 3°S the central Andes probably provide the best example of a "liminal" belt built on the edge of a continent, but entirely upon sicilic crust, by processes related to subduction of oceanic lithosphere. The typical paleogeographic setting during the Mesozoic was one of elongated basins and intervening highs parallel both to the present trend of the Andes and to a subduction zone active since the lower Jurassic. During the Cretaceous, as much as 12 km of marine sediments and subduction related volcanics were deposited within the western or "Andean" basin of central Peru which was floored by the thinned crust. In the eastern or "Subandean" basin as much as 10 km of conformable/disconformable sediments ranging from lower Paleozoic to Pliocene in age accumulated. The period of Andean tectogenesis began in the Albian. It comprises at least five discrete phases of compression; on the whole, strain migrated progressively from west to east. Pulses of compression are related to changes in both the rate of convergence and dip of the subduction zone. They gave rise to simple concentric folds and to steep thrusts, and also to fold and thrust belts. The most recent phase is late Neogene in age. It created the

Subandean fold and thrust belts of Peru and Bolivia and extended farther north in Ecuador and Colombia, where it gave rise to the basement-cored folded and upthrust block of the Eastern Cordillera.

In the central Andes the main igneous pulses are Cretaceous, Paleocene, late Eocene - early Oligocene, early Miocene and late Miocene in age. The large linear coastal batholith of Peru was emplaced between 100 and 32 m.y.

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EVIDENCE FOR LARGE-SCALE HORIZONTAL DISPLACEMENTS WITHIN THE NORTH AMERICAN CORDILLERA

Two-thirds of the Cordillera consists of lithospheric fragments or terranes, that originated mainly as ensimatic volcanic arcs and ocean basin deposits, and came to their present positions in the continental margin mostly in latest Mesozoic time. Many terranes carry paleontological and paleomagnetic records different from those of other terranes and from rocks deposited along the ancient continental margin. These records indicate south to north displacements in excess of 1000 km relative to cratonic North America, generally with eastern terranes displaced the least. East-west displacements are not as well documented, but are most clearly demonstrated in the northern Cordillera by a terrane containing Permian faunas similar to those in strata bordering the western Pacific and in the Alpine-Himalayan mountain chains, but completely different from those in flanking terranes which have affinities with coeval North American faunas. Offsets of geological markers across fault zones record the latest displacements. Compressional structures demonstrate a few hundred of kilometres of east-west shortening, but south to north dextral transcurrent faults have cumulative displacements, probably mainly post-Middle Cretaceous, well in excess of 1000 km, in good agreement with the paleontological and paleomagnetic records.

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EOCENE HORIZONTAL STRETCHING AND DUCTILE NECKING OR CONTINENTAL LITHOSPHERE ASSOCIATED WITH TRANSFORM FAULTING WITHIN THE CANADIAN CORDILLERA

The continental lithosphere beneath the North American Cordillera was stretched, during Early and Middle Eocene time, within an area of about 150,000 sq. km. in central British Columbia and northeastern Washington. East-west extension was linked to slip on right-hand transform faults, some of which overlap en echelon. It reflects the clockwise rotation, relative to the North American plate, of smaller plates of Cordilleran lithosphere that become partly coupled to oceanic lithosphere lying outboard from North America. It was superimposed upon older compressional deformation resulting from subduction, collision and tectonic accretion along the western margin of North America during Mesozoic and Paleocene time. Analysis of geologic structures and tectonic fabrics shows that stretching involved:
(1) inhomogeneous ductile necking, and the development of crustal-

scale mega-boudins in a hot metamorphic infrastructure at middle to lower crustal levels;
(2) brittle deformation and listric normal faulting in a cold suprastructure at upper crustal levels;
(3) rapid tectonic denudation, with consequent abrupt thermal quenching and embrittlement of the metamorphic infrastructure; and
(4) the intrusion of swarms of north-trending of dykes.

The metamorphic infrastructure moved outward and upward, along listric normal faults, from the zones of ductile necking. The unmetamorphased sedimentary rock of the suprastructure, together with overlying clastic sediments that accumulated in assymetric grabens during listric normal faulting, were tilted as they moved downward along the curved, concave-upward listric normal faults, toward the zones of crustal necking. Granitic igneous rocks that were emplaced in the zone of necking during stretching were deformed and cut by normal faults during further stretching.

These relationships between listric normal faulting and inhomogeneous ductile stretching of continental crust illustrate general principles that are applicable to the analysis of the stretching of continental lithosphere elsewhere.

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TECTONICS OF THE PACIFIC AREA

The problem of the Pacific Ocean is one of the most difficult in tectonics. It became in the focus of attention due to the ideas of G.Darvin, E.Suess, V.I. Vernadsky, H. Stille, N.S. Shatsky, B. Hizen. In the USSR the studies of this problem are carried out in two directions: regional-tectonic (in the ocean and its framework, and general Pacific).The study of bedrocks of oceanic bottom and ophiolites in the continental margin enabled us to compile the generalized geological section of the Earth crust beneath the Pacific Ocean characterized by certain specific features in various structural forms of the ocean floor. On the Pacific western periphery the oceanic crust and the mature continental one are divided by a broad (sometimes up to some thousand kilometers) zone, where the formation of the continental crust is still going on. The nearer the ocean, the younger the age of the granite-metamorphic layer. Correspondingly, the continental crust proceeds at the expense of transformation of the oceanic one. The tectonic piling plays an important role in this process. The geological history of the framework dates back to the ancient times. The Sikhote-Alin' developed as a near-oceanic zone since the beginning of Paleozoic. The history of the ocean in Paleozoic has not been elucidated. The latest data on the Shirshov range geology in the Bering Sea and Sakhalin allow us to consider the age of the ocean as old as Triassic. There appear more and more evidence testifying to the horizontal movement of tectonic slices inside the oceanic crust and lithosphere in general. Corresponding deformations were revealed both in the central regions of the ocean (faults Clarion, Nova, Magellan) and in the margins (Tonga trench). This process seems likely to be related to the thickening of the crust in Shatsky, Hess and Magelan Rises. Thereby, the tectonic piling of lithosphere slices is most probably a process proceeding throughout the Earth. The elucidation of the essence of tectonic and magmatic development of the oceanic lithosphere is associated with distinguishing geochemically and petrochemically specific features of large provinces in rocks of the 2nd and 3rd crust layers, and their correlation to structural heterogeneities. In the USSR the programme "Lithos" elaborates this problem.

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ТЕКТОНИКА ТИХООКЕАНСКОЙ ОБЛАСТИ ЗЕМЛИ

Тихоокеанская проблема принадлежит к числу наиболее трудных в тектонике. Мысли Дж.Дарвина, Э.Зюсса, В.И.Вернадского, Г.Штилле, Н.С.Шатского, Б.Хизена придали ей особенную остроту.

В СССР исследования проводятся в двух направлениях: регионально-тектоническом (в океане и обрамлении) и общетихоокеанском. Изучение коренных пород океанского дна и офиолитов континентальной окраины позволило составить обобщенный геологический разрез земной коры под Тихим океаном, имеющим некоторые особенности в разных структурных формах океанского ложа. На западной периферии Тихого океана океаническая кора и зрелая материковая разделены широкой (местами до нескольких тысяч км) зоной, где образование континентальной коры происходит в настоящее время. Чем ближе к океану, тем возраст гранитно-метаморфического слоя моложе. Соответственно континентальная кора образуется за счет преобразования океанической. Важная роль в этом процессе принадлежит тектоническому скучиванию. Геологическая история обрамления выясняется до глубокой древности. Сихотэ-Алинь развивался как приокеаническая зона с начала палеозоя. История океана в палеозое не раскрыта. Новейшие данные по геологии хребта Ширшова в Беринговом море и Сахалина позволяют удревнить возраст океана до триаса. Появляется все больше свидетельств горизонтального движения тектонических пластин внутри океанической коры и литосферы вообще. Соответствующие деформации обнаружены как в центральных районах океана (разломы Кларион, Нова, Магеллана), так и на окраинах (желоб Тонга). Вероятно, с таким процессом связано утолщение коры в поднятиях Шатского, Хесса и Магеллана. Тем самым тектоническое скучивание литопластин-скорее всего процесс общеземной. Раскрытие существа тектонического и магматического развития океанской литосферы связано с обособлением специфических крупных провинций по геохимическим и петрохимическим признакам в породах 2-го и 3-го слоев коры и сопоставления их со структурными неоднородностями. В СССР этому служит программа "Литос".

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TECTONIC DEVELOPMENT OF EASTERN AUSTRALIA IN RELATION TO THE PACIFIC REGION*

Eastern Australia is mainly built by the orogenic, composite, substantially Palaeozoic, Tasman Fold Belt System (Tasmanides), which developed as part of the tectonically complex SW Pacific region.

Late Proterozoic sediments and volcanics of the Australian craton indicate intraplate and passive plate margin setting. However, by earliest Cambrian time a well developed west-Pacific type, active plate margin existed in E. Australia. Hence, break-up, sea-floor spreading coupled with separation and dispersal of microcontinents, and possibly some plate convergence, must have occurred during pre-Cambrian time. Subsequently these Precambrian complexes became the basement to, and internal massives in, the Tasmanides.

Palaeozoic complexes indicate episodic rearrangement of the active plate margin. Episodes of orogeny were caused by changes in the style of B-subduction (Mariana versus Chilean) and by collision of microcontinents, volcanic arcs and other tectonostratigraphic terranes. During orogenies extensional volcanic rifts, marginal basins and other basins were closed and inverted. A-type granites intruded volcanic piles in volcanic rifts. Synkinematic S-type granites were emplaced in high-T metamorphic belts, late and post kinematic S- and I- type granites intruded the inverted belts and earlier stabilized blocks.

The Early Palaeozoic Kanmantoo Fold Belt resulted from collisional movement of inner microcontinents. The development of the Lachlan Fold Belt was complicated. During the Benambran Orogeny, (late Ordovician to Early Silurian) the Molong Volcanic Arc collided with the Victorian microcontinent. The transmitted stress caused easterly thrusting in the Kanmantoo Fold Belt and formation of the Stawell-Bendigo Foreland Fold and Thrust Belt (Cox et al. 1983). The Middle Devonian to Carboniferous Lachlan Fold Belt resulted from closure of a complex back-arc area. The Permian to Middle Triassic New England Fold Belt, displaying composite volcanic arc-fore-arc-accretionary prism complexes was thrust westward over its foredeep Sydney-Bowen Basin.

Mesozoic rifting, break-up and plate separation were clearly connected with the SW Pacific active plate margin, orogenic development of which is still continuing.

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EARLY PALEOZOIC EVOLUTION OF THE CIRCUM-PACIFIC REGION

Though the Pacific plate is less than 200 million years old, the Circum-Pacific ocean basin (= Panthalassic ocean basin) has probably been in existence since Precambrian times. During the Early Paleozoic, the Tasman, Trans-Transantarctic and southern South American margins of the Panthalassic ocean basin appear to have been the site active subduction. This convergent system may have continued north into Southeast Asia and China. In contrast, the western edge of cratonic North America was a passive margin until Late Devonian times (Antler/Caribou Orogeny).

The tectonic evolution of the Panthalasic ocean basin during the Early and Middle Paleozoic can only be unraveled by reconstructing the configuration of the continents along its perimeter. Paleomagnetic data from the continents bordering Panthalassa will be reviewed, and a series of reconstructions, complete with inferred Early Paleozoic plate tectonic boundaries, will be presented.

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OROGENIC DEVELOPMENT OF NEW ZEALAND

Three main orogenic periods, Tuhua (-400 to -360 my), Rangitata (-120 to -100my) and Kaikoura (ca. 25my to present) govern the tectonic development of New Zealand. There are no rocks older than 680my. Rocks affected by the Tuhua orogeny are restricted to the "western foreland". Paleozoic strata have affinities with southeastern Australia. Tuhua orogeny is marked by intrusion of the Karamea batholiths. A complex, greywacke-dominated foreland lies to the east of the foreland and records accretion of clastic wedges deposited on oceanic crust and probably of some exotic terranes, in the Mesozoic, culminating in the Rangitata Orogeny, with intrusion of granites into the western foreland.
Up to this time New Zealand was part of Gondwana, but after protracted rifting in the Cretaceous separated from the supercontinent in the early Tertiary, during opening of the Tasman Sea. The presently active plate boundary through New Zealand was established with separation of Antarctica and Australia, leading to increasing rate of convergence combined with dextral strike slip, and formation of the calcalkaline Taupo Volcanic Zone.

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TECTONICS OF THE NORTH-WESTERN MARGINS OF THE PACIFIC

The North-Western continental margin of the Pacific includes the Western and Eastern tectonic segments that have been finally isolated in Late Mesozoic. Within the Western segment there are areas with continental crusts of different ages. The Eastern segment corresponds to a recent geosyncline belt, the continental crust is under formation here.

Diversity of structural forms in the Eastern Asia resulted from heterogenous structure of the Preriphean substrate. The ungranitized Preriphean granulite-basite crust occurs at the base of plates of platforms, miogeosynclines and rift zones, while the granitized crust formed a socle of shields and median masses. Various types of the Preriphean crust responded to the processes of subsequent destruction differently.

The first active margins clearly appeared in the Devonian due to formation of an ocean. Although ancient, the new Pacific paleoocean originated due to scattered spreading, similar to the Far East marginal seas of a destructive genesis. Removal of the sialic crust from the area occupied by the newly formed Pacific basin was partly compensated by the piling up and thickening of rock slabs in the transitional zones, while in the new ocean there periodically appeared microcontinents whose areas are not outlined yet.

Accretion, destruction and ocean formation took place simultaneously. These processes are correlated with each other and coinside with global folding epochs.

In transitional zones the oceanic crust transformed into the continental one due to spreading out of the granite-metamorphic layer in space and time. An embrionic granite layer can be recognized in the upper part of the ophiolite association section.

Certain hypotheses on structure formation are considering; the conception proposed by A.V. Peive on tectonically stratified lithosphere being preferable.

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ТЕКТОНИКА СЕВЕРО-ЗАПАДНОГО ОБРАМЛЕНИЯ ТИХОГО ОКЕАНА

Северо-западная континентальная окраина Тихого океана охватывает Западный и Восточный тектонические сегменты, окончательное обособление которых произошло в конце мезозоя. В пределах Западного сегмента сосредоточены области с разновозрастной континентальной корой. Восточный сегмент отвечает современному геосинклинальному поясу ; континентальная кора здесь находится в стадии формирования.

Разнообразие структурных форм на востоке Азии предопределено гетерогенным строением дорифейского субстрата. Негранитизированная дорифейская гранулит-базитовая кора находится в основании плит платформ, миогеосинклиналей и рифтовых зон, а гранитизированная образовала цоколь щитов и срединных массивов. Разные типы дорифейской коры по-разному реагировали на процессы последующей деструкции.

Первые активные окраины ясно обозначились в девоне. Их появление есть следствие океанообразования. Тихий палеоокеан новообразованный, хотя и древний, возник в результате рассеянного спрединга подобно дальневосточным краевым морям деструктивного генезиса. Удаление сиалической коры с пространства, занятого новообразованной Тихоокеанской впадиной, частично компенсировалось скучиванием и утолщением пластин горных пород в переходных зонах, а в новообразованном океане периодически появлялись микроконтиненты, площади которых пока еще не оконтурены.

Аккреция, деструкция и океанообразование происходили почти одновременно :они коррелируются между собой и совпадают с глобальными эпохами складчатости.

В переходных зонах совершалось сложное преобразование океанической коры в континентальную путем разрастания в пространстве и во времени гранитно-метаморфического слоя. Эмбриональный гранитный слой распознается в верхней части разреза офиолитовой ассоциации.

Рассматриваются некоторые гипотезы структурообразования; отдается предпочтение концепции тектонической расслоенности литосферы, сформулированной А.В.Пейве.

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TECTONICS AND GEOLOGICAL NATURE OF NORTH-WESTERN SEGMENT OF THE WEST PACIFIC ACTIVE MARGIN

According to dredging and deep sea drilling the basement projections in Bering,Okhotsk and Japan Seas and in the North of Philippine Sea are made up by metamorphosed sedimentary-volcanogenic, metamorphic and intrusive geosyncline complexes having the age from 40-50 million years (upper Paleogene) up to 2.3 billion years (Archean). They reveal a great resemblance to the rocks of adjacent continental and island lands. Sedimentary cap in Bering and Okhotsk Seas is made up by Cenozoic sedimentary-volcanogenic weakly consolidated rocks with thickness of 9-11 km. As to the tectonics, the above mentioned marginal seas are treated as neoplatforms with a cap, complicated by structures of the type of arched uplifts, swells, depressions, rifts. It seems that Japanese, Ryukyu, Kuril-Kamchatka and Aleutian Island arcs originated on continental basement, whereas Idzu-Bonin probably on oceanic one. Deep sea basins of marginal seas and deep sea trenches are superimposed structures. As geomorphological objects they have originated like island arcs in late Cenozoic (upper Miocene-Pliocene) and continue to form at present. Judging from the available materials the geological nature of the North-Western sector of West Pacific active margin seems to be a compound block mosaic, which during its development as a transition zone continent - ocean had undergone the vertical, horizontal and rotational displacements.

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ТЕКТОНИКА И ГЕОЛОГИЧЕСКАЯ ПРИРОДА СЕВЕРО-ЗАПАДНОГО СЕГМЕНТА ЗАПАДНО-ТИХООКЕАНСКОЙ АКТИВНОЙ ОКРАИНЫ

Согласно данным драгирования и глубоководного бурения, выступы акустического фудамента в Беринговом, Охотском, Японском морях и на севере Филиппинского моря сложены метаморфизованными осадочно-вулканогенными, метаморфическими и интрузивными геосинклинальными комплексами с возрастом от 40-50 млн. (верхний палеоген) до 2, 3 млрд. лет (архей), обнаруживающими большое сходство с породами прилегающей материковой и островной суши. Осадочный чехол образован кайнозойскими осадочно-вулканогенными слабо уплотненными породами мощностью в Беринговом и Охотском морях до 9-10 км. В тектоническом отношении перечисленные моря трактуются как неоплатформы, чехол которых осложнен структурами типа сводовых поднятий, валов, прогибов, рифтов. Представляется, что Японская, Рюкю, Курило-Камчатская, Алеутская островные дуги заложились на континентальном основании, Идзу-Бонинская, Марианская -, вероятно, на океаническом. Глубоководные впадины окраинных морей и глубоководные желоба являются наложенными структурами. Как геоморфологические объекты они так же, как островные дуги, заложились в позднем кайнозое (верхний миоцен-плиоцен) и продолжают формироваться в настоящее время. На основании имеющихся материалов геологическая природа северо-западного сектора Западно-Тихоокеанской активной окраины представляется как сложная мозаика блоков, испытавших в процессе его (сектора) развития как зоны сочленения континента с океаном вертикальные, горизонтальные и вращательные перемещения.

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CHILEAN VS. MARIANA TYPE SUBDUCTION ZONES

Various geophysical and geological phenomena characteristic of subduction zones, such as back arc extension, arc volcanism and seismicity, are difficult to explain in terms of a single model for down-going slabs of cold oceanic lithosphere. Comparative studies of different subduction zones are instructive in this regard and lead to the recognition of two fundamentally contrasting modes controlled by the strength of mechanical coupling between down-going and overriding plates. High stress Chilean-type subduction zones are characteristic of continental arcs, whereas island arcs with actively spreading back arc basins are typified by low-stress Mariana-type subduction.
With this distinction in the mode of subduction, diversity in many other phenomena related with trench-arc-back arc systems may be explained in a consistent manner, e.g. regional stress distribution, vertical movements, heat flow, mineralization, sediment subduction/accretion, crustal accretion/erosion and collision.
The possible factors controlling the degree of mechanical coupling between down-going and overriding plates are the difference in the nature, mainly the density, of the subducting plate and the motion of the overriding plate relative to the position of the trench line. The former is determined by the age and "continentality" of the subducting plate and the latter by the absolute motion of the overriding plate, if the trench line is stationary. It should be noted that trench line can be moved by asthenospheric flow, roll back of subducting plate and trenchward advancement of overriding plate, causing extension and closure of back arc basins. Since all these factors can change with time, the mode of subduction at any particular subduction zone can also change with time. This may account for the opening and closure of back arc basins in the ancient subduction zones.

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TRANS-ELEMENTS OF THE MARGINAL SEA - ISLAND ARC - OCEAN FLOOR SYSTEM

Island arcs and active continental margins are characterized by faults of different geodynamic environments and tectonic nature. The largest elements, formation of which reflects conditions of compression (seismofocal zones, thrusts and underthrusts often with strike-slip component), are traced along them. In general normal faults on outer slopes of deep-sea trenches and rift structures of marginal seas in the backarcs strike conformably. In island arc systems and in continental margins transverse structural elements vary according to their morphological and dynamic characteristics. The analysis of gravity and magnetic field maps, printed and compiled last years, including the results of submarine relief investigation, structure of sedimentary cover and basement blocks, peculiarities of seismicity distribution allow to identify trans-structural elements in the systems of marginal sea - island arc - ocean floor. In the Northern and Western Pacific such lineaments are traced through the juncture of island arcs or their separate parts from ocean floor into marginal seas or continental massifs. Among them there are lineaments in juncture regions of Izy-Bonin and Volcano island arcs, Mariana and Yap, Kuril-Kamchatka and Aleutian flanks and also some transverse elements of island arcs out of their boundaries (faults of Tuskarora and Bussol Gulf, Kodiak Island region, etc...). Tectonic nature of trans-elements is different. In some cases they may be boundaries between old heterogeneities of the Earth crust and upper mantle, in other - they may reflect lithosphere reaction on the existed stress field. Island arc flanks and regions of their intersection by trans-elements are favourable for ores localization of some types.

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СКВОЗНЫЕ ЭЛЕМЕНТЫ СИСТЕМЫ ОКРАИННОЕ МОРЕ-ОСТРОВНАЯ ДУГА-ЛОЖЕ ОКЕАНА

Островные дуги и активные континентальные окраины характеризуются разломами различных геодинамических обстановок и тектонической природы. Вдоль них прослеживаются крупнейшие элементы, становление которых отражает условия сжатия (сейсмофокальные зоны, надвиги и поддвиги, часто со сдвиговой компонентой), и наряду с этим в целом согласно с ними простираются сбросы внешних склонов глубоководных желобов и, располагающиеся в тылу островных дуг раздвиговые структуры окраинных морей. Разнообразны по морфологическим и динамическим признакам в системах островных дуг и континентальных окраинах и поперечные структурные элементы. Анализ ряда изданных и составленных в последнее время карт гравитационного и магнитного полей, а также полученные в последние годы результаты изучения подводного рельефа, структуры осадочного чехла, строения блоков фундамента и особенности распределения сейсмичности позволяют выделить сквозные структурные элементы в системах окраинное море-островная дуга-ложе океана. В северной и западной частях Тихого океана подобные линеаменты прослеживаются через места сочленения островных дуг или отдельных их частей из ложа океана в пределы окраинных морей или континентальных массивов. К их числу можно отнести линеаменты, устанавливаемые в местах сочленения дуг Идзу-Бонинской и Волкано, Марианской и Яп, района флангов Курило-Камчатской и Алеутской дуг. К ним относится и ряд поперечных элементов дуг, выходящих за их пределы (разломы Тускарора, залива Буссоль, района острова Кодьяк и др.). Тектоническая природа сквозных элементов неоднозначна. В одних случаях они, по-видимому, представляют собой границы между древними неоднородностями земной коры и верхней мантии, в других отражают реакцию литосферы на существующее поле напряжений. Фланги островных дуг и места пересечения дуг сквозными элементами благоприятны для локализации ряда типов оруденения.

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EURASIA/PACIFIC RELATIVE MOTION DURING THE LAST 130 MA AND ITS BEARING ON OROGENESIES IN NORTHEAST ASIA

Data for relative plate movements in the global scale during the last 70 m.a. and for plate movements in the hot spot frame during the last 130 m.a. were used to compute Eurasia/Pacific motion. The Kula/Pacific motin parameters were also determined for the 60-130 m.a. interval.

Three stages in the Eurasia/Pacific interaction can be outlined:
(1) 130-70 m.a. when the Kula plate moved with the rate of 10 cm/year northwestwards perpendicularly to the Eurasia's margin, and when Eurasia moved in the hot spot frame southwards toward to the Kula movement. The large orogeny within the Verkhoyansk-Kolymian region and development of an active continental margin of the Andean type (with the Okhotsk-Chukotka and Sikhote-Alin volcanic belts) along the

edge of the continent were related with this plate interaction pattern.
(2) 70-40 m.a. when the Pacific plate move NNW along the Eurasia margin with the rate of 6-7 cm/year. At that time subduction zones and related orogenic events occurred mainly along the segments orthogonal to the plate motion, in the Shimanto zone (Japan) and the Koryak-Kamchatka volcanic arc which was collided with the Asia margin in Late Eocene.
(3) 40-0 m.a. when the Pacific plate motion again became orthogonal to the Asia margin. However, Eurasia move in the hot spot frame north-north-eastwards, that is oblique to the Pacific plate motion, so giving way for marginal sea opening behing the ancored subduction zone in NW Pacific.

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ДВИЖЕНИЯ ПЛИТ ТИХОГО ОКЕАНА ПО ОТНОШЕНИЮ К ЕВРАЗИИ ЗА ПОСЛЕДНИЕ I30 МЛН.ЛЕТ И СВЯЗЬ С НИМИ ОРОГЕНИЧЕСКИХ СОБЫТИЙ НА СЕВЕРО-ВОСТОКЕ АЗИИ

Для расчета движений плит Тихого океана по отношению к Евразии использованы данные по перемещениям плит относительно горячих точек за последние 70 млн.лет. Были вычислены также параметры движения плиты Кула относительно Тихоокеанской плиты с 60 до I30 млн.лет.
Выделяется три этапа взаимодействия плит:
I) I30-70 млн. лет, когда плита Кула со скоростью I0 см/год двигалась на СЗ перпендикулярно краю Азии и когда Азия по отношению к горячим точкам перемещалась на юг навстречу движению плиты Кула; с этим этапом связаны интенсивная орогения в Верхояно-Колымской области и в последующем формирование активной окраины андийского типа с Охотско-Чукотским и Сихотэ-Алиньским вулканическими поясами;
2) 70-40 млн.лет, когда Тихоокеанская плита двигалась на ССЗ вдоль края Азии со скоростью 6-7 см/год; в это время зоны субдукции (и связанные с ними орогенические события) существовали на отрезках, перпендикулярных движению Тихоокеанской плиты, в частности в Корякско-Камчатской вулканической дуге, которая в конце эоцена столкнулась с краем Азии;
3) 40-0 млн.лет, когда движение Тихоокеанской плиты вновь стало перпендикулярным краю Азии, но перемещение Азии в системе горячих точек было направлено от заякоренной зоны субдукции или косо по отношению к ней; в результате возникла современная система островных дуг и спрединговых окраинных бассейнов.

АРХЕЙСКАЯ ЛИТОСФЕРА И ЭВОЛЮЦИЯ КОРЫ НА РАННЕЙ СТАДИИ ИСТОРИИ ЗЕМЛИ

ARCHAEAN LITHOSPHERE AND EARLY CRUSTAL EVOLUTION

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THE PILBARA CRATON: 1.5 x 10^9 YEARS OF CRUSTAL EVOLUTION AND ASSOCIATED METALLOGENY

The rocks of the Pilbara Craton in northwestern Australia reflect early crustal evolution from 3.5 b.y. to 2.0 b.y. At least four differently *configured depositional* areas are now represented by (in order of decreasinq age) the Warrawoona, Gorge Creek and Whim Creek Groups, and the Mount Bruce Supergroup. The accumulation of these supracrustal sequences was accompanied *by deformation and* granite intrusion, the intensity of which varied with time. All four sequences contain substantial proportions of volcanic rocks, and all but the Whim Creek Group have thick, laterally extensive units of chert and/or iron formation. Despite the apparent repetition of similar geological events, metallogeny within the Craton shows some distinct changes with time. Gold shows a strong affinity to mafic and ultramafic rocks of the Warrawoona Group, and apart from some sediment-hosted veins within the Gorge Creek Group, is virtually absent in higher units. Nickel, although not present in commercial amounts, shows a similar stratigraphic distribution. Conversely, commercial iron ore deposits are absent from Warrawoona Group, but present in small concentrations in the Gorge Creek Group and in overwhelming abundance in the Mount Bruce Supergroup. While *vein copper deposits show a* similar distribution to nickel, lead appears at intervals throughout the sequence. Stratiform base metal deposits were also formed during several different volcanic events, the earliest at about 3.5 b.y., *and the youngest* at 2.0 b.y. Successive generations of granitic rocks within the Craton show increasing chemical fractionation which relates directly to the association of tin-tantalite deposits, and other rare-metal pegmatites, with the youngest granite phase.

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SEDYMENTARY-VOLCANOGENIC FORMATIONS AND GENESIS OF LITHOSPHERE IN EARLY PRECAMBRIAN

Eugeosyncline metamorphic series in the Ukrainian Shield dated 3500-1700 m.y. consist of rithmic sedimentary-volcanogenic formations which include acid, intermediate, basic, ultrabasic volcanogenic rocks and iron-chert chemogenic rocks, which alternate, regularly, in eugeosyncline belts.

Paragenesis of ultrabasic formations in ophiolite series of continental edge is associated with faults which have appeared during the initial stage of mobile zone origin.

Siderophile elements and reduction fluids are the specific geochemical features of ultrabasic formations. Chemogenic iron-chert formations and pyrite deposits were formed as a result of the oxidation-reduction potential change during volcanic activity fall and the development of underwater hydrotermal processes.

Alternation of metabasic formations for ultrabasic ones and after that for acid and intermediate volcanic products is characteristic of greate progressive and regressive stages in the development of volcanic eugeosyncline belts.

Composition resemblance of geosyncline volcanogenic series can be seen everywhere. A deep seated pyrolith of basic (basaltic) composition was, evidently, an original product for volcanic differentiation.

Differentiation of the original product into sialic and simatic fractions was a main tendency during formation of the granite crust which developed under influence of deep-formed fluids, dissipation of hydrogen and hydrocarbon and of the secondary fluids - water and carbon dioxide.

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ОСАДОЧНО-ВУЛКАНОГЕННЫЕ ФОРМАЦИИ И ПРОИСХОЖДЕНИЕ ЛИТОСФЕРЫ В РАННЕМ ДОКЕМБРИИ

В Украинском щите метаморфические толщи эвгеосинклиналей с возрастом 3500-1700 млн.лет сложены ритмическими осадочно-вулканогенными формациями дифференцированных вулканических продуктов, представленных кислыми, средними, основными и ультраосновными вулка-

ногенными, а также железисто-кремнистыми хемогенными формациями, закономерно чередующимися в составе эвгеосинклинальных поясов.
Образование парагенезиса ультрабазитовых формаций в офиолитовых толщах окраин континентов связано с расколами, происходившими во время начальных этапов формирования подвижных зон.
Геохимическая специализация ультрабазитовых формаций характеризуется преобладанием сидерофильных элементов и флюидов восстановительного типа. В периоды затухания вулканической деятельности, когда развивались подводные гидротермальные вулканические процессы, в результате изменения окислительно-восстановительного потенциала образовывались циклические хемогенные железисто-кремнистые и колчеданные отложения.
Смена метабазитовых формаций ультрабазитовыми и затем продуктами кислого и среднего вулканизма свойственна крупным циклам прогрессивных и регрессивных стадий развития эвгеосинклинальных вулканических поясов.
Наблюдается повсеместное сходство составов всех вулканогенных толщ эвгеосинклиналей. Очевидно, исходным продуктом вулканической дифференциации был глубинный пиролит основного (базальтового) состава.
Дифференциация на антагонистические сиалические и симатические продукты представляет собой направленный процесс образования гранитной коры, начиная с древнейших образований, который проходил под воздействием глубинных флюидов, выноса водорода, углеводородов и фторичных флюидов - воды и углекислоты.

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A PARTISAN REVIEW OF ARCHAEAN HIGH-GRADE TERRAINS

Archaean high-grade terrains (HGT) consist of extensively deformed granitoid orthogneisses containing km-scale conformable enclaves of supracrustal material, in which the grade of regional metamorphism ranges from middle amphibolite through granulite facies. The "high-grade" character of HGT does not reflect extreme Archaean thermal regimes, but is merely a consequence of erosion into the deepest levels of ancient orogenic systems. Examples of HGT range in age from <2.7 to >3.7 Ga, and most show evidence of having been modified during several episodes of crustal development. Although HGT can be viewed as the remnants of the earliest continents, they do not represent "reworked" primordial sialic crust, nor did they form synchronously in a single episode of continent formation, but rather they stabilized sequentially at the culmination of what have been termed "accretion-differentiation" events.
Gneisses constitute ∿80% of HGT, and are predominantly tonalitic, trondhjemitic and granodioritic types, with compositions similar in many respects to those of the Circumpacific Mesozoic batholithic complexes. The supracrustal suites include abundant basaltic amphibolite, with some members showing komatiitic affinity. Stratigraphically confined pods of ultramafic rock (dunite, harzburgite, spinel peridotite) are associated spatially with amphibolite, and in some areas, aluminous, ferromagnesian metasediments (such as cordierite-orthoamphibole gneiss) are widespread. The protolith for the latter may be redeposited, hydrothermally altered mafic volcanic rock.

Collectively this assemblage could represent Archaean "oceanic" crust and possibly upper mantle material. Clastic metasediments include semi-pelitic to pelitic gneiss, arkose and quartzite, for which a "continental" provenance is commonly invoked, but not yet demonstrated conclusively: biotite is omnipresent, but muscovite (or Sill+Kf) is typically lacking, reflecting both the relatively K-poor and Fe,Mg-rich nature of these clastic rocks. Various types of calc-silicate gneisses have been recorded, and carbonates (both limestone and dolomite are known to occur) are abundant in some HGT, whereas chert and BIF appear subordinate. This quartzite-(semi)pelite-carbonate association seems more appropriate for a platform/shelf environment in contrast to the "eugeosynclinal" suites of greenstone belts. Future geochemical studies should focus on characterizing better the source area characteristics of HGT metasediments.

Tectonics appear to be dominated by convergent processes, as evidenced by the development of large scale isoclinal to recumbent folds, nappes and thrusts, whereas vertical crustal movements are indicated by the (later) development of domes and basins. Episodes of crustal extension are likewise indicated, as shown by the presence of abundant mafic dike swarms. In many cases, the structural evolution of HGT was completed by the formation of widespread internal and bounding ductile shear zones.

Petrological studies reveal mineral assemblages indicative of Barrovian facies series regional metamorphism, with P-T estimates ranging from 4-10 Kb and 500-900°C and inferred depths of burial locally exceeding 30 km. Although sillimanite is ubiquitous, the local preservation of kyanite indicates a P-T trajectory during metamorphism that passed through pressures greater than that of the aluminosilicate triple point isobar. This type of metamorphic thermal gradient is similar to ones found in younger (e.g., Phanerozoic) orogenic belts, and would seem to preclude previous generalizations regarding "thin hot" Archaean continental crust. It will be extremely important to quantify these observations, especially in terms of the mechanical state of Archaean lithosphere.

In summary, the present author views HGT as the deeply eroded roots of Archaean magmatic "arcs" that develop over regions of mantle downwelling. The supracrustal suites comprise components representing oceanic crust, and the erosion products of the upper levels of the "arc" itself, in some cases augmented by terrigenous material from distal sources. Thus, the spectrum of clastic metasediment types in HGT is probably controlled by proximity of the arc/basin-of-deposition to a pre-existing craton. Structural intercalation of these components concomitant with calc-alkaline magmatism provides a plausible mechanism for bringing about crustal thickening, as proposed by other investigators.

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SEDIMENTOLOGICAL CONSTRAINTS ON THE EVOLUTION OF ARCHEAN TERRANES

Early Archean (>3.0 Ga) crust in South Africa and Australia consists of granite-greenstone and high-grade metamorphic terranes. The two terranes are characterized by different lithological associations and proportions. An analysis of the sedimentary rocks provides important constraints on the evolution of the pre-3.0 Ga crust.

Pre-greenstone (>3.6 Ga) gneisses are present in the high-grade Limpopo Province and western Yilgarn Block and are visualized as possible continental nucleii. Supracrustal rocks in these terranes are exclusively of sedimentary origin consisting mainly of metaquartzite (original arenite), marble (limestone), metapelite (mudstone) and aluminous gneiss (possible wacke). The quartzite-carbonate association implies a stable tectonic setting and the best analogues may be younger passive-margin deposits. Coeval (ca 3.5 Ga) volcanism in the Barberton and Pilbara greenstone terranes took place in an anorogenic, oceanic environment distant from any continental influence. Intercalated sediments are mostly of airfall pyroclastic origin and accumulated in shallow-water environments frequently at or above wave base. Evaporites and biogenic sediments including stromatolites are associated with the volcanics and support the shallow-water interpretation. The sedimentological evidence for relatively shallow oceans is in accord with theoretical estimates of early Archean water depths. The greenstone volcanics are overlain by terrigenous sediments recording the onset of continental margin sedimentation. In the Barberton Mountain Land, influx of extrabasinal detritus was in response to crustal shortening and uplift of a gneissic terrane. The synorogenic deep- and shallow-water sediments represent a flysch-molasse couplet.

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A STUDY OF THE GEOCHEMICAL GRADIENTS ACROSS THE PRECAMBRIAN BASEMENT OF THE VREDEFORT STRUCTURE

The Vredefort structure consists of an overturned sequence of Precambrian strata which forms a polygonal rim around the central basement core. Recent geophysical, geochemical and geological studies have shown that the basement granite core has also been turned on edge, exposing at surface a thick section (14 km) of the Archean crust, increasing in depth towards the centre of the dome. Detailed geochemical profiles across the Vredefort basement provide a unique opportunity to study the distribution of 20 trace elements with depth in the South African Archean crust. The R.E.E. and the major element chemistry provide strong evidence for a two layered crust. The upper 8 km of the Vredefort profile which occurs in amphibolite facies metamorphism is characterised by relatively smooth trends, but strong gradients, showing a general increase in cafemic character with depth. The lower 6 km of the profile which occurs in granulite facies metamorphism, exhibit marked erratic variations which reflect the heterogeneity of the lower Vredefort crust. The deepest zones of the Vredefort crust in the central parts of the dome are depleted in the large ion lithophile elements U, Th, Cs, and Rb relative to the perimeter whereas Ba, Sr, Co, Fe and Sc concentrations increase with depth. The inner regions of the dome are characterised by unusually high K/Rb, Th/U, K/U, K/Th, Ba/Rb and low Rb/Sr ratios, and it is only the outer 5 km of the basement that has elemental ratios which approach those found in "average" surface granites. The overall distribution of the major element chemistry in relation to the trace elements is not consistant with the model of a crust consisting of a granitic layer rich in lithophile elements, overlying depleted granulite facies rocks of intermediate average composition, and the decline in the concentrations of the large radius lithophile elements is only broadly related to the onset of granulite facies metamorphism.

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STRUCTURE AND EVOLUTION OF ARCHAEAN LITHOSPHERE

The elaboration of an adequate model of the formation and evolution of the lithosphere depends both on the selection of the lithosphere evolution model and on isotopic and chemical characteristics of the protolithosphere obtained on that basis. Geological and geophysical data on the Archaean of the East European and East Siberian platforms suggest (1) the presence of a thick continental crust occurred at least within ancient platform framework yet at the earliest stage (> 3.2 b.y.) of the lithospheric development, (2) the essential differentiation of the upper and lower lithospheric substance. The latter is reflected in the heterogeneity of composition of the sialic basement and many characteristics of mobile belts developed on this basement (i.e. sedimentation environment, magmatism, depth of basic rocks melting and regimes of subsequent metamorphic processes). A lateral synchronous heterogeneity occurred at Late Archaean stage (3.2-2.5 b.y.) being recognized by comparing the entire granite-greenstone regions and their fragments represented by greenstone belts. Endogenous regimes were more stable, and variable within different lithospheric segments (i.e. granite-greenstone and granulite-greenstone terrains) as compared to those of earlier stages. Uniform endogenous processes, as exampled by the East European platform, exhibit a heterogenous, progressive displacement in space and time. Recent geophysical indicators of density and thermal inhomogeneities of mantle are consistently correlated with geological and chemical characteristics of Archaean greenstone belts suggesting the significant heterogeneity of lower deepseated portions of the lithosphere and upper mantle in the Late Archaean.

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СТРОЕНИЕ И ЭВОЛЮЦИЯ АРХЕЙСКОЙ ЛИТОСФЕРЫ

Реконструкция условий возникновения и особенностей развития архейской литосферы зависит как от выбора эволюционной модели, так и от полученных на ее основе оценок исходных изотопных и химических характеристик протолитосферы. Геолого-геофизические материалы по архею Восточно-Европейской и Восточно-Сибирской платформ позволяют предполагать уже на самой ранней стадии развития (древнее 3,2 млрд.лет) наличие мощной коры континентального типа, распространенной, по меньшей мере, в пределах древних платформ, а также значительную дифференцированность вещества литосферы, что находит отражение в вариациях состава сиалического фундамента и разнообразии строения мобильных поясов (условий осадконакопления, магматизма, глубины выплавления основных пород и режима последующих процессов метаморфизма). Для позднеархейского этапа (3,2-2,5 млрд.лет) характерна латеральная синхронная гетерогенность структур, выявляющаяся при сопоставлении гранит-зеленокаменных областей в целом и их отдельных фрагментов - зеленокаменных поясов. По сравнению с ранней стадией эндогенные режимы были более стабильными и вместе с тем существенно неодинаковыми в пределах разных сегментов литосферы (гранито-зеленокаменных и гранулито-зеленокаменных областей). Установлено (на примере Восточно-Европейской платформы) последовательное смещение в пространстве и во времени проявлений однотипных эндогенных процессов. Современные индикаторы плотностных и термических неоднородностей мантии обнаруживают устойчивые корреляционные связи с геологическими и химическими характеристиками зеленокаменных поясов, что также свидетельствует о гетерогенности верхней мантии в архее и позволяет судить о геодинамическом режиме формирования докембрийских структур.

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THE PROBLEM OF THE ARCHAEAN IN PHANEROZOIC FOLDED BELTS OF EURASIA

Archaean rocks are known to occur in relict blocks of various dimensions and in infrastructural position being confined to mio- and eugeosyncline zones of many folded belts. Among them the best known sialic associations correlated with cratonic enderbite-granulite and tonalite-gneiss complexes are the following ones: the Erzin and Baidaragin (over 3.1 and 2.8 b.y.) in the Ripheides and Caledonides of Central Asia; the Karategin and others in the Hercynides of Middle Asia (over 2.6 b.y.); the Taratash and Seliankin in mio- and eugeosyncline zones of Hercynian Uralides (over 2.8 and 2.3 b.y.); the Scourian and Pentevrian in the Calenodides of West Europe (over 2.9 and 2.6 b.y.). The different type of Archaean associations arises since the Late Archaean (2.7 b.y.) being represented by two contrast complexes suggesting the passage to a new tectonic style due to the movements of lithospheric plates. On the one hand, these are sialic eclogite-gneiss and eclogite-schist terrains; the oldest of them (i.e. the Vakhan complex in the Pamirs) being finished their early development about 2.0 b.y. ago. On the other hand, these are simatic terrains of the oldest melanocratic basement of folded belts (i.e. the Kemin and others within the folded belts of Middle Asia). At the present time it is commonly emphasized the similarity between Archaean associations of cratons and those of fold belts. However, it can be shown that they differ in many ways.

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ПРОБЛЕМА АРХЕЯ В ФАНЕРОЗОЙСКИХ СКЛАДЧАТЫХ ПОЯСАХ ЕВРАЗИИ

Архейские породы в реликтовых блоках различных размеров и в инфраструктурном залегании известны сейчас во многих складчатых поясах в мио- и в эвгеосинклинальных зонах. Среди них наиболее известны сиалические ассоциации, сопоставимые с эндербит-гранулитовыми и тоналит-гнейсовыми формациями кратонов: эрзинская и байдарагинская (древнее 3,I и 2.8 млрд.лет) в рифеидах и каледонидах Центральной Азии; каратегинская и другие ассоциации в герцинидах Средней Азии (древнее 2,6 млрд.лет); тараташская и селянкинская в мио- и в эвгеосинклинальных зонах герцинид Урала (древнее 2,8 и 2,3 млрд.лет); скаурийская и пентеврийская в каледонидах Западной Европы (древнее 2,9 и 2,6 млрд.лет) и другие. Иной тип архейских ассоциаций появляется с позднего архея (2,7 млрд.лет) и представлен двумя контрастными формациями пород, отражающими переход к новому стилю тетоники, обусловленному движениями литосферных плит. С одной стороны, это сиалические эклогит-гнейсовые и эклогит-сланцевые образования, древнейшие из которых (например, ваханские на Памире) завершили свое раннее развитие около 2,0 млрд.лет назад. С другой - это симатические образования древнейшего меланократового фундамента складчатых поясов (например, кеминские и другие в складчатых поясах Средней Азии). В настоящее время обычно подчёркивается сходство между архейскими ассоциациями кратонов и фанерозойских складчатых поясов. Между тем их различия могут быть существенными.

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PLANETARY FORMATION: IMPLICATIONS OF CURRENT UNDERSTANDING FOR ORIGIN AND EARLY HISTORY OF THE EARTH

Despite major unsolved problems in the theory of planet formation, the limited variety of alternative mechanisms impose significant constraints on the initial state of the Earth and its earliest history:

(1) A large part of the gravitational energy of the Earth was retained during its formation. This was sufficient to produce global-scale magmatism and volcanism.

(2) Core formation was not a discrete event but proceeded continuously during planetary growth on a time scale of $\sim 3 \times 10^7$ years.

(3) The present Earth's atmosphere, hydrosphere and possibly upper mantle as well, is far from being a sample of the nebula from which most of the Earth was formed, but probably includes late-stage addition of various volatile components from a variety of sources, including those outside the present region of the terrestrial planets.

С И М П О З И У М / S Y M P O S I U M L.04

СОВРЕМЕННЫЕ И ЧЕТВЕРТИЧНЫЕ ДВИЖЕНИЯ ПЛИТ

RECENT AND QUATERNARY PLATE MOTIONS

Conveners: K.Kasahara, G.A.Sobolev

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RECENT CRUSTAL MOVEMENT OF THE EAST AND CENTRAL EUROPE AND THEIR RELATIONSHIP WITH ANCIENT TECTONIC MOVEMENTS AND PHYSICAL FIELDS

One of the basic problems of the recent vertical crustal movements (RVCM) study is an elucidation of their inheritance from the former deformations of the Earth crust in the areas of various tectonic regimes. The RVCM of the East European platform and Carpathian-Balkan orogenic region are well established and it allows to carry out the comparative analysis on a base of the recent published maps. For the East European platform the regional component of the RVCM shows a well defined inheritance from the neotectonic movements and the basement structure. The broad submeridional uplift bounded by the subsidence areas from the west, east and south has been established. The study of a local component of the RVCM reveals the existence of the regular set of uplift and subsidence zones by 400-700 km width. These zones have a slight inheritance from the neotectonic and basement structure. The important feature of the Carpathian-Balkan region is a fine expressed inheritance of the RVCM from neotectonic movement both a regional and a local components of the uplift and subsidence areas. The RVCM of the Carpathian-Balkan region are characterized by the high correlation with Moho discontinuity depths , heat flow values and other parameters, while for the East European platform such a correlation is absent. The different characters of inheritance of the RVCM of the East European platform and Carpathian-Balkan region and probable mechanisms of deep-seated processes are discussed.

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СОВРЕМЕННЫЕ ДВИЖЕНИЯ ЗЕМНОЙ КОРЫ ВОСТОЧНОЙ И ЦЕНТРАЛЬНОЙ ЕВРОПЫ И ИХ СВЯЗЬ С ДРЕВНИМИ ДВИЖЕНИЯМИ И ФИЗИЧЕСКИМИ ПОЛЯМИ

Одна из основных задач изучения современных вертикальных движений земной коры (СВДЗК) заключается в выяснении степени их унаследованности от тектонических движений прошлых геологических эпох в областях различного тектонического режима. Достаточно хорошая изученность СВДЗК Восточно-Европейской платформы и Карпато-Балканского региона позволила провести такой анализ на примере этих двух районов. Для Восточно-Европейской платформы в региональном плане обнаружена достаточно хорошая унаследованность СВДЗК от новейших движений земной коры и глубины залегания фундамента. Выявлено существование широкого субмеридионального поднятия, ограниченного с востока, запада и юга областями опускания. Изучение локальной составляющей СВДЗК позволило установить закономерное чередование зон поднятий и опусканий, ширина которых составляет 400-700 км. Эти зоны локальных опусканий и поднятий лишь частично наследуют структурный план новейших деформаций и глубин залегания фундамента. Карпато-Балканский регион характеризуется высокой степенью корреляции СВДЗК с новейшими движениями земной коры, причем унаследованность четко проявляется как в региональном плане, так и для локальных зон поднятий и опусканий. Сопоставление СВДЗК рассматриваемых областей с физическими полями и глубиной залегания границы Мохоровичича показало, что в Карпато-Балканском регионе такая корреляция четко устанавливается, а для Восточно-Европейской платформы она проявляется слабо или вообще отсутствует. В докладе обсуждаются различные физические механизмы выявленных закономерностей, позволяющие понять различный характер унаследованности СВДЗК в платформенных и орогенических областях.

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CRUSTAL MOTIONS AT PLATE BOUNDARIES, GEODETIC MEASUREMENTS AT KAMCHATKA AND IN THE PAMIRS

One of the acute problems of geodynamics is the correlation of deformation processes at plate boundaries with considerably different mechanism of interaction. Special research of Recent crustal movements by geodetic methods was carried out at the Pamirs-Tien Shan (northern border of Indian plate) boundary and at Kamchatka (north-western Pacific plate).
Geodetic research in the Pamirs (Garm geodynamic test-area) carried out for many years revealed comparatively regular oriented movements along the border fracture zone. From time to time, dislocations are complicated by some variations correlated mainly with local earthquakes (most strong have M of 4 or 5).
For ten years of geodetic research of crustal movements at Kamchatka, main dislocation types in the region have been distinguished. The region is specified by the combination of rather high seismicity (strong earthquakes with M of 7-8 and over) and the belt of active volcanism. Comparatively sharp and large (though local) dislocations within the volcanic belt are typical of the region. The most active seismic zone, that is, the eastern part of the peninsula shows irregularity in dislocations.

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ДВИЖЕНИЯ КОРЫ НА ГРАНИЦАХ ПЛИТ, ГЕОДЕЗИЧЕСКИЕ ИЗМЕРЕНИЯ НА КАМЧАТКЕ И ПАМИРЕ

Одним из важных вопросов геодинамики является сравнение закономерностей деформационных процессов, происходящих сейчас на границах плит с существенно разными механизмами взаимодействия. Специальные исследования современных движений земной поверхности геодезическими методами были поставлены на границе Памира с Тянь-Шанем (северная граница Индийской плиты) и на Камчатке (северо-западная Тихоокеанская плита)
Многолетние геодезические работы на Памире (на Гармском геодинамическом полигоне) выявили сравнительно равномерно направленные подвижки в граничной разломной зоне. Временами смещения осложняются вариациями, в основном коррелирующимися с местными землетрясениями (наиболее сильные с М 4-5).
За 10-летний период геодезических исследований коровых движений на Камчатке выявлены основные типы смещений, происходящих в этом регионе. Особенностью этого района является сочетание весьма высокого

уровня сейсмичности (сильные землетрясения с М 7-8) с наличием пояса активного вулканизма. Для этой области характерны сравнительно резкие и большие, но локальные по площади смещения в пределах вулканического пояса. Отмечается неравномерность смещений в наиболее сейсмоактивной восточной части полуострова.

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SUBSIDENCE HISTORY OF THE THREE GREATS SEDIMENTARY ATLANTIC BASINS OF ARGENTINA

We add some shared characteristics to the already known similitudes (tensional features, cretaceous-cenozoic sedimentary thickness of more than 6000 m. ...) between the Salado, Colorado and San Jorge Argentinian Atlantic basins. They are as follow:
i - High gravity (after the reduction of geology was made)
ii - Two similar subsidence stages.
Geohistory analysis with well data provides a quantitative analysis of basin subsidence and its different components (sedimentary loading, termotectonic subsidence ...). Thermal cooling, long term eustatic changes and gravimetrical models are analyzed.
The rising of asthenospheric materials at upper lithospheric leavels would produce density changes in upper mantle and crust which can justify the high gravity.
The present day data pointed in the geohistory diagram shows increasing subsidence velocity in Colorado and Salado basins (recurrent subsiding tendency).

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MULTI-DIMENSIONAL APPROACHES TO THE STUDY OF THE RECENT PLATE MOTION AND DEFORMATION

This paper reviews, as an introduction to the Symposium, the current status of research of key problems involved in the study of the recent plate motion and deformation. The Working Group 1 of the ICL has set up several key problems for this purpose and has developed discussion since 1980. Investigation of these problems has made us to realize how closely they are mutually linked. For example, precise measurement of relative plate motion, which now seems very promising after geodetic application of space techniques, must be properly corrected for the local and regional crustal deformation around the observational sites. Decaying penetration of seismic slips at plate boundary plane into the plate body will be controlled by the viscous asthenosphere coupled to the lithosphere. Irregular plate motion may mechanically affect the Earth's rotation, and vice versa. The mechanical behaviors of the Earth, like these, might be compared to those of a deformable boat on the ocean with full of passengers. It is needlessto say, that the dynamics of a plate system appear most complex in and around the boundary plane. Progress of our knowledge about this particular space will also be reviewed

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INSTANTENEOUS KINEMATICS OF THE AFRO-ARABIAN RIFT SYSTEM

Parameters of rotation of the African, Arabian, Somali and Danakil plates were determined using new data on the Red Sea axial trough, Afar and the Ethiopean Rift. Azimuths of extensional fractures and transform faults were used to find the instanteneous pole for the Red Sea Rift opening. The data came from the submersible observations performed by the Red Sea Expedition of the Institute of Oceanology, Ac. Sci., USSR, and interpretation of "Gloria" images. Statistic studies of extensional fractures in the axial belts in Afar and in the Ethiopean Rift (Axial Ranges, Wongi Fault belt) were used for the same purpose. Parameters thus obtained (Table 1) differ considerably from previously published. Geological evidence indicates that the main opening of the Ethiopean Rift and Afar occurred since 10 m.y. Before that a two-plate system (African and Arabian) existed with the following parameters of rotation: 32.5 N, 4.4 W, ∠ 0.55.

Table 1. Parameters of rotation

Plates	Instant. pole		10^{-7}deg/y	Finite pole		Angle
	N	E		N	E	
Arabia/Africa*	33.47	24.54	4.2	33.7	21.25	4.71
Arabia/Somali	27.37	24.26	4.4	28.3	21.3	4.9
Arabia/Danakil	5.59	47.27	-5.6	8.8	47.6	-10.8
Danakil/Africa	17.8	38.52	9.36	15.92	39.94	15.01***
Somali/Africa	-35.52	21.81	-0.5	-35.52	21.81	-0.5***
Sinai/Arabia**	32.5	-4.4	-1.15	32.5	-4.4	-1.7
Sinai/Africa	32.29	34.55	3.17	32.29	34.55	3.17***
Danakil/Somali	15.44	37.8	9.65	14.47	39.42	15.3***

*First plate moves relative to the second: "-" clockwise, "+" anti-clockwise rotation.

**After Le Pichon and Francheteau (1978).

***Finite rotation for 10 m.y.

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МГНОВЕННАЯ КИНЕМАТИКА АФРИКАНО-АРАВИЙСКОЙ РИФТОВОЙ СИСТЕМЫ

Параметры вращения Африканской, Аравийской, Сомалийской и Данакильской плит определены с учетом новых данных по геологии осевого трога Красного моря, Афара и Эфиопского рифта. Для определения мгновенного полюса раскрытия Красноморского рифта использовались замеры ориентировки трещин растяжения и трансформных разломов, выполненные в ходе Красноморской экспедиции Института океанологии АН СССР, а также результаты дешифрования изображений дна сонаром бокового обзора "Глория". В Афаре и Эфиопском рифте с этой же целью выполнены массовые замеры трещин растяжения в осевых зонах (осевые хребты, пояс Вончжи). Полученные параметры (см.табл.) существенно отличаются от опубликованных ранее. Геологические данные свидетельствуют о раскрытии Эфиопского рифта и Афара в основном за последние 10 млн.л. До этого существовала система из двух плит - Африканской и Аравийской. (Параметры вращения: 32,5 N, 4,4 W, ∠ 0,55).

Параметры вращения Африкано-Аравийской рифтовой системы

Плиты	Полюс		10^{-7} град/год	Полюс		Угол поворота
	с.ш.	в.д.		с.ш.	в.д.	
Аравия/Африка[x]	33,47	24,54	4,2	33,7	21,25	4,71
Аравия/Сомали	27,37	24,27	4,4	28,3	21,3	4,9
Аравия/Данакиль	5,59	47,27	5,6	8,8	47,6	-10,8
Данакиль/Африка	17,8	38,52	9,36	15,92	39,94	15,01[xxx]
Сомали/Африка	-35,52	21,81	-0,5	35,52	21,81	-0,5[xxx]
Синай/Аравия	32,5	-4,4	-1,15	32,5	-4,4	-1,7
Синай/Африка	32,29	34,55	3,17	32,29	34,55	3,17[xxx]
Данакиль/Сомали	15,44	37.8	9.65	14.47	39.42	15,3[xxx]

[x]Движение первой плиты относительно второй "-" - по, "+" - против часовой стрелки.

[xx]По Le Pichon, Francheteau, 1978.

[xxx]Конечное вращение на 10 млн.л.

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LATE-GLACIAL PALEOGEOGRAPHIC RECONSTRUCTION MODELS FROM NORWEGIAN FJORD AREAS

Descriptive numerical reconstruction models of former sea levels and glaciation are presented together with numerical calculation models of deglaciation chronology. The Oslo fjord area are here used as an example to test the model against results from conventional reconstruction methods. The quality of these models depends on the quality of the calibrational data and the complexity of the models. Such models have to be flexible in order to permit new field information to be added without changing the fundaments of the models themselves. Calculation programs are implemented on a micro computer and the results are presented as paleogeographical maps on a colour graphic raster-monitor. Simple numerical reconstruction models combined with modern colour graphic presentation devices seem to be a useful way of combining an increasing amount of field information, and they permit easier visualization of complex four dimensional time and space patterns.

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THREE-DIMENSIONAL NUMERICAL MODELLING OF CONTINENTAL MARGINAL BASIN DEFORMATION WITH DEEP-SEATED CREEP FLOW

Three-dimensional numerical modelling of both the thermal and the elasto-visco-plastical stress fields is investigated with fictitious boundary conditions by using either the heat conductibility or the stiffness of the exterior medium normal to the artificially selected model as the unknown inflow or the reaction force respectively. Numerical results show that: (1) ground surface deformation is closely related to the temperature-dependent creep flow of the lower lithosphere, (2) faults creep aseismically and stresses accumulate continuously until reaching a level to cause fracture, (3) there is no necessity of surface uplift before subsidence if the domal force at depth is small, because the upward displacements will be compensated by the lateral creep movements in the lower lithosphere, and (4) gravity anomaly can be the consequence of upper crustal deformation due to the deep seated creep flow with no contribution from densities within the mantle.

In summary, I suggest that the crustal deformation and stress state are controlled by the geothermal variations which may be more important than the plate driving force in contributing to intraplate stress, because the plate boundary is far away from the marginal basin.

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RECENT CRUSTAL MOVEMENTS WITHIN THE USSR TERRITORY

Movements and deformations of the Earth's crust and surface are considered as recent (modern) crustal movements (RCM) for the period of some last hundred years.

We can divide the USSR territory into several areas well differentiated from one another on the basis of specific types of the RCM and in conformity with the main tectonic units.

1. Areas of prevailing recent glacio-isostatic movements (the Baltic shield peryphery and the Arctic sea coast). The measurements provide evidence for a long-continued rising movement with rates of 1-2 to 3-5 mm per year.

2. Slightly active platforms (the West-European platform for instance) show sign-varying vertical movements due to some non-tectonic factors. Measured values of the rate are as much as 1-5 mm per year, but as to real tectonic movements, their rate is not likely to exceed some parts of mm per year.

3. Active platforms (such as the Turanian platform eastward of the Caspian Sea) are usually characterized by considerable variability in the sign and rate of vertical movements. Sometimes, sharp (impulsive) displacements occur within some limited areas at a measured rate of tens or even hundreds of centimeters.

4. Mobile belts (Alpine, Central-Asian and Pacific ones within the USSR territory) have some specific features of the RCM. The main ones are as follows:considerable variability of the RCM in space and time, high rate (as high as a few mm or a few cm per year) both of the vertical and horizontal components, and sharp changes of the rate. The horizontal movements are characterized by a trend,whereas the vertical ones frequently change sign. Impulsive seismotectonic displacements occurring from time to time along the faults (up to a few meters in magnitude) are characteristic for the belts.

We believe the main problems of the RCM investigation to consist in next tasks:(1) establishing a relationship between the RCM and geological structures and geophysical fields of different scale; (2) correlating vertical and horizontal and (3) slow and rapid components of the movements; (4) finding relationships between the RCM and Holocene tectonic movements in various structural regions.

The general object of the study under discussion consists in evaluating the role of internal and external factors in the origin of the RCM.

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СОВРЕМЕННЫЕ ДВИЖЕНИЯ ЗЕМНОЙ КОРЫ НА ТЕРРИТОРИИ СССР

К современным движениям земной коры (СДЗК) относятся движения и деформации земной коры и поверхности за последние несколько сот лет. В Советском Союзе широко используются традиционные методы изучения СДЗК - уровнемерный, повторных наземных геодезических измерений, а также геоморфологический, ландшафтный, исторический и др. Западная часть территории страны изучена в отношении СДЗК гораздо лучше, чем восточная, и для нее имеются карты вертикальной составляющей СДЗК в масштабе I:2,5 млн.

По приуроченности к крупнейшим тектоническим структурам и по генезису СДЗК на территории СССР можно выделить следующие области с характерными типами движений.

I. Область господства гляциоизостатических движений (окраины Балтийского щита и побережья полярных морей). Вертикальные движения характеризуются положительным знаком, однонаправленностью, скорость составляет I-2, до 3-5 мм/год.

2. Малоактивные платформы (например, Восточно-Европейская), где вертикальные движения нередко знакопеременны, вероятно,за счет нетектонических факторов. Измеренные величины скорости достигают I-5 мм/год, но реальные тектонические вряд ли превышают доли мм/год.

3. Активизированные платформы (пример - Туранская платформа), где отмечаются знакопеременные вертикальные движения и нередко проявляются импульсные движения с быстрыми смещениями в десятки и даже сотни миллиметров.

4. Подвижные пояса (Альпийский, Центрально-Азиатский, Тихоокеанский в пределах СССР), для которых характерны дифференцированность, контрастность и высокие скорости горизонтальных и вертикальных движений (мм/год и первые см/год), а также направленность горизонтальных и перемены знака вертикальных движений, нередки импульсные подвижки по разломам на величину до нескольких метров.

Основные проблемы изучения СДЗК состоят в выявлении соотношений СДЗК со структурами и геофизическими полями разного масштаба, соотношения вертикальной и горизонтальной, вековых и импульсных составляющих движений, голоценовых и современных движений в разных структурных областях. Особо стоит задача определения кинематики на границах плит. Общая задача заключается в определении роли внутриземных и внешних факторов, то есть в установлении генезиса СДЗК.

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EPEIROGENIC PLATE MOVEMENTS

Consideration has previously been given to the kinematics of epeirogenic movements over the recent geologic past (late Pleistocene) for the continental shelf off the East Coast of North America. It was found that there has been a relative change in elevation of 140 m downward toward the northeast over this longitudinal distance of 3,000 km during the past 18,000 years. Specifically, Miami has been elevated at a rate of 0.8 cm/yr with respect to the Scotian shelf continental margin. The confirming data included the shelf break corrected for progradation, reef building, and glacio-isostatic adjustment; late Pleistocene shores on the continental shelf; dated geological samples of known shallow water origin; buried Pleistocene channels; and recent leveling analysis. The investigations have been extended to the shelf break depth variations for the entire North and South Atlantic passive margins. The epeirogenic movements are considered to be related to perturbations in the small scale, Rayleigh-Benard thermal convection in the upper mantle with time scales of the order of 30,000 - 300,000 years. The resultant epeirogenic oscillations provide an explanation for the numerous cyclic deposition sequences including the cyclothems that are observed throughout the Phanerozoic.

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SEISMOLOGICAL ASPECTS OF THE STRAIN FIELD STUDY

The heterogenity of stress-strain state is one of the intrinsic properties of the rock masses manifested at different scale levels.

The experiments with great rock blocks show that the mosaic of the compressional and dilatational regions as small as ten sentimetres in size arize within the loading blocks. Distribution of the different deformability zones is controlled by a latent rock structure , manifest itself on the early stage (less than 30% of breaking loading) and qualitatively reveals small changes with strain increase.

Observations near the high pressure dams have revealed a mixed picture of the rock masses stress-strain state with the size of heterogenities in units and dozens metres. Ultrasonic and seismic sounding with various wave-lengths were the main methods for the revealing of the structure.

The using of the earthquake source mechanisms and seismic moments makes it possible to calculate the seismotectonic deformation within the Earth crust and to single out the blocks from a hundred metres to ten kilometers in size with great distinctions in the strain rate. The Lode-Nadai factor study gives an important information for the variations of the stress-strain state. The structure of the strain field within the Earth crust have been studied especially carefully for the Dushanbe-Garm region.

The theoretical calculations show that the sesmotectonic deformation field on the Earth surface usually measured by the geodetic methods can be found uniquevocally using the earthquake seismic moment tensors. Thus, one have possibility of comparing the seismological and geodetic data with one another.

The experimental and theoretical results make it possible to separate the stress and strain fields of various class and scale in the regions studied; the structure of the stress-strain field can be revealed in full only when using the complex of the geodetic, deformational and geophysical methods which allows the averaging on the basis of various length measurements.

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СЕЙСМОЛОГИЧЕСКИЕ АСПЕКТЫ ИЗУЧЕНИЯ ПОЛЯ ДЕФОРМАЦИЙ

Одним из существенных свойств напряженных массивов горных пород является неоднородность их напряженно-деформированного состояния, проявляющаяся на различных масштабных уровнях.

Эксперименты на больших блоках горных пород показывают, что внутри нагружаемого блока возникает мозаичная картина областей сжатия и дилатансии размером до десятков сантиметров. Распределение зон различной деформируемости связано со скрытой структурой горной породы, проявляется на ранних стадиях нагружения (менее 30% от разрушающей нагрузки) и качественно мало меняется с ростом напряжения.

Наблюдения вблизи высоконапорных плотин выявили пеструю картину напряжённо-деформированного состояния массива пород размером неоднородностей в единицы и десятки метров. Главным инструментом выявления данной структуры являются методы ультразвукового и сейсмического просвечивания волнами различной длины.

Использование механизмов очагов землетрясений и сейсмических моментов дает возможность вычислить сейсмотектоническую деформацию в земной коре и выделить блоки, существенно различающиеся по величине скорости деформации, размером от сотен метров до десятков километров. Важную информацию о вариациях напряжённо-деформированного состояния несет изучение коэффициента Лоде-Надаи. Особенно тщательно в СССР структура распределения поля деформаций в глубине земной коры изучена для района Душанбе-Гарм.

Теоретические расчеты показывают, что поле сейсмотектонической деформации поверхности Земли, обычно измеряемое геодезическими методами, может быть однозначно вычислено при использовании тензоров сейсмического момента землетрясений. Таким образом, имеется возможность сопоставления данных сейсмологии и геодезии.

Экспериментальные и теоретические результаты дают основание для выделения в изучаемом районе полей напряжений и деформаций различного ранга и масштаба, причем структура напряженно-деформированного состояния может быть полно выявлена только при использовании комплекса геодезических, деформационных и геофизических методов, допускающих осреднение на базах измерений различной длины.

С И М П О З И У М / S Y M P O S I U M L.06

ГЕОХИМИЧЕСКОЕ И ГЕОФИЗИЧЕСКОЕ МОДЕЛИРОВАНИЕ ТЕКТОНИКИ ПЛИТ

GEOCHEMICAL AND GEOPHYSICAL MODELLING OF PLATE TECTONICS

Conveners: C.Froidevaux, V.P.Keondjan

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FORCES DRIVING PLATE MOTIONS AND CRUSTAL COMPRESSION IN THE FOLD-BELTS

Crustal thickness inhomogeneities produce large additional force in the lithosphere (Artyushkov, J. Geophys. Res, 78, 7675, 1973):

$$\Sigma(h) = [\rho(\rho_m - \rho)/2\rho_m]\, h^2 + const \qquad (I)$$

Here ρ, h are the crustal density and thickness, ρ_m - the density of the mantle. Neglecting the friction, the force necessary to compress the crust in the fold belts from the thickness h_1 to the thickness h_2 can be estimated as follows (Artyushkov, Baer, Sobolev, Yanshin, Sovetskaya Geologia, 9, 22, 1982)

$$\Delta\Sigma = \Sigma(h_2) - \Sigma(h_1) = [\rho(\rho_m - \rho)/2\rho_m](h_2^2 - h_1^2) \qquad (2)$$

Intense compression and shortening of the continental crust usually occurs after its strong thinning (Artyushkov and Baer, Izvest. Akad. Nauk SSSR, ser. geol., 9, 25, 1983). The thinning arises due to the distruction of the basaltic layer by the basalt-eclogite transformation. Juxtaposition of a plate of attenuated continental crust ($h\sim20$ km) of predominantly sialic composition on another plate of the same thickness demands of the force $\Delta\Sigma\sim3.10^9$ bar. cm according to (2). Oceanic lithosphere can be preserved in the fold belts, only if its thickness is small: $h\lesssim15$ km. In this case oceanic lithosphere becomes lighter than the underlying mantle which prevents the subduction. Its juxtaposition on (or under) another plate of oceanic lithosphere or attenuated continental crust demands of the force $\Delta\Sigma\sim10^9$ bar. cm.

Strong crustal shortening ceases in the fold belts after the crustal surface becomes elevated by $\sim0,5$ - 1 km above the sea-level. Crustal compression demands of the force $\Delta\Sigma\sim3$-4.10^9 bar. cm in this case. This quantity likely corresponds to the upper limit of the forces driving the plate motions. In order to produce an uplift 4-5 km high from crustal shortening and thickening the forces $\Delta\Sigma\sim10^{10}$ bar. cm are necessary. High uplifts are however arising as a result of vertical crustal movements after the termination of thrusting and folding in the uplifting region. This means, that the mechanisms driving plate motions are unable to produce the forces as high as the above value (Artyushkov, Geodynamics, Moscow:Nauka, 1979).

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СИЛЫ, ПОД ВЛИЯНИЕМ КОТОРЫХ ПРОИСХОДЯТ ДВИЖЕНИЯ ЛИТОСФЕРНЫХ ПЛИТ И СЖАТИЕ КОРЫ В СКЛАДЧАТЫХ ПОЯСАХ

Неоднородности мощности земной коры приводят к появлению в литосфере большой добавочной силы (Artyushkov, J. Geophys. Res. 78, 7675, 1973):

$$\Sigma(h) = [\rho(\rho_M - \rho)/2\rho_M]\cdot h^2 + const \qquad (I)$$

Здесь ρ, h -плотности и мощность коры; ρ_M -плотность мантии. В пренебрежение трением для сжатия коры в складчатых поясах с увеличением ее мощности от h_1 до h_2 требуется сила (Артюшков, Беэр, Соболев, Яншин - Советская геология, 1982, 9, 22):

$$\Delta\Sigma = \Sigma(h_2) - \Sigma(h_1) = [\rho(\rho_M - \rho)/2\rho_M](h_2^2 - h_1^2). \qquad (2)$$

Континентальная кора обычно вовлекается в интенсивное сжатие только после её сильного утонения (Артюшков, Беэр - Изв.АН СССР; Сер. геол., 1983, 9, 25). Утонение происходит в результате разрушения базальтового слоя вследствие эклогитизации. Для надвигания пластин утоненной коры ($h\sim20$ км) преимущественно сиалического состава друг на друга с удвоением мощности ($h=40$ км), согласно (2), требуется сила $\Delta\Sigma\sim3\cdot10^9$ бар см.

В складчатых поясах сохраняется океаническая литосфера только малой мощности ($h \leq 15$ км), более легкая, чем подстилающая мантия. Для осуществления её надвигов (и поддвигов) на океаническую литосферу или утоненную континентальную кору требуются силы $\Delta\Sigma \sim 10^9$ бар см. Сильное сжатие в складчатых поясах заканчивается, когда поверхность коры поднимается над уровнем моря на 0,5-1 км. Для такого сжатия необходимы силы $\Delta\Sigma \sim 3\text{-}4 \cdot 10^9$ бар см. Эта величина, по-видимому, соответствует верхнему пределу сил, под действием которых происходят движения литосферных плит.

Формирование за счет сжатия горных сооружений высотой 4-5 км потребовало бы сил $\Delta\Sigma \sim 10^{10}$ бар см. Такие структуры обычно формируются в результате вертикальных движений, когда образование складок и надвигов в области самого поднятия уже закончилось. Отсюда следует, что механизмы, обеспечивающие дрейф литосферных плит, неспособны создать столь большие силы (Артюшков - Геодинамика, М., Наука, 1979).

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MODELLING OF INTERACTION OF THE BLOCKS OF LITHOSPHERE

Interation of the blocks, separated by fault zones is analyzed for real configuration of blocks, unhomogenuity of fault zones and external forces.

Model allows to check tectonic hypotheses and reproduce time-dependent tectonic processes.

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МОДЕЛИРОВАНИЕ ВЗАИМОДЕЙСТВИЯ ЛИТОСФЕРНЫХ БЛОКОВ

Взаимодействие блоков литосферы анализируется с учетом их реальной конфигурации, неоднородности зон разломов и внешних сил.

Предлагаемая модель позволяет проверять тектонические гипотезы и воспроизводить временной ход тектонического развития.

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ISOTOPE GEOLOGY AND THE GEODYNAMIC RECONSTRUCTION OF OROGENIC BELTS

Since the routine application of radiometric age dating (K-Ar; Rb-Sr and U-Pb) in the 1960's geochronology became a very powerful tool for the unravelling of the complex geological histories of mountain belts. Furthermore, not only the age relations in these commonly polycyclic orogens could be worked out on an absolute scale but information was also gained on the geotectonic origin of the rocks, e.g. if they were formed from relatively old or young continental crust or from oceanic sources. For this objective the Sm-Nd technique, routinely in operation since the late 70's, added considerable success, especially when applied together with the Rb-Sr and Pb-Pb methods and/or with geochemical data.
To illustrate the applicability of isotope geology for a geodynamic reconstruction of an orogenic belt on an absolute scale the development of the Hercynian belt of Europe will be reviewed: Archean formation of continental crust (at least 3.4 b.y. ago), formation of various types of oceanic crust at 2.2 b.y., possibly 1.9 b.y. and at 1.2 b.y., respectively; at least 2-3 orogenic cycles in the Precambrian, rifting and opening of variously large basins between 500 and 600 m.y.; closure of these basins in the Caledonian (ca. 400 m.y.), Acadian (ca. 380 m.y.), and Hercynian (ca 320 m.y.); collision induced thrusting, especially in the Hercynian.

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MANTLE CONVECTION, PLATE MOTION AND THE EARTH'S GRAVITY FIELD

Lithospheric plates form the cold thermal boundary layer of the convecting mantle. Temperature and density contrasts within the lithospheric plates and subducted slabs can be modelled and are fairly well constrained. They are sufficient to drive plate motions with approximately their observed velocities and directions. However, there are undoubtedly temperature variations other than those associated with the lithosphere.
Temperature variations external to the plates can in principle be observed through their influence on seismic velocities, the Earth gravity field, and topography. Their effect on the gravity field is complicated by the fact that the convective flow set up by these density contrasts causes deformation of the boundaries of the convecting

system (including topography at the surface of the Earth). These surface deformations have a significant effect on the Earth's gravity field.

We have investigated the dynamics of geoid anomalies in a convecting Earth including the effects of radial viscosity variations, chemical layering, and self-gravitation. For a density constrast at a given depth within the Earth, the amplitude of the redulting geoid anomaly depends upon whether the mantle is chemically stratified; the sign of the geoid anomaly depends on the variation of viscosity with depth. We find that seismically active subducted slabs are positively correlated with the geoid and can explain 50% of the variance in the geoid at spherical harmonic degrees 4-9. The amplitude of the correlation requires that more high density material than can be explained by seismically active slabs is present near subduction zones. Aseismic slabs penetrating into the lower mantle can satisfy the gravity observations.

Seismic velocity anomalies in the lower mantle (Dziewonski, 1983; Clayton and Comer, 1983) are correlated in a negative sense with the geoid after slab effects are removed. A dynamical model allowing mantle-wide flow with a factor of 10 increase in the effective viscosity of the lower mantle and an additional factor of 10 decrease in the effective viscosity in the upper mantle near subduction zones can satisfy these observations. Such a model is also consistent with the global distribution of seismicity and stress orientation in subducted slabs, as well as the dips of Benioff zones.

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THE DISTINCTION OF DIFFERENT SOURCES OF MANTLE MATERIAL WITHIN THE KIMBERLITE SAMPLE

Kimberlites provide geologists with their most direct glimpse of mantle materials and processes at relatively large depths in the continental upper mantle; however, the distinction in time, space and petrogenetic origin of different types of that material is complex. The Cr-poor megacrysts with quenched high-temperature mineral chemistry probably offer the closest approach to the crystallisation products of asthenospheric magma, and although these megacrysts have been petrogenetically linked to various kimberlite magmas, these links must be viewed circumspectly.

The majority of peridotite nodules, by virtue of their relatively low-temperature mineral chemistry and depleted compositions are probably of lithospheric origin, and may have characteristics more related to early orogenic rather than stable continental shield situations. The search for primitive, fertile and/or asthenospheric peridotite source materials has tended to highlight certain geochemical features of the high-temperature deformed peridotite nodules. However these rocks may represent complex partly metasomatic compositions because they show: (1) considerable variation in Mg/(Mg + Fe); (2) variable and sometimes markedly depleted CaO, Al_2O_3 and Na_2O contents; (3) irregular and sometimes high Cr_2O_3 values; (4) features which may be attributed to metamorphic and metasomatic re-equilibration in some cases.

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ENRICHMENT PROCESSES IN THE MANTLE: METASOMATISM OR RECYCLING

Ideas about the chemical differentiation of the mantle have evolved as a result of new isotopic data on Sr, Nd, Hf, Pb, He, Ar, and Xe, as well as data on trace element concentrations in mantle-derived basalts. Early models about an enriched upper asthenosphere were gradually abandoned in favor of a two-layer model with a depleted upper and a primitive lower mantle. This "standard model" was based largely on a linear correlation between Sr and Nd isotope ratios and the growing acceptance of deep-mantle plumes. It has recently been reinforced by the discovery of anomalously high $^3He/^4He$ ratios in samples from some oceanic islands. Nevertheless, many of the other geochemical parameters can be reconciled with this standard model only through special pleading. For example, the highly radiogenic and unequivocally nonprimitive isotope ratios of Pb require a late increase of the U/Pb ratio in the OIB (ocean island basalt) sources; so the "primitive" lower mantle source must have lost Pb to the core as late as 2 Ga ago. Also, the number of ocean islands that do not lie on the original linear trend of OIB defined by Sr and Nd data is ever increasing. At present, a minimum of at least four isotopically distinct mantle components appear to be required.

The high absolute abundances of incompatible trace elements in OIB also require special pleading if they are to be reconciled with an origin from a primitive source, because they would appear to be derived by much smaller degrees of partial melting than are the lower abundances found in MORB. It is not obvious why primitive (and therefore relatively fertile) sources derived from deep, relatively hot regions in the mantle should yield smaller melt fractions than the depleted sources located in the relatively cool upper mantle. Thus, the most striking observation about OIB is their highly enriched, not primitive, character. Although regions of primitive mantle may or may not exist, there is now little doubt that regions of enriched mantle do exist and are tapped by at least some ocean island volcanism.

The realization of the importance of enriched source regions has led to a rash of new geochemical mantle models that are all variations or combinations of two geochemical themes: metasomatism (M) and recycling (R). M-models generate enriched regions in the mantle by internal redistribution of incompatible elements via the fluid phase (hydrous or silicate). They are based on observed metasomatic features in mantle xenoliths and on the difficulties encountered in modelling the composition of OIB from ordinary mantle. R-models are inferred from "observed" subduction of oceanic lithosphere, crust and its sedimentary cover, and from the observation that chemical heterogeneities are preserved in the mantle for gigayears, despite the existence of convective mixing. Published suggestions as to the origin of the source material of oceanic islands by now include recycled terrigenous sediments, oceanic crust, depleted oceanic lithosphere, oceanic crust plus lithosphere, enriched subcontinental lithosphere, and foundered continental crust.

M-models are difficult to test because of the lack of physico-chemical constraints and because the metasomatized xenoliths give no clue as to the distance of metasomatic transport, which might be centimeters or hundreds of kilometers. Tests for crustal recycling require recognition of crustal geochemical signatures. These might include stable isotopes and trace element ratios that are strongly affected by near-surface processes, e.g. I/Cl, Cs/Rb, K/U. R-models do not exclude the possibility of small or large scale metasomatism. However, the interstitial fluid must transport incompatible elements more efficiently than does solid-state mantle convection.

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TECTONIC STRUCTURE OF THE MANTLE

The large-scale structure of the mantle is central to the study of the plate-tectonic evolution of the Earth. Two alternative models lead to significantly different scenarios for the dynamic and thermal state of the mantle: i) That the whole mantle is uniformly mixed as a single unit, and ii) That the upper and lower mantle are separate geochemical and convective systems. Although not definitive, a variety of data from experimental petrology, seismology and isotope geochemistry generally support the second model in which the largest region of the planetary interior, the lower mantle, does not participate directly in the geological processes observed at the Earth's surface. This would imply that the Earth is farther from a thermal steady state and that the deep interior is hotter than if the whole mantle is uniformly mixed as in the first model. The most definitive evidence required to evaluate these two models is likely to come from quantitative experiments on minerals at the pressures and temperatures of the lower mantle.

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GEOCHEMISTRY OF MAGMATIC ROCKS AND PALEOGEODYNAMIC RECONSTRUCTIONS

The analysis of recent active zone of the Earth allows to separate a limited number of geodynamic environments to be distingueshed. They are associated with intraplate activity (geodynamic environment of hot spots and fields) and with different character of plate interaction: rift zones (constructive plate boundaries), island arcs and active continental margins (destructive plate boundaries), Californian type (interaction of continental plates with mid-ocean ridge system), etc. The magmatic rocks formed in different active zones of the Earth are geochemically different. There is a strictly limited set of regularly combined rocks in each geodynamic environment.
The geochemical features of magmatic rocks of different geodynamic environments are most clearly traced in basaltoid series for which a fairly representative material has been accumulated. Thus, tholeiite basalts of hot spots (oceanic island trapps) contain increased

concentrations of lithophilic elements; in oceanic rift zone tholeiites the concentrations of these elements are, in contrast, too low; tholeiite basalts of island arcs are characterized by low cromium, nickel and cobalt contents, whereas these values are 2-3 fold higher in basalts of active continental margins. The geochemical differences of magmatic rocks are determined by both physicochemical conditions of magma generation and the role of three sources of matter, i.e., lithosphere including the Earth crust, asthenosphere and subasthenospheric plums involved in the formation of parent magmas of each geodynamic environment.
The analysis of a series of Phanerozoic mobile zones (Central Asia, Ural, North America, etc.) gives ground to state that the geochemical features of magmatic rocks are due to the geodynamic environments of their formation rather than to their age. This provides a reliable basis for the reconstruction of paleoactive zones in mobile belts, comparable with recent zones.

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ГЕОХИМИЯ МАГМАТИЧЕСКИХ ПОРОД И ПАЛЕОГЕОДИНАМИЧЕСКИЕ РЕКОНСТРУКЦИИ

Анализ современных активных зон Земли позволяет выделить ограниченное количество геодинамических обстановок. Они связаны с активностью внутри литосферных плит - геодинамические обстановки "горячих" точек и полей с различным характером взаимодействия плит: рифтовых зон (конструктивные границы плит), островных дуг и активных континентальных окраин (деструктивные границы плит), калифорнийского типа (взаимодействие континентальных плит с системой срединно-океанических хребтов) и др. Магматические породы,формирующиеся в различных зонах Земли, отличаются геохимически. В каждой геодинамической обстановке существует строго определенный набор пород, находящихся между собой в закономерных сочетаниях.
Наиболее четко геохимическая специфика магматических пород различных геодинамических обстановок прослеживается на примере базальтоидных серий, по которым накоплен достоточно представительный материал. Так, толеитовые базальты горячих точек (океанические острова, траппы) содержат повышенные концентрации литофильных элементов; в толеитах рифтовых зон океанов концентрации этих элементов,напротив,очень низки; толеитовые базальты островных дуг отличаются,в свою очередь,низкими содержаниями хрома, никеля и кобальта, в то время как в базальтах активных окраин континентов содержания этих элементов в 2-3 раза выше. Геохимические различия магматических пород определяются как фи-

зико-химическими условиями магмообразования, так и ролью трех источников вещества - литосферы, включая земную кору, астеносферы и подастеносферных плюмажей, участвующих в формировании первичных магм каждой геодинамической обстановки.

Анализ магматизма ряда фанерозойских подвижных зон (Центральная Азия, Урал, Северная Америка и др.) позволяет утверждать, что геохимические особенности магматических пород связаны не с возрастом, а с геодинамическими условиями их формирования. Это дает надежную основу для реконструкции палеоактивных зон в подвижных поясах в сопоставлении с современными зонами.

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RIDGE SUBDUCTION AND VERTICAL MOTION OF OVERRIDING PLATE

The arrival of a ridge in the subduction zone induces two appreciable effects : local collision and isostatic adjustement of the involved area. The purpose of this paper is to quantify these two phenomena by means of modelling. Thus, the comparison of the obtained results with observed data (vertical movements of the overriding plate) in the Central New Hebrides Island Arc may be done. The two principal conclusions are the following :

- isostatic disequilibrium could be a major cause for uplift of the over riding plate;
- meanwhile, local collision could not give a satisfactory explanation on the amount of this uplift because its location and the high compressive stresses (~ 10 km) needed to produce the required amplitude (600 m), disagree with available data.

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GRAVITATIONAL CIRCULATION IN THE UPPER MANTLE: IMPLICATIONS FOR PLATE TECTONICS, CRYSTAL ACCRETION AND MANTLE EVOLUTION

A quantitative description of upper mantle convection and related plate dynamics is given in which the principal driving force is the longitudinal density gradient within the upper mantle between the spreading ridge and subduction zone. The effects of plate forces, lithospheric density changes, and viscosity variations are considered and included in the derivations. The results are applied to a description of the observed plate velocities, plate velocity variations as a function of plate geometry, asymmetric seafloor spreading, spreading ridge migration, ocean floor relief, and asymmetric variations in ocean floor relief. A second component of upper mantle circulation between the warmer and less dense spreading ridges and the cooler and more dense deep continental regions is also considered. This second component leads to a possible explanation for the bimodal plate velocity distribution, passive margin effects of intraplate seismicity and stress state, and crustal accretion. Further, both components of upper mantle circulation are important to mantle evolution through geologic time and could conceivably lead to an evolution from a primitive pyrolite upper mantle to an upper mantle consisting of eclogite overlain by peridotite.

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GEOCHEMICAL CONSTRAINTS ON SCALES OF MANTLE CONVECTION

The principal part played by geochemical studies in investigation of the scale of convective motions in the Earth's interior is one of identifying the existence and longevity of chemical reservoirs. A number of geochemical observations are difficult to reconcile with the notion that convection that extends throughout the entire mantle, particularly if a small scale flow is required in the upper mantle. These include the estimated mass balance of Sr and Ne isotopes between the continental crust and mantle, the relative abundances of primordial and radiogenic rare-gases in mid-ocean ridge basalts and at hotspot sites, and the marked imbalance of the radiogenic helium flux and the heat flux from the mantle. Published and new geochemical data relevant to this topic will be reviewed and discussed in the light of the available geophysical constraints.

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RADIAL STRUCTURE OF THE MANTLE CONVECTIVE CIRCULATION

An important current issue in the ongoing geophysical debate concerning the style of convection in the earth's mantle is whether the radial structure consists of a single cell or several (2?) cells. Various arguments have been advanced in favour of the competing views but no one of these appears definitive. Although geochemical data on Nd and Sr concentrations in MORB and OIB were initially taken as strong support for the two cell model, recent reanalyses of the data have strongly undermined this interpretation. More recent support for the same model has been sought in the observed isotropic concentrations of Xe, He, and Ar gas in basalts from the two characteristic regions. Balancing these geochemical arguments are several geophysical observations which have been invoked as support for the alternative whole mantle circulation model. These include the fact that the viscosity structure of the mantle does not appear to exhibit the sharp variations of viscosity with depth which should be characteristic of a layered circulation. Furthermore the layered convection model appears to require a decoupling of the motion of the oceanic lithosphere from that in the underlying mantle and this is difficult to accommodate with other geophysical, particularly seismic, data. Several of these arguments will be discussed in detail within the context of a general review of the issue.

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GEOID HEIGHTS AND LITHOSPHERIC STRESSES FOR A DYNAMICAL EARTH

Mass heterogeneities in the Earth crust and mantle are known to exist at all depths and for a large range of wavelengths characteristic of their lateral extent. They are the sources of measurable quantities like topography, tectonic stresses and geoid. Quantitative relationships between these surface observables and deep sources are established for various Earth viscosity structures with radial symmetry. For an homogeneous mantle, the surface stresses and the geoid grow with the depth of the perturbing heterogeneity but decrease markedly beyond a critical depth proportional to the wavelength. In the presence of physical or chemical stratification of the mantle this last decoupling phenomenon is shown to be more complex. The ratio geoid over topography, called the admittance Z, may then change sign. The same is true for the ratio geoid over lithospheric stresses called the Runcorn number Ru. Lower mantle sources are the only candidate capable of explaining the large wavelength geoid undulation with an acceptable magnitude of Z and Ru. This conclusion does not hold if the spherical symmetry of the viscosity structure is broken as it is for the Earth's lithosphere for which the plates are separated by zones of weakness. In this second framework it is shown that upper mantle return flow is also capable of generating the geoid without producing too big a topography and too strong tectonic stresses. The two types of contribution are expected to occur in the Earth. Further progress will require carefull data analysis and correlation between topography, stresses, geoid and deep density structures.

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RHEOLOGICAL PROCESSES UNDERLYING SUBDUCTION

The subduction of the oceanic lithosphere is studied from the thermo-rheological point of view. The generation of heat kernels by sliding and viscous friction is studied with relation to magma-generation. The dynamic temperature distribution during the downgoing process is computed starting from an initial temperature distribution.
On the basis of the above computed temperature field the motion of the slab and the mantle is studied by means of finite element compu-

tation. In this analysis of Newtonian viscous fluid or a generalised Maxwell body is assumed with temperature and pressure depend viscosity.
The stressfield and displacement field are computed and a study is made of the Wadati Benioff Zone.

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RHEOLOGY OF THE OCEANIC AND CONTINENTAL LITHOSPHERE

There are basically two hypotheses governing the behavior of the lithosphere: (1) The lithosphere has an elastic rheology and (2) the lithosphere has a viscoelastic rheology. I will argue in favor of the first hypothesis although the variation of the thickness of the elastic lithosphere with time is an important variable. I first consider the oceanic lithosphere. The oceanic lithosphere has considerable rigidity as evidence by the lack of intraplate deformation. Data on the bending rigidity of the oceanic lithosphere comes from studies of lithospheric flexure at ocean trenches and under the load of ocean islands and seamounts. The elastic thickness of the elastic lithosphere is about one-half the thickness of the thermal lithosphere associated with plate tectonics. This difference can be explained by the dislocation creep of olivine. At temperatures above about 1200°C the mantle behaves as a fluid, at temperatures above about 700°C elastic stresses are relaxed by creep on geological time scales. Studies of seamounts of various ages show very little relaxation arguing against a viscoelastic lithosphere. At ocean trenches the oceanic lithospheres appear to fail in bending by plastic deformation. The continental lithosphere behaves quite differently than the oceanic lithosphere. There is much more intraplate deformation in the continents. Examples include the western United States and China. Reactivtion of pre-existng zones of weakness such as fault zones also appear to play an important role in the deformation of the continents. There is ample field evidence that intermediate depth crustal rocks are subject to fluid-like deformations at relatively low tempertures. Folding, boudinage, and other evidence for such deformation can be attributed to the soft rheology of quartz and to the role of water in such deformation mechanisms as pressure solution creep. Many features of continental tectonics can be explained in terms of an intracrustal asthenosphere attributed to these deformation mechanisms. Intracrustal decollements are associated with many orogenies, examples are the Alps and the southern Appalachians. The behavior of the San Andreas fault can also be explained in terms of an intracrustal asthenosphere. Delamination of the continental lithosphere is also a mechanism that plays an important role in the behavior of the continents.

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VARIING INHOMOGENEITY OF THE EARTH INTERIOR DURING ITS HISTORY

In the accumulation process the uppermost layers of the planets have undergone an impact transformation due to infalling bodies. According to our calculations, the mass distribution law of bodies had the form $n(m) \propto m^{-q}$; $q \lesssim 2$, which is in agreement with the observed distributions of the asteroids and of bodies responsible for impact craters on the Moon, Mercury e.a. The size spectrum of primary inhomogeneities in the Earth was determined by two processes. Cratering of its surface layer by impacts of bodies of different size and composition smoothed out inhomogeneities with smaller scale. But the largest lateral inhomogeneities (λ 100-1000 km) could retain the compositional differences of the order of 1% and the density differences $\delta\rho/\rho = 10^{-2}-10^{-3}$. At the same time in the zones where a partial melting occurred a differentiation of the primary matter began. The sizes of the melted zones were determined by the sizes and velocities of impacting bodies. According to the experiments on melting of meteorites we assume that main liquidus phases were Fe-Ni melt with addition of FeS or FeO (depending on f_{O_2}), ferrobasaltic melt, olivine and pyroxene. The density differences of these phases are between 0.5 and 5 gcm^{-3}. Our calculations show that the relaxation of large-scale inhomogeneities with $\delta\rho/\rho \lesssim 10^{-3}$ at the beginning was suppressed by a violent process of separation and removal of a heavier component into the core. Our estimates of the differentiation rate are in agreement with the isotope and paleomagnetic data indicating the core formation within the first billion yrs of the Earth history. The modern tectonics, plate tectonics, irregular pole drift seem to be caused by a continuing adjustement of the mantle toward a more equilibrated (more stratified) state. Large-scale gravitational anomalies can be connected with the compositional fluctuations in the mantle with $\lambda \sim 10^3$ km; $\delta\rho/\rho \sim 10^{-3}$. Short-wave compositional fluctuations in the mantle ($\lambda \sim 10$-100 km; $\delta\rho/\rho \sim 10^{-2}$) are recognized only by seismic methods through anomalies of travel-times of compressional waves from distant sources.

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ИЗМЕНЧИВАЯ НЕОДНОРОДНОСТЬ НЕДР В ХОДЕ ЭВОЛЮЦИИ ЗЕМЛИ

В процессе образования планет их приповерхностные слои подвергались ударной переработке падавшими телами. Согласно нашим расчетам, спектр масс тел $n(m) \propto m^{-q}$, $q \leq 2$, что подтверждается наблюдениями в поясе астероидов и статистикой кратеров на Луне, Меркурии и др. телах Солнечной системы. Спектр первичных неоднородностей Земли был обусловлен двумя процессами. При падении тел разного состава в процессе кратерообразования происходило перемешивание и сглаживание неоднородностей состава. Но крупномасштабные латеральные неоднородности ($\lambda \sim$ I00-I000км) могли иметь отличия в составе $\sim$ I% и отличия в плотности

$\delta\rho = 10^{-2}-10^{-3}\,\bar{\rho}$. В то же время в возникавших зонах частичного расплава происходила дифференциация первичного вещества. Масштабы зон расплава определялись размерами и скоростью падавших тел. В соответствии с экспериментами по плавлению метеоритного вещества мы принимаем, что основными ликвирующими фазами были: $Fe - Ni$ расплав с примесью FeS или FeO (в зависимости от fO_2), ферробазальтовый расплав, оливин и пироксен. Разность плотностей этих фаз 0,5-5г см$^{-3}$. Согласно нашим расчетам,релаксация крупномасштабных неоднородностей с $\delta\rho/\bar{\rho} \lesssim 10^{-3}$ вначале была подавлена бурным процессом отделения и ухода тяжелой компоненты в ядро. Наши оценки скорости дифференциации согласуются с изотопными и палеомагнитными данными, указывающими на образование ядра в первый млрд.лет жизни Земли. Современная тектоника, подвижки плит, нерегулярный дрейф полюсов, по-видимому, обусловлены продолжающейся перестройкой мантии к более равновесному (стратифицированному) состоянию. Крупномасштабные гравитационные аномалии объясняются флуктуациями состава в мантии с $\lambda \sim 10^3$км, $\delta\rho/\bar{\rho}$ 10^{-3}. Коротковолновые мантийные флуктуации состава ($\lambda \sim 10-100$км, $\delta\rho/\bar{\rho}$ 10^{-2}) проявляют себя лишь в сейсмике, обуславливая аномалии времен пробега продольных волн от далеких источников.

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SPHERICAL SHELL TECTONICS - FORMATION AND DEVELOPEMENT OF SUBDUCTION ZONES

The lithospheric plate is a "spherical shell" rather than a "plate". A spherical shell often deforms in a very different way from our naive expectation. We made hemispherical shells of polyvinyl chloride resin using a specially designed heater attached to a press. The vinyl shell was capped onto a part of the plaster sphere with its edge shaved in a form of a real deep seismic zone. The shell was then bent at the edge to fit the miniature deep seismic zone. The fitness was in general very good. A better fit was achieved for several subduction zones by making a cut into the vinyl shell. The result strongly indicates that large lithospheric deformation occurs firstly by bending and secondly by tearing. Shear and extension are negligible. Subduction zones tend to form a chain of arcs along a great circle. In an attempt to understand this tendency, the circumference edge of the cylindrical vinyl shell was quasi-hydrostatically compressed from outward until it was buckled. The radial displacement of the edge was measured by a specially designed zero-force touch sensor. A scaling of the experimental result suggests that the lithospheric "shell" with an effective thickness of 30 km would buckle in a wavy form with apparent lengths 15 to 35° in fair agreement with the real lengths of island arcs, implying that the arcuate form of a subduction zone is a consequence of lithospheric buckling. Some mode of back-arc opening may be accounted for by a progressive growth of buckling from smaller amplitudes and shorter wavelengths to greater amplitudes and longer wavelengths.

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MAPPING THE UPPER MANTLE:
THREE DIMENTIONAL MODELLING OF EARTH STRUCTURE
BY INVERSION OF SEISMIC WAVEFORMS

A method has been developed for the inversion of mantle wave seismograms for the three dimensional distribution of seismic wave velocities. The method has been applied to data from the global digital networks (International Deployment of Accelerometers, Global Digital Seismograph Network); the selected data set consists of some 2000 seismograms corresponding to 53 events and 870 paths. The moment tensors of the earthquakes are determined through an iterative procedure which minimizes the corrupting influence of lateral heterogeneity.

Two global models of shear wave velocity in the upper mantle, expanded up to degree and order 8 in spherical harmonics, and described by a cubic polynomial in depth have been constructed. For the first model (M84A) no a priori information has been incorporated and for the second model (M84C) simple models of oceanic and continental crustal structure have been specified.

The model predictions reproduce much of what is known about the dispersion of mantle waves, e.g. high phase velocities for shields, low velocities at ridges, a strong degree 2 pattern for Rayleigh waves. Since the method makes use of complete waveforms, overtone data are also included. It is shown that the model is reproducible, in that substantially the same model can be constructed from each half of the total data set considered independently.

The model M84C, which we take to be the better representation of heterogeneity, shows that ridges and shields are major features in the depth interval 25-250 km. The ridges of the southern Pacific and the larger shields persist to 350 km, but the South East Indian Rise and much of the Mid-Atlantic Ridge are underlain by high velocities at this depth. At 350 km low velocity features are associated with some hot spots: Gulf of Aden, Hawaii, Iceland, Kerguelen, Tristan da Cunha.

At 450-650 km major features are a broad plateau of high velocities incorporating South America, much of the South Atlantic and parts of West Africa, a broad region of low velocities in the central and eastern Pacific, high velocities in the west Pacific and low velocities in the Gulf of Aden.

Although most of the above statements are also true of model M84A the effect of the crustal correction is significant. Model M84A shows a high positive correlation with the geoid for degrees 2 and 3; paradoxically this is largely destroyed when the distribution in crustal thickness is taken into account. Degrees 4 to 7 show a significant negative correlation.

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ON THE MECHANISM OF DEVELOPMENT OF EASTERN ASIA CONTINENTAL MARGINS ADJACENT TO THE NORTHWESTERN PACIFIC

On the basis of geomechanical analysis and model expriments we believe that the formation of island arcs are mainly due to compression, while back arc basins with much thinner continental crust and younger oceanic crust sometimes are due to extension. In this process interlayer gliding and lithospheric or/and crustal fractures play a great role. The stress field in this area may be comparable with that in beam-bending in engineering mechanics. In its rear part behind the neutral plane secondary lateral compression results, so on the inner side of the arc where lies a rigid land mass third extension is induced which accelerated formation of back arc basins, such as the Japan Sea, the East China Sea, etc.

In view of global tectonics, the opening-up of Atlantic Ocean with passive margin is due to the creep of both American continents and Eurasian-African -Australian continents toward the Pacific Ocean respectively. This creep induces the formation of active margins on the W.Pacific. The active and passive margins might be formed due to an united stress field.

Geohistorical analysis shows that near all the island arcs outside mainland of China were graduatly detached from the Asia Continent during Mesozoic and Cenozoic times, because oceanic plateaus or seamounts mainly composed of continental crust scattered in the W.Pacific. They may be regarded as relics of Asia continent.

Model experiments indicate that the geological bodies in higher position with lower density more easily overthrust on the lower position with higher density. Thus, the Eastern Asia continent and its fragments overthrusting on the Pacific Ocean rather that Pacific plate underthrusting Asia continent is considered as the mechanism of development of Asia continental margins.

ГЕОЛОГИЧЕСКИЕ, ГЕОФИЗИЧЕСКИЕ И ГЕОХИМИЧЕСКИЕ ПАРАМЕТРЫ ГЛУБИННЫХ СТРУКТУР КОНТИНЕНТОВ И ОКЕАНИЧЕСКИХ БАССЕЙНОВ

GEOLOGICAL, GEOPHYSICAL AND GEOCHEMICAL CONSTRAINTS ON THE DEEP STRUCTURE OF THE CONTINENTS AND OCEAN BASINS

Conveners: K.Fuchs, N.V.Sobolev

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ON THE DETERMINATION OF ANOMALOUS ZONES BY THE VELOCITY AND ABSORPTION OF SEISMIC WAVES IN THE EURASIAN LITHOSPHERE

The paper presents results of investigation of spatial distribution of zones of low values of longitudinal wave velocities and high values of longitudinal and transversal wave absorption in the Eurasian upper mantle. The determination of the anomalous zones was carried out through long seismic probing profiles.
The procedure of determining the high absorption zones is based on studies of the mechanism of interference oscillation formation in the tailend of the earthquake seismograms ('coda' waves).
The authors note a number of regularities in the distribution of high absorption zones over the area of Eurasia and correlation of the zones with velocities and types of large geological structures.
The problem of integration of different seismic methods of studying the upper mantle is discussed. A general scheme of the determination of anomalous zones by velocity and absorption in the Eurasian upper mantle is presented.

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О РАСПРЕДЕЛЕНИИ АНОМАЛЬНЫХ ЗОН ПО СКОРОСТИ И ПОГЛОЩЕНИЮ СЕЙСМИЧЕСКИХ ВОЛН В ЛИТОСФЕРЕ ЕВРАЗИИ

Приводятся результаты изучения пространственного распределения зон пониженных значений скорости продольных волн и повышенных значений поглощения продольных и поперечных волн в верхней мантии Евразии. Выделение аномальных зон продольных скоростей производится на основе длинных профилей сейсмического зондирования.
Методика выделения зон повышенного поглощения основана на изучении

механизма формирования интерференционных колебаний в хвостовой части сейсмограмм от землетрясений ("кода" волн).
Отмечаются ряд закономерностей в размещении зон повышенного поглощения на территории Евразии, корреляция этих зон со скоростями и с характером крупных геологических структур.
Обсуждаются вопросы комплексирования различных сейсмических методов изучения верхней мантии.
Приведена сводная схема распределения аномальных зон по скорости и поглощению в верхней мантии Евразии.

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STRUCTURAL MODEL OF THE SUBCRUSTAL LITHOSPHERE IN CENTRAL EUROPE (A REVIEW)

The results of different seismological studies of the deep European lithosphere, including the research in spatial variation of relative P residuals and their three-dimensional inversion, are reviewed. The combined effects of inhomogeneities and anisotropie structures are observed. Lateral inhomogeneities are mainly due to undulations of the lithosphere-asthenosphere boundary. The most severe topography of this discontinuity is observed in the Alpine-Carpathian orogenic system. Early P arrivals indicate three deep-seated inhomogeneities in the Western Alps, Eastern Alps and East Carpathians. These inhomogeneities most probably represent palaeosubductions of the still cold lithosphere rooted at a depth of 200-250 km in the asthenosphere. No such roots are observed in the central part of the Alps and in the West Carpathians. The three-dimensional inversion of the residuals provides consistent results to a depth of about 160 km. In deeper layers the velocity perturbations are partly biased by the effects of the large-scale anisotropic structures within the subcrustal lithosphere.
The existence of large-scale anisotropic structures is derived from spatial variation of P residuals which show systematically early arrivals from one side and late arrivals from the opposite side at seismological stations within large tectonic units. The best fit for the observed P residuals is obtained for anisotropic structures dipping at angles between 30° and 50° with the velocity maximum oriented in the dip direction and the velocity minimum perpendicular to it. The P anisotropy of these structures of 6 to 9% agrees with the

anisotropy determined by laboratory measurements of olivine-rich ultramafites. The observed anisotropic structures provide new structural information about the geodynamic development of deep continental tectonics.

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ND-ISOTOPES AND CONTINENTAL LITHOSPHERIC EVOLUTION

Recent Nd and Sr-isotopic studies on a variety of young terrestrial igneous rocks have shown their derivation from depleted, enriched and primitive mantle-reservoirs. These isotopic data in conjunction with data on basic and acid igneous rocks of the Archean and the Proterozoic have provided a basis for quantitative models of mantle evolution.

Our Nd-isotopic data on a variety of continental igneous rocks from throughout the earth's geologic history support a model of lithospheric evolution in which the earth's lower mantle is essentially undifferentiated for Sm-Nd and Rb-Sr systems. This lower mantle is overlain by a depleted mantle which may be residual after the extraction of the continental crust. In support of this model, we provide Nd-isotopic data in kimberlites from India, southern Africa, China, U.S.A. and the U.S.S.R. We also provide data on mafic-ultramafic inclusions in the 90-million-year-old southern African kimberlites, which are believed to represent a complete cross-section of the present-day continental lithosphere. Further, our Nd-isotopic data on continental mafic, alkalic and acid igneous complexes from the Archean and the Proterozoic of Canada, India, U.S.A. and Finland suggest that the ancient and the present-day continental lithosphere are very similar in their composition, structure and evolutionary characteristics.

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DEEP STRUCTURE OF EXTENDED CONTINENTAL CRUST:
RECENT RESULTS FROM COCORP REFLECTION SURVEYS IN THE U S

Recent COCORP field activity has focussed on rifted terranes, including a regional traverse across the Basin and Range Province of the western U.S. This traverse extends from the Sierra Nevada Mountains of California to the central Colorado Plateau of Utah. Results from the eastern part of the Basin and Range demonstrate that Cenozoic extension of the crust in this area was accomodated by low-angle intracrustal detachments, the most prominent of which can be traced up to 120 km laterally and to depths in excess of 15 km. High-angle normal faults evident at the surface do not penetrate these underlying detachments. Some of these low angle extensional faults may be reactivated Laramide thrusts. Although results from the western and central portions of the traverse are still in rudimentary stages of analysis, it is already clear that reflections from Moho depths are common and surprisingly undisturbed along much of the traverse. COCORP has also completed surveys across part of the southern Basin and Range and adjacent Mojave Desert area of southern California. The crust beneath the Mojave is characterized by correlatable bands of deeply penetrating reflectors which may represent Mesozoic thrusts or the roots of Cenozoic extensional detachments to the east. Midcrustal reflectors can be traced undisturbed beneath the surface trace of the Garlock fault, suggesting that this major

Cenozoic strike-slip fault does not penetrate vertically to lower crustal depths. As is the case for the Basin and Range traverse, reflections from Moho depths beneath the Mojave seem relatively unaffected by deformation in the overlying crust. Unusually strong reflections from beneath the Death Valley graben just north of the Mojave area suggest a midcrustal magma body similar to one observed on earlier COCORP surveys in the Tertiary Rio Grande Rift. New COCORP surveys in the central U.S. reveal a much older extensional structure, the Proterozoic Keweenawan rift, buried beneath the Paleozoic platform cover. This rift is an asymmetric half-graben bounded by moderately east-dipping normal faults. It is interpreted to be filled with volcanics and clastics, based in part upon its distinctive bimodal seismic stratigraphy. The rift basin appears to have formed by domino-style fault block rotation. In contrast to observations from more recently rifted areas, distinctive reflections at Moho depths are absent in the vicinity of the Keweenawan rift. Instead, the base of the crust in this extended Precambrian terrain seems to correspond to the lower limit of distributed intracrustal reflections.

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DEEP STRUCTURE AND DYNAMICS OF THE OCEANS LITHOSPHERE

Oceanic lithosphere differs from continental one in a number of features: 1) more widely distributed mafites and ultramafites in volcanogenic-sedimentary layer, which results to a considerable extent from their better protection from erosion; 2) more strongly pronounced linear and arch-like character of major morphostructural units; 3) higher permeability for magmatic melts and fluid-gas components; 4) specific character of the "drainage-shell" caused by interactions of thick outer hydrosphere and deep juvenile water. Some peculiarities of oceanic crust structure are accounted for primary heterogeneity of structure - substance complexes which existed before the Meso-Cenozoic oceanization stage, as well as for pulsative Earth radial compression and dominating tangential stresses across the strike of sea-floor structural units. Within mid-oceanic ridges arch uplifting occures with rift valleys appearing as simple forms of plate subsidence in the shape of narrow deep sutures. The expansion impulses that were instantaneous on a scale of geological time and which are recorded by seismic waves of rift earthquakes result from high-stressed lithosphere reaction on the presence of rock destabilization zones, which are peculiar "release cavities" where relaxation of stresses takes place. From this point of view tension stresses in the earthquake foci across the strike of rift valleys cannot be regarded as indicators of geodynamic condition of dominating lithosphere expansion existing over a long period of time.

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ГЛУБИННОЕ СТРОЕНИЕ И ДИНАМИКА ЛИТОСФЕРЫ ОКЕАНОВ

Океаническая литосфера отличается от континентальной по целому ряду признаков: I) большей распространенности в вулканогенно-осадочном слое мафитов и ультрамафитов, что в значительной мере предопределено их лучшей сохранностью от эрозии; 2) более четко выраженной линейности и дугообразности крупнейших морфоструктурных элементов; 3) повышенной проницаемости для магматических расплавов и флюидно-газовых компонентов; 4) специфике "дренажной оболочки", обусловленной взаимодействием мощной внешней гидросферы с глубинными ювенильными водами. Некоторые особенности строения океанической литосферы объясняются первичной неоднородностью структурно-вещественных комплексов, существовавшей до мезозойско-кайнозойского этапа океанизации, а также пульсирующим радиальным сжатием Земли и преобладающей ориентацией тангенциальных напряжений вкрест простирания структурных элементов океанического дна. В пределах срединных хребтов происходит сводовое воздымание земной коры, на фоне которого рифтовые долины предстают как частные формы блокового оседания литосферы в виде узких глубинных швов. Мгновенные в масштабе геологического времени импульсы расширения, отмечаемые по сейсмическим волнам рифтовых землетрясений, представляют собой реакцию высоконапряженных объемов литосферы на существование в ее верхних горизонтах зон разупрочнения пород - своеобразных "ослабленных полостей", в которых и происходит разгрузка напряжений. С этих позиций наличие в очагах землетрясений растягивающих напряжений, ориентированных вкрест простирания рифтовых долин, нельзя рассматривать как показатель длительно существующей геодинамической обстановки преобладающего растяжения литосферы.

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THERMAL STATE OF THE CONTINENTAL LITHOSPHERE

The thermal state of the lithosphere exerts a strong influence on chemical and physical properties of rocks and hence plays an important role in geodynamic processes. The success in extrapolating direct measurements of temperature in the upper 1% of the lithosphere downward through the remaining 99% depends on our knowledge of (a) the mode of heat transfer within the lithosphere, (b) thermal properties of the medium and their pressure, temperature and composition derivatives and (c) the boundary conditions to the heat transfer problem.

A simple but useful assumption for the continental lithosphere (valid for 70% of continental areas comprising stable tectonic elements) is that heat transfer within the lithosphere is governed by steady state conduction. The sub-lithospheric thermal state is assumed to be adiabatic. Geotherms, parametric in surface heat flow, based on these asumptions and using strong depth dependent thermal conductivity and heat production are presented. Properties of these geotherms include: (1) a nearly constant gradient through the upper crust because the decrease in thermal conductivity at higher temperatures for felsic rocks counteracts the decreasing heat flow caused by crustal radioactivity; (2) wide divergence of geotherms in the 50 to 150 km range amounting to more than 500°C differences at sub Moho depths between rifts and shields, and (3) convergence of geotherms below 250 km as convective heat transfer dominates. Computed temperatures are most sensitive to changes in surface heat flow and in order of decreasing sensitivity to upper crustal thermal conductivity, its temperature dependence, and to upper crutal heat production. Pressure dependence of thermal parameters, lower crust and mantle heat production and Moho depth are insensitive parameters. This family of static steady state geotherms is consistent with xenolith geotherms, with partial melt requirements and with a variety of seismological observations.

In orogenic belts associated with plate interactions, static, steady state, 1 dimensional heat transfer does not apply. A number of alternative models are available and are discussed.

The final problem in determining the thermal state of the continental lithosphere is interpreting continental heat flow measurements which are the most important boundary conditions for the thermal state problem. Corrections to heat flow measurements (including effects for topography, topographic evolution, subsurface geological structure and groundwater movement) may not always be recognized and thus constitute noise in the measurements. Only when this "noise" is minimized can reliable regional heat flow values be assigned and trends in heat flow or reduced heat flow versus age be recognized.

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MAGMATISM OF THE OCEAN FLOOR AND SOME ASPECTS OF OCEAN LITHOSPHERE DYNAMICS

The generalization of recent experimental petrology, and observations on oceanic igneous rocks, minerals, melt inclusions and glass compositions lead to the conclusion that the various primary melts of oceanic region were separated over 2 depth interval of 100 km in the mantle. The compositions of the individual primary melts and degrees of their differentiation depend on the depth of separation.
Three main groups of igneous ocean rocks significantly differing one from another due to different depth of their primary melt separation, are discussed here. Two of them are represented by low potassium ocean tholeiites - MORB-1 and MORB-2*. MORB-1 includes the products of differentiation of primary melt separated from spinel lherzolite (depth 30-50 km), MORB-2 - those separated from plagioclase lherzolite (depth 15-30 km). The third group includes the complex of alkali rocks formed due to differentiation of the primary melt separated from garnet lherzolite (more than 80-100 km depth). The geographical distribution of all three groups seems regular. MORB-1 is most wide spread on the ocean bottom, MORB-2 appeared only on limited

*MORB is TOR (Tholeiite of Ocean Rift sistem) in russian version.

parts of Mid-Ocean Ridges during the last 10-20 milhon years. The alkali group is localized only in islands and in some undersea volcanoes.

The study of the relation between tectonic structures and geophysical fields of the oceans and also the distribution of different depth of primary melt separation led us to the conclusion that the geodynamic conditions of the ocean lithosphere formation are variable.

The preliminary conclusions are as follows. Oceanic lithosphere thickness is about 80-100 km along all its continuation, except for relatively narrow unstable zones of diapirism. The spreading of ocean lithosphere has never been continuous. The peculiarities of the magmatic process observed show the periodical change of spreading for stable, quiet tectonic conditions. The frequency and continuation of this change is related to the depth of primary melt separation and degree of their differentiation.

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МАГМАТИЗМ ДНА ОКЕАНА И ВОПРОСЫ ДИНАМИКИ ОКЕАНСКОЙ ЛИТОСФЕРЫ

Обобщение последних данных экспериментальной петрологии и материалов по океанским магматическим породам, минералам, расплавным включениям и закалочным стеклам привело к заключению о том, что первичные магматические расплавы отделяются от океанской мантии в интервале глубины порядка IOO км. Состав первичного расплава и характер его дифференциации зависят от глубины его отделения от мантии.

В океанах присутствуют три главные группы магматических пород, заметно отличающиеся по составу, так как их первичные расплавы отделяются от мантии на трех разных уровнях глубины. Две из этих групп представлены низкокалиевыми толеитами ТОР-I и ТОР-2*. ТОР-I включает продукты дифференциации первичного расплава, отделяющегося от шпинелевого лерцолита на глубине 30-50 км, а ТОР-2 - при расплаве, отделяющемся от плагиоклазового лерцолита на глубине I5-30 км. Третья группа включает сложный комплекс щелочных пород, образовавшихся

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* ТОР - толеиты океанских рифтов (соответствуют МОРВ).

за счет дифференциации первичного расплава, отделившегося от гранатового лерцолита на глубине 80-100 км.

Географическое распределение всех трех групп достаточно закономерно. TOP-I - наиболее распространенная группа, TOP-2 появляетсяв ограниченных участках срединных хребтов в течение последних 10-20 млн лет.

Группа щелочных пород образует острова и встречается на некоторых подводных вулканах. Исследование взаимосвязи между тектоническими структурами дна океана, их геофизическими полями и распределением глубины отделения первичных расплавов приводит к заключению об изменчивости геодинамических условий формирования океанской литосферы. Сделаны следующие предварительные выводы. Океанская литосфера сохраняет мощность порядка 80-100 км на всем ее протяжении за исключением узких нестабильных зон, связанных с диапиризмом. Раздвижение океанской литосферы никогда не было непрерывным. Наблюдаемые особенности магматического процесса свидетельствуют о периодической смене раздвижения и тектонического покоя. Частота и продолжительность этих периодов контролируют глубину отделения расплавов от мантии и характер их дифференциации.

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ANOMALIES OF THE MANTLE FROM DEEP SEISMIC SOUNDING ON LONG RANGE PROFILES

Probing the earth's mantle by controlled source experiments on long range seismic profiles with densely spaced arrays of mobile stations have revealed features of the mantle which could not have been resolved by classical seismological methods. The depth range of penetration reaches down to 800 km, with specially high resolution to about 400 km. The main features are:

P-wave velocities are dependent on azimuth. The anisotropy is compatible with a preferred horizontal alignment of the fast a-axis of olivine. The degree of preferred orientation is depth-dependent.

The high velocities observed in the upper mantle are not compatible with classical petrological models unless anisotropy is taken into account.

The topmost mantle seems to be less depleted in basalts than the zone below 50 km.

Whenever densely spaced observations are available the horizontal P-wave velocities in the upper mantle throughout the zone Bullen B exceed those of the PREM-model by up to 10%. Under shield areas the P-velocity distributions to a depth of 400 km do not provide evidence for an asthenospheric low velocity zone.

Comparison of longrange profiles in various shield areas show clearly lateral variations of travel times up to 3 secs for the reflection from the top of the transition zone.

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A TWO-SHIP "WIDE APERTURE" CDP-SURVEY ON THE NORTH ATLANTIC TRAVERSE

Seismic reflection investigations of the deep layers in offshore areas could be improved theoretically by using the "wide aperture CDP" method, in which an approximately 9,000 - 10,000 m long transmitter-receiver system is simulated by using conventional seismic survey units.

The Federal Institute for Geosciences and Natural Resources (BGR) together with the Lamont-Doherty Geological Observatory, the University of Texas at Austin and Prakla-Seismos GmbH tested this method and carried out a two-ship seismic survey off Florida.

Problems and solutions concerning the determination of the position of the ship's location, the synchronisation and geometry of the survey systems and the seismic data processing will be discussed. Stacked seismic reflection data for the offsets 0-3 km, 3-6 km and 6-9 km will be presented. According to the stacked reflection seismic data the oceanic crust has

i) a specially very heterogenous crustal structure;

ii) a distinct separation into an upper oceanic layer 2 and a lower oceanic layer 3 was not recognizable in the reflection seismic records;

iii) an unusually thin crust exists around fracture zones.

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CONSTRAINTS ON CHEMICAL DEPLETION OF THE UPPER MANTLE

It is well established that the source region of mid-ocean ridge basalts (MORB) is depleted in many trace elements. The evidence for this depletion was originally derived primarily from the abundances of radiogenic isotopes in MORB, but the elemental abundances themselves contain a much more comprehensive (though intrinsically more ambiguous) record of the depletion history.

Constraints on the depletion history and mechanism are provided by the following general characteristics of normal (=depleted) MORB: (1) Lower-than-primitive $^{87}Sr/^{86}Sr$ and higher-than-primitive $^{143}Nd/^{144}Nd$, $^{176}Hf/^{177}Hf$ and $^{40}Ar/^{36}Ar$ ratios demonstrate source depletion of Rb, Nd, Hf and Ar relative to Sr, Sm, Lu and K, respectively. In each pair, the more highly depleted element is also the more highly incompatible (Pb isotopes do not fit this pattern and require special explanations). (2) The enrichment factor (EF) of MORB concentration over primitive-mantle concentration varies systematically with the bulk partition coefficient (D) of each element. (3) The function EF versus D has a distinct maximum in all MORB. (4) The magnitude of this enrichment maximum for average normal MORB is EF(max) = 10, and the elements that lie near this maximum (intermediate and heavy REE, Hf, Zr, Y, and Ti) are moderately to highly incompatible and have bulk partition coefficients (in mantle lherzolite) of D = 0.01 to 0.05.

(5) The degree of variability of the elemental concentrations, expressed as the standard deviation (SD), is large for very highly incompatible elements (e.g. Ba, Rb, Cs, Th), decreases systematically with increasing D, reaches a minimum near D = 1 (most of the major elements), and then increases again for highly compatible elements such as Ni.

The above constraints can be met by a simple model of two-stage extraction of incompatible elements from the initially primitive mantle. During the first stage, a very small fraction of the material was extracted as melt or other fluid phase in the presence of clinopyroxene and possibly garnet. A small portion of this fluid remained in the residue and prevented the concentrations of the most highly incompatible elements from becoming negligibly small. This depleted residue was incompletely homogenized by mantle convection and, after a time interval of about 2 Ga, was remelted to produce MORB. The sum of the extracted fluid fractions in stages one and two is approximately constant and quite small, on the order of F(1) + F(2) = 0.05. If allowance is made for fractional crystallization of MORB, the maximum degree of melting during the production of MORB is still only about 10 percent. The small magnitude of the extracted fluid fractions is a mass balance requirement, which holds regardless of the complexities, tectonic or geochemical, of ancient continental-crust extraction from the mantle. This conclusion is qualitatively confirmed by very strong evidence for residual clinopyroxene (or similar aluminous phase) during MORB production: greater-than-primitive Zr/Al (as well as Hf/Al, Y/Al, HREE/Al) ratios demonstrate that Al is held back in the mantle during MORB production. Another unconventional conclusion is derived from the highly variable concentrations of the very-incompatible-element concentrations (Ba, Rb, Cs, etc,) of MORB: the MORB source is rather poorly mixed by convection, despite the comparatively uniform $^{87}Sr/^{86}Sr$ ratios. The alternative explanation, namely that a well-mixed MORB source is subjected to highly variable degrees of melting (during MORB production), cannot be reconciled with the high degree of uniformity of the moderately incompatible elements (REE, Zr, Hf, Y). The relatively high variability of Nd and especially Hf isotopic compositions in MORB provide further evidence against the existence of a well-mixed MORB-source reservoir.

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GEOLOGY OF THE OCEAN FLOOR

A steady state of seafloor spreading and lithospheric plate-consumption has resulted in a relatively young age of the ocean floor. Interpretation of seafloor magnetic anomalies and deepsea drilling indicated that the present ocean floor is nowhere older than Jurassic.

The sediments of the ocean floor are mainly biogenic and pelagic but turbidites are common in trenches and in marginal basins. Calcareous oozes consisting of mannoplankton and foraminiferal skeletons are almost ubiquitous. Siliceous oozes are present in equatorial and polar oceans and in regions of upwelling. Deep ocean floor beneath the calcite-compensation level is underlain by red clays. Hard grounds and erosional phenomena are found in areas of active bottom-current activities.

The deepsea sediments provide a record of paleoceanographic history. Analysis of oxigen-isotope of foraminiferal tests indicated warm oceans during the Jurassic and Cretaceous. A cooling trend started in early Eocene. Stepwise temperature-decreases took place during the middle Eocene, early Oligocene, middle Miocene, late Plestocene. The late Mesozoic oceans may have bottom currents driven by heavier saline waters. Stagnation and/or expansion of oxigen-minimum zone led to widespread occurrence of black shales. The start of glaciation in the Atlantic during late Eocene seemed to have initiated the first Atlantic bottom waters, and resulted in a change from thermophilic to coldwater (psychrospheric) bottom faunas on ocean floor. Analysis of carbon-isotopes suggested variations of plankton productivity in surface waters of open oceans. Calcite-compensation level was high during the Eocene and Miocene epochs, when the productivity of calcareous planktons were relatively reduced. The ocean sediments also gave a continous record of biologic evolution since the middle Jurassic. Dating by microfaunal, nannofloral zonations and by magnetostratigraphy permits global correlation with an accuracy at 10^5 to 10^6 year range. The record of ocean planktons clearly indicated a catastrophic event, at the end of the Mesozoic Era, when mass took place.

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OPHIOLITES AND PALEOOCEANIC LITHOSPHERE

The recent geologic data for the World ocean floor and folded belts of the continents leaves no doubts that ophiolite are the fragments of paleooceanic crust emplaced in orogenic zones by tectonic processes. The bottom part of the oceanic crust is difficult to explore, while the upper part has been studied fairly well enough. To reconstruct the environment of paleooceanic lithosphere we used volcanic series and associated sediments.

Two ophiolite types have been separated. The first one (Troodos, Newfoundland, Khan-Taishir and East Prikhubsugulia, Mongolia) is examplified by island arc differentiated calc-alkaline and tholeitic series and rocks of specific composition: komatiites and/or marianite-boninites. The second one (Norwey, Chili) includes mainly tholeiites intermediate between the abyssal and island arc types, similar to tholeiites from marginal basins. Volcanic-sedimentary rocks of the both types are represented by deep-sea and shallow-water deposits and shelf facies of both island arc and marginal basin environments.

The presence of specific low-Ti high-Mg lavas of marianite-boninite series indicates a definite tectonic regime, as these rocks are only known from the basement of forearcs. The tectonic position of komatiites is less clear, indicating a possible setting island arc or trough setting that had appeared due to rifting of the active continental margins. The conditions responsible for the formation of paleooceanic lithosphere, irrespective of age, correspond to a vast geotectonic environment: active continental margin-marginal basin-frontal arc. This setting involves the extension zones of: continental margins, backarc basins, interarc rifts and island arcs systems. The paleooceanic lithosphere in a number of cases consists of tectonic nappes with various layers of oceanic lithosphere, transported to regions of tectonic convergence on the continent or in the basement of the island arcs, which have undergone metamorphism and fold deformations. Evolution of paleooceanic lithosphere is due to variation of the composition and thermal regime of the Upper Mantle. This reflects in a replacement of the protooceanic crust of the Precambrian greenstone belts by a paleooceanic crust of Riphean and Phanerozoic ophiolites, also evolution of ultrabasic magmas: komatiitic, picritic and marianite-boninitic.

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ОФИОЛИТЫ И ПАЛЕООКЕАНИЧЕСКАЯ ЛИТОСФЕРА

Комплекс данных по геологии дна Мирового океана и складчатым поясам материков не оставляет сомнений, что офиолиты являются фрагментами палеоокеанической коры, тектонически перемещенными в орогенные зоны. Низы океанической коры мало доступны для исследований в современном океане, в то время как верхние части ее хорошо изучены. Для воссоздания обстановки формирования палеоокеанической литосферы использованы вулканические серии и ассоциирующие осадки.
Выделено два типа офиолитов. П е р в ы й (Троодос, Ньюфаундленд, Хан-Тайшир и Восточное Прихубсугулье МНР) характеризуется присутствием островодужных дифференцированных известково-щелочных и толеитовых серий, а также пород специфического состава: коматиитов и (или) марианит-бонинитов. В т о р о й (Норвегия, Чили) включает в основном толеиты, промежуточные между абиссальными и островодужными и аналогичными толеитам окраинных бассейнов. Вулканогенно-осадочные породы обоих типов представлены глубоководными, мелководными и шельфовыми фациями островодужной и окраинно-морской обстановок.
Присутствие специфических низко-Ti, высоко-Mg лав марианит-бонинитовой серии указывает на определенный тектонический режим, поскольку соответствующие породы пока известны только в фундаменте передовых

островных дуг. Тектоническая позиция коматиитов менее ясна, указывая на возможные обстановки островных дуг или трогов, возникших через рифтообразование активных континентальных окраин.
Условия формирования палеоокеанической литосферы независимо от возраста соответствуют обширной геотектонической обстановке активная континентальная окраина -окраинный бассейн- передовая дуга, включающей зоны растяжения на окраинах континентов, задуговые бассейны, междуговые рифты, системы островных дуг. Палеоокеаническая литосфера в большинстве случаев представляет тектонические пластины, содержащие различные слои океанической литосферы, перемещенные в области тектонического скучивания на континенте или в основании островных дуг, претерпевшие метаморфизм, складчатые деформации и вовлеченные в формирование континентальной литосферы.
Эволюция палеоокеанической литосферы связана с изменением состава и теплового режима верхней мантии. Это отражено в смене протоокеанической коры зеленокаменных поясов докембрия палеоокеанической корой рифейских и фанерозойских офиолитов и в эволюции типов ультраосновных магм: коматиитовой, пикритовой, марианит-бонинитовой.

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DYNAMICS OF MANTLE MAGMA GENERATION WITHIN THE CONTINENTAL AND OCEANIC SEGMENTS OF LITHOSPHERE

The thermodynamics and kinetics of melt origination and dynamics of melt accumulation in extensive solid medium are considered for 2 models: initial continuous solid medium and solid medium with scattering fluid inclusions.
It has been found, firstly, that the stable nuclei generation is possible only when overheating takes place of solidus temperatures, in particular, at high volume effects of the isobar temperatures of the solidus. The required overheating in eclogites is 350-450°C, in a monomineral forsterite it is 100°C, while in gabbroic rocks is amounts to 40-60°C (with pressure in the upper mantle). Secondly, melting takes place at insignificant overheating.
The first model corresponds to a non-differentiated mantle which has not yet reached the stages of partial melting (in "protooceanic segments of the lithosphere) or to a "restite" mantle", from which the readily fused components were practically removed with the fluid.
The second model characterizes the mantle at its intermediate stage of differentiation, when regressive crystallization of the residual

melts results in the occurrence of fluid inclusions. It is shown that specific nature of magma generation in the solid medium in the course of progressive heat evolution of the Earth leads to a progressive melting of the mantle from the upper levels to the lower ones (resulting in the mantle differentiation from the upper levels to the lower ones), to the quasiperiodic change of the upwelling heat flows with a possibility of appearing of large lateral heterogeneities within the initially uniform layers. The differences in the course of magma injections from horizons with various preliminary differentiation are shown. In particular, the local centers do originate, in which melting of the overheated substance proceed "as a whole"(in the form of komatiite lavas. On cooling due to the loss of heat at melting they are evacuated to the basalt melts. The obtained results supplemented by geologic observations are consistent with the early history of the Earth and oceanic continental joints.

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ДИНАМИКА МАНТИЙНОГО МАГМООБРАЗОВАНИЯ В КОНТИНЕНТАЛЬНЫХ И ОКЕАНИЧЕСКИХ СЕГМЕНТАХ ЛИТОСФЕРЫ

Термодинамика и кинетика зарождения расплава и динамика его скоплений в протяженной твердой среде исследованы для двух моделей: изначально сплошной среды и твердой среды с рассеянными флюидными включениями.

Получено, что в первом случае образование стабильных зародышей расплава возможно только при значительных перегревах относительно температур солидуса, особенно при большом объемном эффекте изобарического плавления. Необходимый перегрев составляет для эклогитов 350°-450°С, для мономинерального форстерита около 100°С, тогда как для габбро 40-60°С (при давлениях, отвечающих верхней мантии). Во второй модели плавление начинается уже при малых перегревах.

Первому случаю соответствует недифференцированная мантия, которая не прошла ни одного этапа частичного плавления (в "протоокеанических" сегментах литосферы) или, напротив, "реститовая" мантия, из которой восходящими движениями расплава удалены практически все легко летучие компоненты. Вторая модель характеризует мантию на промежуточных этапах дифференциации, когда регрессивная кристаллизация остаточных расплавов неизбежно приводит к появлению флюидных включений.

Показано, что специфический механизм магмообразования в протяженной твердой среде в ходе прогрессивной термической эволюции Земли обуславливает дискретное поэтапное выплавление из отдельных мантийных горизонтов с последовательным продвижением на все более глубокие этажи, с чем связаны поэтапная дифференциация мантии сверху вниз и циклические изменения величин восходящих тепловых потоков. Тот же механизм приводит к возникновению больших латеральных неоднородностей даже в исходно однородной мантии. Последовательность магматических проявлений существенно различна для областей с неодинаковой степенью предварительной дифференциации мантии. В частности, в первой модели сначала *возникают локальные центры, в которых перегретая мантия плавится* "целиком" (приводя к образованию коматиитовых магм). Охлаждение за счет потерь на теплоту плавления обуславливает в процессе роста очагов эволюцию в сторону базальтовых ("эвтектоидных") расплавов. Во второй модели выплавление начинается сразу с базальтовых магм.

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RHEOLOGY OF THE LITHOSPHERE FROM THE GRAVITY FIELD

Estimates of the transfer function (admittance) between the gravity field and topography were obtained recently over many tectonic units in the oceans and continents. Admittance Z(k) is estimated objectively from surface observations, gravity or geoid anomalies and topography, without any a priori hypothesis. Z(k) in wavelengths 10 to 500 km bears information on rheological properties of the lithosphere. The longer-wavelength Z(k) is attributed to thermal anomalies within the mantle. We review implications of the transfer function studies over oceans and continents. Two important aspects of the method are (1) best statistical procedure to estimate Z(k), (2) reasonable interpretation of estimates. Regular gravity surveys of North America, Eurasia and Australia provided a basis for continental studies. Over the oceans, a combination of satellite altimetry and sea gravimetry made it possible to separate components of Z(k) of mechanical and thermal origin. We found that a removal of the longest wavelength background from the gravity and topography prior to computations of the admittance may be of critical importance. Understanding of the admittance strongly depends on the wavelengths considered. The short-wavelength band over the oceans is well-explained with the elastic plate model as demonstrated by A.B. Watts. The model assumes that the lithosphere deforms under the load of the overlying topography. The mechanism cannot reasonably be applied to folded continental areas, and an alternative is discussed that the topography and gravity are both produced by deep-seated sources. As concerns the long-wavelength Z(k), we review all available estimates in terms of thermal mantle convection and of variable lithspheric thickness.

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РЕОЛОГИЯ ЛИТОСФЕРЫ ПО ДАННЫМ О ГРАВИТАЦИОННОМ ПОЛЕ

Оценки передаточной функции (адмиттанс) между гравитационным полем и топографией были получены в последнее время для многих тектонических зон океанов и континентов. Адмиттанс $Z(k)$ объективно оценивается по данным, наблюдаемым на земной поверхности (аномалии силы тяжести или геоида), без какой-либо априорной гипотезы. $Z(k)$ в диапазоне длин волн IO - CO км содержит информацию о реологических свойствах литосферы. Более длинноволновый $Z(k)$ связывается с термическими аномалиями в мантии. Мы рассматриваем результаты исследования передаточной функции для океанов и континентов. Двумя важными аспектами данного метода являются: I) наилучшая статистическая процедура для оценивания $Z(k)$; 2) обоснованная интерпретация оценок. Регулярные гравиметрические съемки Северной Америки, Евразии и Австралии составили основу для континентальных исследований. Что касается океанов, то сочетание спутниковой альтиметрии и морской гравиметрии дало возможность для разделения компонент $Z(k)$ механического и термического происхождения. Мы установили, что снятие наиболее длинноволнового фона из данных гравитационного поля и топографии, проводимое перед вычислением адмиттанса, может иметь критическое значение. Интерпретация адмиттанса сильно зависит от рассматриваемых длин волн. Коротковолновый диапазон для океанов хорошо объясняется моделью упругой плиты, как показано А.Б.Уоттсом. В этой модели предполагается, что литосфера деформируется под нагрузкой топографии сверху. Такой механизм не может обоснованно применяться к складчатым континентальным областям, и в качестве альтернативы рассматривается гипотеза, что и топография и гравитационное поле вызваны глубинными источниками. В связи с длинноволновым $Z(k)$ мы рассматриваем все имеющиеся оценки с точки зрения термической конвекции в мантии и переменной толщины литосферы.

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"THE EUROPEAN GEOTRAVERSE PROJECT"

The "European Geotraverse" (EGT) has been planned as a major geoscience project which will run for 6 years (1983-1988) involving collaborative efforts of geoscientists from different European countries. The broad aim of the EGT Project is to secure an understanding of how the continental lithosphere formed and reacted to changing physical and geometric conditions through successive tectonic episodes. Europe provides one of the best scenarios for such a project because, from north to south, it is made up of a number of tectonic provinces ranging in age from the Precambrian to the currently active region of the Mediterranean.

The European Geotraverse covers a swathe of ground some 100 km wide and 4000 km long from the North Cape to North Africa. For practical purposes it is divided into three segments; the northern one covering the Precambrian provinces of Fennoscandia, the central one crossing the Hercynian realm of Central and Western Europe and the southern one traversing the Alpine-Mediterranean region. The Geotraverse is planned to take account of variations in three dimensions and is located to take advantage of existing information, especially from the larger scale geophysical measurements, such as the recent "Fennoscandian Long-Range Seismic Project" (FENNOLORA), which has provided a regional pattern of the crust and upper mantle structure underlying the northern EGT segment.

The main investigations within the EGT have been grouped into a "Joint Programme" which comprises several geophysical and geological cooperative studies of the European lithosphere. Although certain techniques are proposed for the full length of the geotraverse to provide continuity and depth of information, most of them will be applied selectively. The EGT Project has been approved by the General Assembly of the European Science Foundation (ESF) in November 1982. The funding of the "Joint Programme" which amounts to 14.3 million Swiss Francs will be secured through national contributions. The cost of the coordination is financed through an "Additional Activity" of the ESF.

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DEEP SEISMIC SOUNDING IN THE EASTERN PACIFIC

Deep seismic sounding studies in the eastern Pacific during the past several years have concentrated on the problem of the genesis and early evolution of the oceanic crust. The large scale, multi-institutional Rivera Ocean Seismic Experiment (ROSE) studied the regional seismic structure of the Pacific and Cocos plates out to ages of several million years while smaller experiments such as the MAGMA expedition concentrated on small areas of fast-spreading rise axis at lithosphere ages of 500,000 years and less. A review of historical data in the Pacific reveals no strong evidence for systematic crustal evolution beyond ages of 5 million years. Furthermore, the modern experiments cited above require that the major stages of crustal evolution must occur within a few kilometers of the rise axis. Strong evidence exists, from both refraction and reflection studies, for magma bodies near the rise axis which are responsible for the formation of the plutonic part of the ocean crust. Experiments on slow-spreading rise crests in the Pacific Northwest, on the other hand, do not support the hypothesis of a steady state crustal magma chamber and counterexamples, such as the propagation of crustal shear waves across a rise axis, exist in the case of fast-spreading ridges. Seismic work, in conjunction with Deep Sea Drilling Project hole 504B and ophiolite studies, lend support for an ophiolite model for the generation and evolution of the oceanic crust at intermediate to fast spreading ridges. In this model the high gradients in elastic parameters in the upper crust are associated with extrusive volcanics overlying a gabbroic central crust. The gradients in velocity are controlled largely by decreasing porosity, increasing pressure and an increasing grade of metamorphism associated with the high temperature crustal magma chamber and shallow hydrothermal circulation. The central crust is formed by the differentation of a magma chamber which is periodically resupplied by injection of melt from a depleted mantle. The transitional Moho is formed by cumulate layering of refractory pyroxene and olivine gabbros. A finely layered Moho is consistent with both wide-angle refraction data and narrow-angle multichannel reflection work. The observations of vertical reflections from the Moho do not require a sharp contrast between the crust and upper mantle. Finally, several well-studied counterexamples now exist in the eastern Pacific which are inconsistent with the popular model of upper crustal (layer 2A-2B-2C) evolution associated with hydrothermal circulation and the filling of upper crustal cracks and pores.

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OBS DEEP STRUCTURE STUDIES IN THE WESTERN PACIFIC

Six long-range controlled-source seismology experiments have been concentrated on the Western Pacific Basin from 1971, where one of the oldest oceanic lithospheres exists. The experiments made use of sensitive ocean bottom seismographs. The directions of the profiles, 1000 - 1800 km long, were chosen to provide a wide azimuthal coverage.

The results show that the oceanic lithosphere has a large-scale anisotropy where the velocity changes 4 - 7 %. The anisotropy extends from the depth of 40 to 140 km, or more, beneath the sea bottom: the anisotropy extends over the entire thickness of the lithosphere. In the direction of the maximum velocity, the lithosphere is basically two-layered: 8.0 - 8.2 km/s layer and 8.6 km/s layer. The interface is 50 - 60 km deep beneath the sea bottom.

The azimuth of the velocity maximum is 150 - 160°, clockwise from north. It coincides with the "fossil" direction of spreading of the Pacific Plate, whereas it differs from the present direction by about 30°. The change of the spreading direction occurred 40 million years ago. The "frozen" anisotropy would set an important constraint on mechanical properties of the lower oceanic lithosphere. The efforts to increase the resolution of the dependence of the anisotropy on depths are being made.

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MANTLE XENOLITHS AND THE PROBLEM OF THE COMPOSITION OF THE LOWER PART OF CONTINENTAL LITHOSPHERE

Most of the deep-seated xenoliths in kimberlites and alkaline basalts represent the source of information on the composition of the upper part of both continental and oceanic lithosphere from the Moho surface to 100 km deep. Below the quartz-coesite (Cs) and especially graphite-diamond phase boundaries, the lithosphere of the stable parts of the continents within the depth of 100-200 km (to 250 km) is composed of the ultramafic (peridotitic) and mafic (eclogitic) rocks being different for various regions. Among the pyrop-bearing ultramafic compositions both harzburgites (Ol+Opx+Gar+Chr±Fe±Sf) and dunites (Ol+Gar+Chr) highly predominate over lherzolites (Ol+Opx+ +Cpx+Gar±Ilm±Chr±Rut±Sf) and wehrlites (Ol+Cpx+Gar+Chr). Lherzolite rocks are represented here presumably by the sheared varieties to occur at a shallower depth and granular varieties at a greater depth. Among the eclogites there have been commonly fixed the paragenesis (Gar+Cpx+Rut±Sf±Fe) and various rocks from the Al-oversaturated to calc silicate ones containing additional Ky, Cor, Ilm, Cs. The aboundance of coesite-bearing eclogites is confirmed by the finds of diamondiferous coesite eclogites in Yakutian kimberlites and also by the finds of nearly 30 diamonds with coesite inclusions in various regions from the Urals to Australia. The silica-bearing diamondiferous eclogite parageneses are represented by three types: 1) Gar+Cpx+ +Cs±Rut; 2) Gar+Cpx+Ky+Cs±Rut; 3) Gross+Cpx+Cs. Some of these eclogites as found from both the extra-light and superheavy carbon isotopic composition of the diamonds might have been formed owing to the subduction of the crustal volcanic-sedimentary rocks containing organic carbon to the mantle. The coexistence of coesite eclogites and ultramafic rocks all over the world in the bottom part of the continental lithosphere in the diamond stability field supplemented by geothermobaromatric data indicates that equilibration temperatures of the primary assemblages of Precambrian lithosphere are presumably between 1000 and 1200°C. A principal possibility of schematic mapping of various lithosphere levels corresponding to the deep-seated facies has been displayed using the deep-seated inclusions in kimberlite rocks.

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МАНТИЙНЫЕ КСЕНОЛИТЫ И ПРОБЛЕМА СОСТАВА НИЖНЕЙ ЧАСТИ КОНТИНЕНТАЛЬНОЙ ЛИТОСФЕРЫ

Большая часть глубинных ксенолитов в кимберлитах и щелочных базальтоидах содержит информацию о составе верхней части литосферы континентов и океанов - от поверхности Мохо до глубин порядка 100 км. Ниже фазовой границы кварц-коэсит (Cs) и особенно графит-алмаз на основании изучения коэситосодержащих и алмазосодержащих парагенезисов установлено, что литосфера стабильных участков континентов в интервале глубин 100-200 (до 250 км) сложена породами ультраосновного (перидотитового) и основного (эклогитового) составов, в переменных соотношениях для разных регионов. Среди пиропсодержащих ультраосновных составов резко преобладают гарцбургиты (Ol +Opx+ Gar+Chr +Fe + Sf) и дуниты (Ol +Gar +Chr) над лерцолитами (Ol +Opx+Cpx+Gar +Ilm +Chr +Rut + Sf) и верлитами (Ol +Cpx+ Gar +Chr). Лерцолиты представлены здесь преимущественно катаклазированными разностями на меньших глубинах и зернистыми - на больших. Среди эклогитов, наряду с наиболее распространенным парагенезисом (Gar +Cpx+ Rut + Sf +Fe) установлены разнообразные породы от пересыщенных глиноземом до известково-силикатных, содержащие дополнительно соответственно Ky, Cor, Ilm, Cs. Повсеместная роль коэситосодержащих эклогитов подтверждена как находками алмазоносных коэситовых эклогитов в кимберлитах Якутии, так и установлением в различных регионах от Урала до Австралии около 30 алмазов, содержащих включения коэсита. Кремнеземсодержащие алмазоносные эклогитовые парагенезисы представлены тремя типами: I) Gar +Cpx+Cs +Rut ; 2) Gar +Cpx+Ky +Cs + Rut; 3) Gross +Cpx+Cs. Часть этих эклогитов, как свидетельствует облегченный и утяжеленный изотопный состав углерода алмазов, могла образоваться за счет погружения в мантию блоков вулканогенно-осадочных пород континентальной коры, содержащих органогенный углерод. Повсеместное сосуществование коэситовых эклогитов и ультраосновных пород в нижней части континентальной литосферы в области устойчивости алмаза наряду с данными, полученными с помощью геотермобарометрии, свидетельствует о температурах равновесия первичных парагенезисов докембрийской литосферы преимущественно в интервале I000-I200°C. Продемонстрирована принципиальная возможность схематического картирования разных уровней литосферы в соответствии с фациями глубинности, по глубинным включениям в кимберлитах.

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ROLE OF BASALT-ECLOGITE TRANSITION IN FORMATION OF STRUCTURE AND EVOLUTION OF THE CONTINENTAL CRUST

Basalt-garnet granulite-eclogite phase transition could determine the structure and type of evolution of the mafic lower continental crust. Phase composition, density and elastic properties of the rocks strongly depend upon the rate of the transition.
The rate of the basalt-eclogite ph.tr. is low if there is no fluid in the rocks. It's magnitude is limited by the rate of volumetric diffusion of ions within the mineral grains and it rapidly decreases with decreasing temperature. 1. Mafic rocks are metastable in the cool crust of platforms. Their phase composition reflects the P,T conditions of the previous epoch of strong heating of the crust. The calculated density-depth and elastic velocity-depth relations in the lower crust fit well the deep seismic sounding data on platforms if the time needed for the complete transformation of the dry natural basalt is $\tau \sim 10^7$-10^9 years at T=800°C. This value does not contradict other independent estimates of the τ value. 2. The layer of garnet granulites and eclogite which is 0,1-0,3 g/cm^3 denser than the underlying ultramafic mantle rocks forms during cooling of the thick crust (H$\geqslant$45-50 km) of high mountain regions. The blocks of this layer should tear away from the crust and sink into the mantle (Yanshin et al., 1977). The calculated value of the remaining crustal thickness (H$\approx$35-45 km) is about the average thickness of the continental crust.

Fluids with low water content penetrating the lower continental crust may lead to strong acceleration of the ph. tr.; the value of τ being about 10^6 years at T = 400-600°C. The ph. tr. in large volumes of the lower crustal rocks results in increase of their density by 0,2-0,3 g/cm^3 and intense isostatic subsidence of the lithosphere.

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РОЛЬ ПЕРЕХОДА БАЗАЛЬТ-ЭКЛОГИТ В ФОРМИРОВАНИИ СТРУКТУРЫ И ЭВОЛЮЦИИ КОНТИНЕНТАЛЬНОЙ КОРЫ

Фазовый переход базальт-гранатовый гранулит-эклогит может определять структуру и характер эволюции нижней континентальной коры основного состава. Фазовый состав, плотность и упругие свойства при этом сильно зависят от скорости перехода.

В отсутствии в породах флюида скорость перехода базальт-эклогит мала. Она определяется скоростью объемной диффузии ионов в зернах минералов и быстро падает с температурой. I. Основные породы холодной коры платформ метастабильны. Их фазовый состав отражает равновесное состояние, достигавшееся в предыдущую эпоху сильного прогрева коры. Расчетные зависимости от глубины плотности и скорости продольных волн в нижней коре хорошо согласуются с данными ГСЗ для платформ, если время полного превращения сухих базальтов коры составляет $\tau \sim 10^7 - 10^9$ лет при T = 800°C. Эта величина не противоречит оценкам времени τ другими способами. 2. При охлаждении мощной коры крупного горного сооружения (H $\geqslant$ 45-50 км) в ее нижней части образуется слой гранатовых гранулитов и эклогита с плотностью на 0,I-0,3 г/см^3 большей, чем плотность подстилающей ультраосновной мантии.

Блоки пород такого слоя могут оторваться от коры и погрузиться в мантию (Яншин и др., 1977). Расчетные значения мощности оставшейся части коры, H$\approx$35-45 км, близки к средней мощности коры континентов. Проникновение в нижнюю кору из мантии флюидов с низким содержанием воды может вызвать резкое увеличение скорости перехода базальт-эклогит, так что он происходит за время $\sim 10^6$ лет уже при T = 400-600°C.

Фазовый переход в больших объемах пород нижней континентальной коры приводит к увеличению их плотности на 0,2-0,3 г/см^3 и интенсивному изостатическому опусканию литосферы.

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THE ELAS-PROJECT

The ELAS-project was recommended by the International Association of Geomagnetism and Aeronomy in 1977. Geophysicists of 19 countries participate in this project which is one of the key projects identified by the Interunion Commission on the Lithosphere. At the IUGG General Assembly (1983) the International Association of Seismology and Physics of the Earth's Interior joined the ELAS-project. The main goal of the ELAS-project is construction of deep geoelectrical models for large-scale tectonic units.

Some approaches are worked out for this purpose:

1. A separation of deep information and surficial geological noise.
2. Interpretation of field data for models with gradual resistivity profiles.
3. An estimation of the minimal horizontal size of the partial melting zone which allows its identification.

Preliminary results of the ELAS-project are as follows:

There is a low-resistivity zone beneath the North Pacific which can be interpreted as a partial melting zone. Its conductance decreases from 10^4 Siemens near the East Pacific Rise to 10^3 Siemens near the Marianna Islands.

The latter value is near the threshold of magneto-telluric soundings. Similar values are obtained beneath Precambrian plates. It means that partial melting is practically absent. In contrast, the Asia/Pacific transition area has a low-resistivity zone with conductance about $5 \cdot 10^3$ Siemens (Sakhalin Island). A similar zone was investigated at some intracontinental active areas, for instance, at the Pannonian Basin (A. Adam).

Besides asthenospheric data, important information was obtained concerning the Earth crust. The anomalously low resistivity was found in the middle crust of active areas. In Western United States its conductance reaches some 10^3 Siemens. The most likely sources of low resistivity are the supercritical water solutions in the crust.

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ПРОЕКТ "ЭЛАС"

Проект „ЭЛАС" был принят в 1977 г. Международной ассоциацией геомагнетизма и аэрономии. В его выполнении участвуют I9 стран. Цель проекта, являющегося одним из ключевых по определению Межсоюзной комиссии по литосфере, - изучение электропроводности астеносферы крупных геотектонических структур, которая тесно связана со степенью частичного плавления.

Для достижения поставленной цели создана система методических приемов. I. Выделение информации о глубинной электропроводности на фоне при поверхностных геологических помех. 2. Способы интерпретации электромагнитных зондирований градиентных сред с идентификацией зоны частичного плавления по значениям сопротивления ниже 10^2 Ом·м. 3. Оценка размеров астеносферных зон, которые могут быть надежно картированы. В ходе выполнения проекта установлено: I. В северной части Тихого океана имеется астеносферная зона низкого сопротивления, интерпретируемая как следствие частичного плавления. Ее полная проводимость уменьшается от 10^4См вблизи оси Восточно-Тихоокеанского поднятия до 10^3См у Марианского желоба (возраст свыше 160 млн.лет). 2. Под докембрийскими плитами континентов полная проводимость астеносферы не превышает порога чувствительности зондирований (около 10^3См). Частичное плавление отсутствует, либо слабо развито. 3. Континентальные рифты можно разделить на 2 группы: сопровождающиеся аномалиями глубинной электропроводности (Байкальский рифт, провинция Бассейнов и Хребтов) и не имеющие таковых. 4. В области перехода между Тихим океаном и азиатским континентом выделяется астеносферная зона низкого сопротивления с проводимостью до $5 \cdot 10^3$См, детально изученная на Сахалине. 5. Подобная же зона обнаружена и в некоторых внутриконтинентальных активных регионах (Паннонский бассейн).

Хотя главная задача проекта - изучение астеносферы, получена информация о геоэлектрических особенностях литосферы континентов и переходных областей. В районах с развитой астеносферой существует коровая зона низкого сопротивления, связанного, по-видимому, с повышенной проницаемостью и обогащением надкритическими растворами. Ее полная проводимость может достигать нескольких тысяч См (запад Северной Америки).

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DENSITY DETERMINATION OF EARTH CRUST AND UPPER MANTLE ROCKS AND THE PETROLOGICAL INTERPRETATION

The density determination technique is developed on the base of idea implying predominent block nature gravity anomaly sources. The density of deep-seated substances is investigated with the aid of reper blocks, law of density changes with depth of which is supposed to be known. While investigating the crustal rocks densities to the depths

10-12 km the following blocks were taken as the repers: blocks of granitic massifs with the density supposed to be constant with the depth or not exceeding 2.7 g/cm^3, blocks of metamorphized rocks within Verkhoyansk complex with the densities of 2.68-2.72 g/cm^3 as well as blocks of sedimentary rocks within the Mesozoic-Cenozoic depressions with known law of density changes with depth from drilling data, ets. The law of density changes with depth is supposed to be approximately linear in all the density determination of upper mantle. The preference of petrological interpretation of geophysical data on the density basis is substantiated on the availability of close relationship between the density and chemical composition of silica rocks, which make it possible to calculate the density from the chemical composition, considering the empirically defined ratio between oxygene anions number in volume unit and the density of the rock. The upper mantle rocks density determination in northern part of Okhotsk sea and block within south-Eastern part of Yana-Koyma fold zone, displaced vertically across Okhotsk-Chukchi volcanogenic belt fault, demonstrated that at the depth of 110-120 km the layer roof with densities of 3.5-3.6 g/cm^3 occurs, which is considered to be the layer of mantle eclogites and astenostratum.

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ПЛОТНОСТНОЕ ЗОНДИРОВАНИЕ ЗЕМНОЙ КОРЫ И ВЕРХНЕЙ МАНТИИ И РЕЗУЛЬТАТЫ ЕГО ПЕТРОЛОГИЧЕСКОЙ ИНТЕРПРЕТАЦИИ

На основе представлений о преимущественно блоковой природе источников, с которыми связаны аномалии силы тяжести, разработаны методы плотностного зондирования земной коры и верхней мантии. Плотность глубинных образований исследуется с помощью реперных блоков, относительно которых полагается известным закон изменения плотности с глубиной. При изучении плотности пород земной коры до глубин 10-12км в качестве реперов использовались блоки гранитных массивов, плотность которых принималась неизменной с глубиной или не превосходящей 2,7 г/см^3, блоки метаморфизованных пород верхоянского комплекса с плотностью 2,68-2,72 г/см^3, блоки осадочных пород мезо-кайнозойских впадин с известным по данным бурения законом изменения плотности с глубиной и т.д. При плотностном зондировании верхней мантии закон изменения плотности с глубиной принимался в первом приближении линейным.

Предпочтительность петрологической интепретации геофизических данных на плотностной основе обосновывается существованием тесной связи между плотностью и химическим составом силикатных горных пород, позволяющей рассчитать плотность по химическому составу с учетом эмпирически определенной зависимости числа анионов кислорода в единице объема от ее плотности.

Плотностное зондирование верхней мантии в северной акватории Охотского моря и блока юго-восточной части Яно-Колымской складчатой зоны, смещенных по разлому Охотско-Чукотского вулканогенного пояса, показало, что на глубине около 110-120 км располагается кровля слоя с плотностью пород 3,5 - 3,6 г/см^3, который рассматривается как слой мантийных эклогитов и астенострата.

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NATURE OF TRANSITION BETWEEN THE UPPER AND THE LOWER MANTLE FROM THE OBSERVATIONS OF P TO S CONVERTED WAVES

Testing of hypotheses of mantle composition and dynamics often requires from seismic methods more resolution than they are able to provide. To meet demands for higher resolution, the method of detection of P to S converted phases from distant earthquakes was developed and applied to sets of long-period records from a number of seismograph stations. The most significant results thus obtained are those related to the lower boundary of the asthenosphere (the bottom of the upper mantle). 1. While previously known estimates of depth of this boundary were scattered between approximately 620 and 720 km, the depths found from observations of converted phases are close to 640 km. 2. The normal S-velocity stratification around 640 km depth can be represented by a high-gradient layer 50 km thick terminated at the bottom by a relatively sharp discontinuity. There is an indication of weak elastic anisotropy in the high-gradient layer. 3. In regions of recent thermal agitation of the upper mantle, the thickness of the high-gradient layer is about 100 km or more while the sharp discontinuity is absent. The following observations are important as well: 1. According to high-pressure experiments, the depths of the phase transitions that are the most likely candidates for the 640-km boundary are around 720 km at 1000°C temperature. 2. In subduction zones, this boundary, marked by the earthquakes with the maximum hypocenter depths, is 60 km deeper than that in the normal mantle.
The observed properties of the 640-km transition can be reconciled with the hypothesis of phase transition provided: (1) there is a well pronounsed thermal boundary layer at the base of the upper mantle and (2) the slope of the corresponding phase boundary is negative (-30 bar/°C). This conclusion has a number of implications for the mantle composition and dynamics.

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ПРИРОДА ПЕРЕХОДА ОТ ВЕРХНЕЙ МАНТИИ К НИЖНЕЙ ПО ДАННЫМ НАБЛЮДЕНИЙ ОБМЕННЫХ ВОЛН

Проверка гипотез, касающихся состава и динамики мантии,часто требует от сейсмических методов большей разрешающей способности, чем они в состоянии дать. Чтобы удовлетворить этим требованиям, разработан и применен к наблюдениям ряда сейсмических станций метод выделения и интерпретации обменных волн PS. Наиболее важные из полученных результатов относятся к нижней границе астеносферы. I. В то время как прежние оценки глубины этой границы были рассеяны между 620 и 720 км глубины, найденные по наблюдениям обменных волн очень близки к 640 км. 2. Нормальный разрез для S -волн на глубинах около 640 км может быть представлен слоем с большим градиентом скорости мощностью 50 км, подстилаемым относительно резкой границей. Имеется указание на слабую скоростную анизотропию градиентного слоя. 3. В районах недавнего теплового возбуждения верхней мантии мощность градиентного слоя составляет около I00 км или более, а резкая граница отсутствует. Кроме того,важны следующие данные. I. В зонах субдукции обсуждаемая граница, маркируемая землетрясениями с максимальной глубиной очага, находится на 60 км глубже, чем в нормальной мантии. 2. По данным экспериментов при высоких давлениях фазовые переходы, являющиеся кандидатами для объяснения обсуждаемой границы, происходят при температуре I000^{o}C на глубинах около 720 км.

Наблюдаемые свойства 640-километровой границы хорошо согласуются с гипотезой фазового перехода при условии, что: I) в подошве астеносферы находится хорошо выраженный тепловой пограничный слой и 2) наклон соответствующей кривой фазового равновесия отрицателен (-30^{o} бар/град С). Эта интерпретация приводит к ряду важных следствий, касающихся динамики и состава мантии.

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THERMAL STATE OF OCEANIC LITHOSPHERE

Two simple models have been useful in describing the cooling of oceanic lithosphere with age: the plate (slab) and uniform half-space models. These models are indistinguishable up to about 80 m.y. age, when sea floor depth for the plate model flattens compared to the depth versus square root of time relationship predicted for the half-space cooling model. The observed flattening of the plate model

may be explained by small-scale convection beneath the plate, or by effects of "hot-spot" activity in the past. The models are not as sensitive to heat flow, and heat flow surveys accurately reflect lithospheric cooling only if the sea floor is completely covered by a reasonably thick (-100 m) sedimentary layer.
Uncertainties in the thermal state of ocean lithosphere will be considered. Bettor seismic data should help to resolve the remaining uncertainties, especially at great depths.

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DSS IN THE ATLANTIC

The structure of the Earth crust in the Atlantic ocean was determined by DSS methods at approximately 350 points. In most cases the length of the time distance curves by this determination extended not more than up to 70-100 km. The DSS results were limited by Moho depth calculations and velocity estimations for the uppermost part of mantle. (All known review and generalizations were undertaken on this background).
The long range DSS profiles of subcrust lithosphere are rare in the Atlantic. They show a variety of subcrustal deep structure. Some unexpected results were observed. For example, great volumes of high velocity materials were found under the normal oceanic crust in Angola basin.
DSS data on long range profiles in the Atlantic are discussed. Comparisons are undertaken with data from another methods and with the long range DSS data available for Pacific.
Some suggestions about nature of the subcrustal layering of oceanic lithosphere are presented.

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ГСЗ В АТЛАНТИЧЕСКОМ ОКЕАНЕ

В Атлантическом океане определение строения земной коры методом ГСЗ проведено примерно в 350 точках. В большинстве случаев длины годографов были менее 70-I00км,что позволило изучить скорости и глубины второго и третьего слоев , а также определить положение поверхности М и оценить скорости в кровле верхней мантии. На этой основе сделаны известные обобщения.

Длинные годографы,дающие сведения о подкоровой части литосферы, в Атлантическом океане немногочисленны. Они показывают,что в отдельных регионах земная кора,близкая к нормальной,сменяется по глубине толщей с повышенными скоростями сейсмических волн.Иногда эта толща занимает огромные объемы подкоровой части литосферы(Ангольская котловина).

В докладе рассматриваются материалы ГСЗ с длинными годографами в Атлантике.Проводится сопоставление с данными других методов,а также с результатами,полученными в Тихом океане.

С И М П О З И У М / S Y M P O S I U M L.08

СВЕРХГЛУБОКОЕ БУРЕНИЕ НА КОНТИНЕНТАХ

DEEP CONTINENTAL DRILLING

Conveners: E.A.Kozlovsky, H.Vidal

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THE FRENCH PROGRAM OF CONTINENTAL DRILLING

Presently two program are beginning in France, dealing with the continental crust, in the light of the International Lithosphere program of the International geodynamics commission.

One is a program of seismic reflexion profiling (ECORS : Etude continentale et océanique par Réflexion et Réfraction sismique), the other is a program of continental drilling (Geologie Profonde de la France). The first is an indirect exploration of the complete continental crust, the second a direct recovery of the first five kilometers. The two are complementary ; they are planned to be developped simultaneously.

For the program Geologie Profonde de la France (Deep Geology of France) the studies before drilling are beginning in several directions in order to plan a successive program of drilling for a decade.

A first direction is linked with the ECORS program of seismic profiling. The objectives are tectonic : how large are the allochtonous bodies and how deep could they be followed. Three targets are in view : the frontal Variscan contact in Northern France and below Paris basin (the Faille du Midi in the Coal basin of Northern France and Belgium) ; the frontal alpine belt in Savoie and Dauphiné (in regions so-called autochtonous) ; the Northern Pyrenées basement massifs (classically regarded as more or less autochtonous).

A second direction is the geology of the basins. Three targets are proposed : the margin of the South-East mesozoic basin along the Cevennes for the study of subsidence, diagenesis, sedimentology, stratigraphy ; the Northern Aquitaine basin in order to get informations about the hidden permo-triassic faulted basins and their paleozoic basement ; the southern Paris basin where the top of the regional magnetic anomalie seems to be at a shallow depht.

A third direction, specific to the drilling program, is the basement of France. Three targets are prepared : Central Brittany in order to find below the late Proterozoic (Brioverien) the oldest basement of France ; in the southwestern Massif Central (Limousin) for testing the metamorphic-tectonic relationships in a classical region of petrological studies ; in the Northern Massif Central (Bourbonnais) where granitic plutons show a metallogenic environment.

Finally two projects concern the volcanism and the associated phenomenons : the Volcanism itself in the Mont Dore (Massif Central) and the Hydrothermalism of the Cezallier plateau (Massif Central).

At the end of 1983, after the preliminary studies, a first classification of the targets will be done in order to put the effort on two or three site surveys in 1984 ; the beginning of the drilling is planned for the end of 1984 or the beginning of 1985.

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TECHNICAL AND TECHNOLOGICAL ASPECTS OF SUPERDEEP DRILLING

1. In the USSR the drilling of deeper than 4500 m wells has begun in the 40-s when the task of searching for deep oil and natural gas deposits was set for the first time.

2. In the 60-s preparatory work has begun on creating technical means for dilling superdeep (10 to 12 thous.m) wells with the purpose of solving certain scientific and practical geological problems

3. The present state and development prospects of using the conventional rotary method for drilling more than 10,000 - 11,000 m deep wells are analyzed in the report. The advantages of using for this purpose downhole drilling motors in combination with light-alloy drill pipes and a new pilot-hole drilling method are substantiated.

4. There are given research and development effort results taken as a basis for development of a Set of technical and technological means for drilling the first in the world СГ-3 well of the total depth of 15 thousand meters in crystalline formations of Kola Peninsula. Characteristics of drilling equipment and tools being used there are given in a concise form as well as technical and economic results of drilling the unique well to the depth of 11,662 m.

5. Main data are given regarding the change of the drilling process results with depth; conclusions are made with respect of trends of further improvement of technical means necessary for carrying out the predetermined superdeep drilling program with scientific purposes.

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ТЕХНИКО-ТЕХНОЛОГИЧЕСКИЕ АСПЕКТЫ СВЕРХГЛУБОКОГО БУРЕНИЯ

I. В СССР бурение скважин глубиной более 4500 м было начато в сороковых годах, когда впервые была поставлена задача поиска залежей нефти и газа на больших глубинах.
2. В шестидесятых годах были начаты подготовительные работы по созданию технических средств бурения и исследований сверхглубоких скважин IO-I2 км для решения научных и практических задач в геологии.
3. В докладе анализируются современное состояние и перспективы применения общепринятой технологии роторного бурения скважин на глубину более IO-II км. Обоснованы преимущества технологии бурения забойными двигателями в сочетании с бурильными трубами из легких сплавов и новым способом проходки скважин опережающим стволом.
4. Приведены результаты научно-исследовательских и опытно-конструкторских работ, положенных в основу создания комплекса технико-технологических средств для бурения первой в мире скважины в кристаллических породах проектной глубиной I5 км - СГ-3 на Кольском полуострове. Даны краткая характеристика используемого бурового оборудования, инструментов и технико-экономические результаты проходки уникальной скважины до глубины II662 м.
5. Приведены основные данные об изменении показателей бурового процесса с ростом глубины и сделаны выводы о направлениях дальнейшего совершенствования технических средств для выполнения намеченной программы сверхглубокого бурения с научными целями.

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THE CONTINENTAL DEEP DRILLING PROGRAM (KTB) OF THE FEDERAL REPUBLIC OF GERMANY

In 1979, German geoscientists conceived the plan of a scientific deep drilling in continental crust, as a contribution to the International Lithosphere Program (ILP). The first drill-hole will hopefully be started in 1987, and is intended to reach a depth of about 10 km. The preliminary investigations will allow, by 1985, to fix the scientific and technological targets and an appropriate drilling site.

Preliminary surveys are being carried out at four potential locations. Three sites (western margin of the Bohemian Massif, Black Forest, Hohenzollern Graben of the Suevian Alb) are situated in the Variscan crystalline basement. These are intended to explore geophysical discontinuities (well reflected in seismic, magneto-telluric and conductivity investigations), at temperatures ranging up to 300°C.

These sites are expected to provide new insight into the nature of geophysical discontinuities, into the kinetics of mineral deformation and mineral reactions under in-situ conditions, and to reveal the composition and role of fluids in these processes. Further objectives are the structure of the crust (thrust- and nappe-tectonics in the mid-European Variscides), mechanisms of intra-plate seismicity, the increase and transformation of stress at stress-barriers, and contributions to the hot-dry-rock technology.

A fourth location is situated at the southern margin of the Hohes Venn (S of the Brabant Massif). It is aimed at the character of a pronounced seismic reflector, which plays a key-role in the understanding of Caledonian and Variscan crustal structures in the area.

The KTB is flanked by the German Continental Deep Reflexion Program (Dekorp), by geophysical investigations on the German segment of the "European Geotraverse", and by a disciplinary priority program aiming at the composition, structure, and geodynamic behaviour of the lower crust.

The preliminary studies are being managed by the Alfred-Wegener Foundation (AWS), the Federal Ministry of Research and Technology (BMFT), and the German Research Society (DFG) with its commission for cooperative geoscientific research ("Geokommission").

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A PROGRAM TO STUDY PRECAMBRIAN BASEMENT ROCKS IN THE MIDCONTINENT REGION, U.S.A.

Crystalline crust in the midcontinent region of the U.S.A. is covered by about a kilometer of Phanerozoic rocks. Data from this region are essential to understanding the evolution and properties of the continent and must be obtained from geophysical studies or samples from deep drill holes. We have studied the geochronology, petrography, and chemistry of the central midcontinent for the past 12 years and are now expanding our program. We obtain cores and cuttings by cooperating with petroleum and mineral exploration companies. We also have past experience in "piggy-backing" on holes drilled near basement and are now funded to contract for limited deepening and coring of selected holes. A major feature of our work is that we rely upon U-Pb data from zircons for geochronology; we obtain accurate ages from small samples of zircon which can be separated from small amounts of basement material. Where possible we also obtain major and trace element data. Additionally, we are building a consortium of scientists who can carry out other studies. We are using these data to delineate age and petrographic provinces in the subsurface, using aeromagnetic and gravity anomaly maps to help locate and extend boundaries.

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THE STRUCTURE OF THE CRUST IN THE EASTERN PART OF THE EUROPEAN HERCYNIDES

The determinant feature of the structure of the Earth crust in the eastern part of the European Hercynides (and in Central Europe altogether) is the W-E direction of its elements. This trend is exhibited above all in the relief of the M-discontinuity and in the structure

or the deeper crust layers, and is reflected prominently in the near-surface structure of the units of different age. It controls mainly the course of the Cadomian, Hercynian and Alpine orogenic belts in Central Europe and the tectonic phenomena of platform stages following the orogenic cycles, viz. the block structure. The complementary meridional direction is revealed in transverse undulations of the surface of the M-discontinuity and, together with W-E trends, in the lithofacies and tectonic development of most the younger units.
The analysis of the structure of the Earth's crust within the Bohemian Massif shows that already in Cadomian times the orogenic belt experienced a downwarp analogous to that observable at the Alps/Carpathians contact between the cities Vienna and Ostrava. It is possible to interpret in similar terms the structure of the eastern and north-eastern margins of the Bohemian Massif, which until recently was explained as an arcuate closure of the Hercynian orogenic belt alone or as its axial wedging out. The new interpretation, however, postulates the extension of the Hercynides, partly in the basement of the West Carpathians, eastwards into the Scythian platform. Which of these theories is true could be cleared up by a deep borehole located at the eastern margin of the Bohemian Massif. The analysis of the geological and tectonic structure of the units, results of deep seismic sounding and interpretation of the gravity and magnetic fields demonstrate that the most appropriate location would be the area between Nàmest and Mohelno in central Moravia, where to a depth of 10 km in the supra - crustal structure similar phenomena as in the anomalous Ivrea zone have been recognized. A deep borehole drilled in this area might help in solving other general problems such as the relationship between the super- and infrastructure (underthrusting of a part the Moravo-Silesian region beneath the Moldanubicum), the origin of the granulite-ultrabasite and eclogite assemblages, the correlation with the results of borings in the Kola Peninsula, and the differences in the formation of the continental crust in shields and mobile zones, as well.

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СТРУКТУРА ПОВЕРХНОСТИ ЗЕМНОЙ КОРЫ ВОСТОЧНОЙ ЧАСТИ ЕВРОПЕЙСКИХ ГЕРЦИНИД

Признаком, определяющим строение земной коры в восточной части европейских герцинид (и во всей Средней Европе), является направление запад - восток. Оно проявляется в рельефе поверхности Мохоровичича и в строении более глубоких частей коры, однако, проявляется и в

строении геологических комплексов различного возраста. Особенно оно проявляется в направлении орогенических поясов кадомского, герцинского и альпийского складкообразования в Средней Европе и в тектонических феноменах, образующихся на этапах развития платформ, следующих после отдельных орогенических циклов, т.е. в блоковом строении. Комплементарное меридиональное направление проявляется в поперечной волнистости поверхности Мохоровичича и вместе с направлением запад - восток также в литофациальном и тектоническом развитии большинства более молодых геологических комплексов.
Анализ строения земной коры показывает, что в области Чешского массива уже во время кадомского складкообразования в орогеническом поясе проявился аналогичный прогиб, какой можно наблюдать на контакте Альп и Карпат между Веной и Остравой. Подобным способом можно интерпретировать строение восточной и северо-восточной окраины Чешского массива, которое до сих пор объяснялось как дугообразное замыкание только герцинского орогенического пояса или как его осевое выклинивание. Это, однако, предполагает продолжение герцинид, частью и в фундаменте Западных Карпат, далее к востоку в область скифской платформы. Правильность некоторой из этих интерпретаций может объяснить глубокая скважина, которую нужно было бы провести в восточной окраине Чешского массива. Анализ геологического и тектонического строения комплексов, анализ результатов сейсмического зондирования, интерпретация гравиметрического и магнитного поля показывают, что скважину лучше всего пробурить в Средней Моравии на территории между городами Намешть и Могельно, где в супракрустальном строении на глубине 10 км были обнаружены подобные феномены, установленные до этого в аномальной зоне Иврея. Глубокая скважина в этой области способствовала бы решению и других общих проблем отношения верхнего и нижнего строения (субдукция части моравско-силезской области под молданубикум), решению проблематики образования гранулит-ультрабазитовой и эклогитовой ассоциации и сравнению с результатами, полученными в скважине на Кольском полуострове, и выявлению различий в образовании континентальной коры в щитах и в мобильных зонах.

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CONTINENTAL SCIENTIFIC DRILLING TO 5.5 KM IN THE SALTON SEA GEOTHERMAL FIELD, CALIFORNIA, USA

The Salton Trough, at the apex of the Gulf of California, where sea floor spreading systems of the East Pacific Rise transition into the San Andreas transform fault system, is a site where continental rifting and sedimentary basin formation are going on today. The largest thermal anomaly in the Trough, the Salton Sea Geothermal Field, is of interest for both its thermal regimes and its mineral resources.

Wells drilled to 2 km in this system, in the deltaic sediments of the Colorado River, have encountered temperatures 350°C and metal-rich brines containing 250,000 mg/L of total dissolved solids.

A private company, Republic Geothermal, Inc., proposes to drill a well to a depth of 3.7 km in this system beginning at the end of 1983, to obtain steam for electrical generation. This well will provide rock and water samples from depths greater than any other well in this field. Funds from the U S Department of Energy are available to deepen this well to 5.5 km for scientific purposes during the second half of 1984. The deepened well will be cored continuously and a comprehensive suite of experiments performed in what would be the deepest geothermal well in the world. This is one of the hottest and most saline geothermal fields known; unless temperature reversals occur, bottom hole temperatures should be between 400 and 500°C.

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TECHNICAL ASPECTS OF IMPLEMENTING THE SCIENTIFIC OBJECTIVES OF A CONTINENTAL DEEP BOREHOLE IN THE FEDERAL REPUBLIC OF GERMANY

An organisation consisting of a coordination office and five working groups (drilling, logging, sampling, interpretation/modelling, site determination/geophysics) has been set up to prepare a feasibility study for the planned research project. For this study extensive use has been made of the experience gained from ultra-deep boreholes (USSR, USA) and hot dry rock projects (USA, UK, FRG). Cost estimates and time requirements for drilling deeper than 10 km are now available.

Special attention has been paid to the drilling problems in connection with the great target depth (hook load of the rig, torque, downhole turbines, bits, casing, coring, etc.) and to the expected high temperatures (> 300°C). Measuring While Drilling should make it possible to reach wellsite decisions for rock and fluid sampling, as well as for the appropriate choice of a geophysical well survey program.

Considerable difficulties may arise with respect to the borehole measurements, fluid sampling, and data transmission by the logging cable. New objective-oriented well survey instrumentation will be developed by the service companies and universities. The surveying costs are expected to amount to 40% of the total financial volume.

Comprehensive laboratory analysis of rock and fluid samples, as well as surface geophysics, are necessary to attain the scientific goals.

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DATA MANAGEMENT FOR THE U.S. CONTINENTAL SCIENTIFIC DRILLING PROGRAM*

A special concern of the U.S. Continental Scientific Drilling Committee (CSDC) (formed by the National Academy of Sciences) was that opportunities for obtaining information from scientifically interesting holes drilled, or planned, might be lost. The Committee endorsed 1) piggyback experiments in holes of opportunity to maximize the information returned per drilling dollar, and 2) making maximum use of geologic information, geophysical and geotechnical data, and samples already obtained.

The Department of Energy (DOE) Office of Basic Energy Science (OBES) recognized that much drilling done by various federal energy programs was uncoordinated and not always reported in a timely fashion, thereby losing the savings resulting from one hole serving several purposes.

Because Lawrence Livermore National Laboratory (LLNL) already maintained a very large, well-used database system of information obtained for DOE's Underground Weapons Testing Program, OBES funded LLNL to establish a database cataloguing all DOE drilling information. This database was soon expanded to include all federal drilling, e.g., by the Department of the Interior's United States Geological Survey, and eventually to include all discoverable scientifically valuable holes proposed or drilled in the U. S. A network has been established of individuals sympathetic to the Committee's goals, especially State Geologists, to alert LLNL of these drill holes.

Now researchers inform LLNL of desired information or possible holes for further experimentation. Holes are selected and sorted from the database on one or more parameters including location, depth, purpose, information obtained, and principal investigator who may be contacted regarding the hole. Over 350 requests have been filled, and examples of these and the several piggyback experiments arranged in holes of opportunity will be discussed, as will a study related to a national drill core repository.

* Work performed under the auspices of the U.S. Department of Energy by the Lawrence Livermore National Laboratory under contract number W-7405-ENG-48.

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THE RESULTS OF GEOCHEMICAL AND GEOPHYSICAL INVESTIGATIONS IN KOLA SUPERDEEP HOLE (SG-3)

A great amount of various geophysical investigations have been made under severe PT conditions to a depth of 11.5 km in SG-3 hole.
A thick zone of velocity and density inversion has been detected below 4.6 km by the distribution of P- and S-wave velocities and density.
Maximum ρ, V_p and V_s values have been observed in igneous rocks in the upper part of the section. Deeper ρ, V_p, V_s decrease abruptly, and conversely, porosity, permeability, and anisotropy in-

crease. Variation of these properties is inverse at the Proterozoic-Archean boundary (6.5 km).

A low-velocity channel controls : processes of metamorphism and granitization, zoning of ore mineralization, and heat generation, gas behaviour, and distribution of radioactive, rare-earth and other elements. This zone seems to be responsible for the physicochemical and thermodynamic state of crystalline rocks in deep zones of the Earth's crust. Physical properties (electric, magnetic, etc.) of rocks have been measured and the composition and state of crystalline rocks have been estimated continiously for two major stratigraphic systems, Proterozoic and Archean.

Zones of increased concentrations of radioactive elements have been detected. Maximum U, Th and K concentrations are associated with secondary microcline granite bodies and veins. A refined crustal section has been obtained and the proportion of radiogenic heat has been estimated with higher accuracy (more than 60 percent of heat is generated in the crust).

SG-3 hole intersected "seismic interfaces" which were previously constructed from deep seismic sounding. Inaccuracies of previos constructions have been recognized and a complex geological nature of seismic interfaces has been demonstrated.

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РЕЗУЛЬТАТЫ ГЕОХИМИЧЕСКИХ И ГЕОФИЗИЧЕСКИХ ИССЛЕДОВАНИЙ (ГИС) КОЛЬСКОЙ СВЕРХГЛУБОКОЙ СКВАЖИНЫ (СГ-3)

Выполнен широкий круг геофизических исследований (ГИС) до глубины II,5 км, показаны высокая информативность ГИС при изучении свойств, состава геологического разреза, технического состояния ствола скважины, их возможности и ограничения ГИС в тяжелых термобароусловиях. Построены распределение скоростей P- и S-волн, а также гистограмма плотности. В разрезе СГ-3 максимальные значения плотности и скоростей V_p и V_s наблюдаются в изверженных породах верхней части разреза (0-4,5 км), глубже отмечено скачкообразное уменьшение V_p, V_s и ρ и, наоборот, увеличение пористости, проницаемости и анизотропии пород. Изменение указанных свойств на границе протерозоя и архея (глубже 6,5 км) имеет обратный характер.

Зона пониженных скоростей контролирует процессы метаморфизма и гранитизации, зональность рудной минерализации и теплогенерацию, поведение газов, распределение радиоактивных, редкоземельных и др. элементов. Эта зона предопределяет физико-химическое и термодинамическое состояние кристаллических пород глубинных зон земной

коры и дает новое объяснение "сейсмическим границам". Оценено напряженное состояние пород, вскрытых скважиной по комплексу ГИС, оценены свойства, состав и состояние пород двух крупнейших формаций земной коры: протерозоя и архея ; проведено уточнение расчленения разреза земной коры.
По распределению радиоактивных элементов по разрезу СГ-3 выявлены зоны повышенных их содержаний в разрезе архея; максимальные содержания U, Th и К отмечены в телах и жилах вторичных микроклиновых гранитов; уточнена доля радиогенного тепла (свыше 60% тепла генерируется в земной коре).

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JOINT PROGRAM OF DEEP CRUSTAL STUDY OF USSR TERRITORY

Intensive development of the national economy of the USSR necessitates systematic study of geological structure and mineral resources of the country. The solution of this problem is based primarily on the intensification of regional geological and geophysical investigations and fundamental studies in all Earth sciences.
The work is implemented under the National Program of Deep Crustal Investigations including the total package of geological, geophysical and geochemical investigations and drilling of deep and superdeep holes to study the evolution and structure of deep crustal layers, to improve theories of litho and tectogenesis, magma generation and metamorphism, to elucidate the relation of these processes with migration and localization of hydrocarbons and ore-forming fluids, and to improve, on this basis, the theory and equipment to be used in the study of the Earth interior and in mineral exploration.
The territory of the USSR is now being covered by a network of interconnected regional geophysical profiles tied to deep and superdeep boreholes. More detailed investigations are planned on this basis to be carried out within separate regions and geotectonic elements.
It is planned to increase the amount of superdeep drilling. Drilling of the Kola borehole (now at about 12,000 m) and Saatly hole (now at 8,300 m) will continue. In 1984 - 1985 three holes with the targets of 12 - 15 km and six deep stratigraphic holes will be spudded.
A data base for processing and analysing the data obtained is under development and upgrading. The results of deep geological and geophysical, cosmogeological and airborne geophysical investigations will be used to construct 3-D models of various orders for the whole ter-

ritory of the USSR, to establish the mechanism of formation and distribution of mineral deposits, to assess quantitatively the prospects of most important petroliferous and metalliferous provinces and to determine the main lines of future prospecting and exploration work.

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КОМПЛЕКСНАЯ ПРОГРАММА ГЛУБИННОГО ИЗУЧЕНИЯ ТЕРРИТОРИИ СССР

Инстенсивное развитие экономики нашей страны требует системного изучения геологического строения СССР и расширения его минерально-сырьевой базы. Решение этой задачи обеспечивается в первую очередь усилением региональных геологических и геофизических работ, исследований фундаментального характера в области всего комплекса наук о Земле.

С этой целью осуществляется Национальная программа глубинного изучения недр страны, включая весь комплекс геологических и сверхглубоких скважин по изучению особенностей эволюции и строения глубинных слоев земной коры, усовершенствованию теоретических основ лито- и тектогенеза, магмообразования и метаморфизма, выяснению связи их с процессами миграции и локализации углеводородов и рудообразующих веществ и на этой основе усовершенствование научных основ и технических средств для изучения недр Земли, прогноза, поисков и разведки месторождений полезных ископаемых.

Проводятся работы по созданию единой для территории СССР каркасной системы взаимоувязанных региональных геофизических профилей, опирающихся на глубокие и сверхглубокие скважины. На этой основе планируются более детальные исследования в пределах отдельных регионов и геотектонических элементов.

Намечено значительное увеличение объемов сверхглубокого бурения. Продолжится бурение Кольской (глубина в настоящее время около I2000м) и Саатлинской скважин (глубина около 8300 м). В I984-I985 годах начнется проходка скважин глубиной до I2-I5 км и шести глубоких опорных скважин.

Создается и расширяется база обработки информации. На основе комплекса глубинных, космогеологических и аэрогеофизических исследований будут созданы объемные модели разных порядков для территории страны в целом, выявлены условия формирования и закономерности размещения месторождений полезных ископаемых, дана количественная оценка перспектив основных нефтегазоносных и рудных провинций и определены главные направления поисковых и геологоразведочных работ на перспективу.

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GEOLOGICAL INVESTIGATIONS OF THE KOLA SUPERDEEP BOREHOLE

1. The Pechenga nickeliferrous region where the Kola superdeep borehole is located is a key area for the eastern part of the Baltic shield. The drilling of the Kola borehole created unique possibilities for complex investigations of lower zones of the Precambrian continental crust and evaluation of many geological theories.
2. It was expected from geophysical and geological observations on the surface that the borehole would meet the "granitic" layer at 4,7 km and the "basaltic" layer at 7,0 km. The real section disagrees with the supposed one and provides vast direct information on the composition of Proterozoic and Archean formations at previously unaccessable levels.
3. New data radically changed our knowledge on the vertical range of ore formation in the Earth crust, on the factors which determine metamorphic zonality and rock deformation style, on recent geothermal and gas-water regime of crystalline basement.
4. The Kola borehole was also used for comparison and improvement of alternative models, for example, on the geological nature of inclined and horizontal seismic boundaries. At the same time the drilling of the Kola superdeep gave rise to a series of new problems.

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ГЕОЛОГИЧЕСКИЕ РЕЗУЛЬТАТЫ ИЗУЧЕНИЯ КОЛЬСКОЙ СВЕРХГЛУБОКОЙ СКВАЖИНЫ

I. Печенгский никеленосный район, где расположена Кольская сверхглубокая скважина, является ключевым для восточной части Балтийского щита. Проходка Кольской скважины создала уникальные возможности для комплексного изучения нижних зон докембрийской континентальной коры и оценки многих геологических гипотез.
2. По результатам геофизических и геологических наблюдений на поверхности ожидалось, что скважина вскроет "гранитный"слой на 4,7 км и "базальтовый" слой на 7 км. Фактический разрез не согласуется с пред-

полагавшимся и содержит обширную прямую информацию о составе протерозойских и архейских формаций на ранее недоступных глубинах.

3. Новые данные решительно изменили наши представления о вертикальном диапазоне рудообразования в земной коре, о факторах,определяющих метаморфическую зональность и характер деформаций горных пород, о современном температурном и газово-водном режиме кристаллического основания.

4. Кольская скважина также использована для сравнения и усовершенствования альтернативных моделей, например, о геологической природе наклонных и горизонтальных сейсмических границ. Вместе с тем бурение Кольской сверхглубокой скважины породило серию новых проблем.

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SOME RESULTS AND PROSPECTS OF DEEP DRILLING IN EARTHQUAKE SOURCE

Deep and superdeep drilling gives large opportunities for the study of physical processes in earthquake source directly. First of all the results of these investigations are important for the solving of earthquake prediction problems. Highly interesting and informative predictional features of tectonic earthquakes have been discovered with borehole observations: electromagnetic and acoustic pulse radiation of rock deforming; variations of underground water pressure, temperature, chemical and gas composition; radon emanation; oil and gas yield fluctuation, etc. Anomalously decreased heat flood was discovered in a borehole, drilled in the upper part of the 1966 Tashkent earthquake source (M=5.3; h=3-8 km). If this unexpected anomaly is resulted from rapid adiabatic dilatation of rocks and gases filling them, we'll receive new possibilities in understanding of seismic source physics and other geological processes. On the other hand some technical difficulties appear while deep drilling of mobile, seismoactive crust sections. Rock deformations preceding, accompanying and following even moderate earthquakes could be essential and result in borehole damages. Thus, during the Tashkent earthquake rock displacement amplitude seemed to exceed 20 cm in the source, and the earth surface was strained with amplitude to 4 cm. resulting in ceasing the drilling at a depth of 2.46 km instead of planned 3-3.5 km. The violation of drilling regime was observed during the analogously intensive Nazarbek earthquake, but with deeper source, which occured in December, 1980 in the Tashkent suburb, where another deep borehole was under drilling.

In consequence, the drilling was ceased at a mark of 1.6 km instead of planned 2.0 km. The drilling of 5-6 km. borehole in the central part of the Tashkent source, which stopped practically its seismic activity, but keeps its physical properties is planning now.

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НЕКОТОРЫЕ РЕЗУЛЬТАТЫ И ПЕРСПЕКТИВЫ ГЛУБОКОГО БУРЕНИЯ В ОЧАГИ ЗЕМЛЕТРЯСЕНИЙ

Глубокое и сверхглубокое бурение открывает большие возможности для изучения физических процессов непосредственно в очагах землетрясений. Результаты этих исследований важны прежде всего для решения проблемы предсказания сейсмических катастроф. С помощью скважинных наблюдений обнаружены весьма интересные и информативные прогностические признаки тектонических землетрясений: электромагнитное и акустическое импульсное излучение деформируемых горных пород; изменение напора, температуры, химического и газового состава подземной воды; эманация радона; флуктуации дебита нефти и газа и другие признаки. Обнаружен аномально пониженный тепловой поток в скважине, пробуренной в верхнюю часть очага Ташкентского землетрясения 1966 года (магнитуда 5,3; глубина очага 3-8 км). Если эта неожиданная аномалия обусловлена быстрым адиабатным расширением горных пород и заполняющих их газов, откроются новые пути к пониманию физики сейсмического очага и других геологических процессов.

С другой стороны, возникают определенные технические трудности при глубоком бурении подвижных, сейсмически активных участков земной коры. Деформации пород, предшествующие, сопутствующие и последующие даже за умеренными по величине землетрясениями, могут быть существенными и способны вызвать повреждение скважин. Так, при Ташкентском землетрясении амплитуда перемещения пород в очаге, по-видимому, превысила 20 см, а земная поверхность испытала деформацию с амплитудой до 4 см, что привело к прекращению в 1968 г. бурения на глубине 2460 м вместо проектной 3000-3500 м. Нарушение режима бурения наблюдалось также при аналогичном по величине Назарбекском землетрясении, происшедшем в 1980 г. в пригороде Ташкента, где в стадии бурения находилась другая глубокая скважина. В результате подземных толчков и деформаций бурение было прекращено на отметке 1600 м вместо запланированных 2000 м.

Планируется бурение 5-6-километровой скважины в центральную область Ташкентского землетрясения, очаг которого практически прекратил свою сейсмическую деятельность, но сохранил физические свойства.

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UK DEEP DRILLING ACTIVITIES, PAST, PRESENT AND FUTURE

Drilling for purely scientific purposes in the UK has been carried out mainly by the Institute of Geological Sciences. Between 1955 and 1975, many continuously cored boreholes in the depth range 1 km to 2 km were sunk to solve specific local geological problems. Since 1975, scientific boreholes and geothermal wells, in the depth range 1.5 km to 3 km, have been drilled using faster, open-hole techniques with conventional coring and sidewall coring restricted to predetermined targets. To maximize scientific information from these boreholes, extensive suites of downhole geophysical logs are recorded. Good penetration rates in soft Mesozoic rocks give way, at depth, to poorer rates in older, harder formations using conventional oil drilling techniques. Results from recent drilling of granite in Cornwall to 2 km depth, however, suggest that good rates of progress may be expected using downhole motors.
Collating information from the existing geological database, deep boreholes and recently acquired deep seismic reflection data it is possible to isolate some of Britain's outstanding, deep geological and geophysical problems. Looking forward to the time when funding may be available, potential sites for a UK programme of super deep scientific boreholes are considered and a geological prognosis given for drilling to basement (lower crustal) levels in the UK landmass.

С И М П О З И У М / S Y M P O S I U M L.09

ПОИСКИ И ОСВОЕНИЕ ПОДЗЕМНЫХ ВОД В ПОЛУПУСТЫННЫХ ЗОНАХ
GROUNDWATER EXPLORATION AND DEVELOPMENT IN SEMI-ARID ZONES

Conveners: D.E.Ajakaiye, A.G.Babaev

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METHODS OF GEOLOGICAL PROSPECTING OF SUBTERRANEAN WATER IN SEMI-DESERTS OF KAZAKHSTAN AND THE PROSPECTS OF THEIR UTILIZATION

Hitherto deserts and semi-deserts of Kazakhstan were considered to be waterless.
However, researches made by us indicate, that episodic and concentrat-

ed precipitation and water migration from mountainuous regions result in the formation of subterranean water reserves.
To detect subterranean water reserves geological prospecting methods developed by U.M. Akhmedsafin and his associates were widely applied.
The above mentioned methods for spotting subterranean water reserves are based on estimation of certain features which include vegetation, relief and geological structure.
Vegetation, especially, xerophytes, can grow if their root system is bound with subsoil waters at a small depth; black saksaul can grow provided subsoil water exists at a depth of 5-8 metres; whereas the poplar (tourangah) is indicative of fresh subsoil water at a depth of 3-5 metres etc.
Relief serves as an indicator of the depth of subsoil waters. Within the high drained terraces and plateau fresh subsoil waters occur at a considerable depth. Reserves of subsoil water tend to form in low terraces, inter-range valleys and are close to the surface. Aeolian complex relief predetermines the change of groundwater bed depth and the quality of water even within a local areas.
Judging from the geological structure we presume whether deposits are water-bearing, efficient, if subterranean waters are mineralized.
Sandy, gravel and pebblous rocks which occur in semi-deserts under a cover of an aeolian formation at a small depth serve as a collector of subsoil waters of good quality.
In deeper horizons a number of geological structures formed by Cretaceous and Paleogenic collectors connected with large artezian basins are found.
The above mentioned geological prospecting criteria open a wide opportunity for their utilization in municipal economy, industry, agriculture, oasis and pasturable irrigation.

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МЕТОДЫ ПОИСКОВ ПОДЗЕМНЫХ ВОД В ПОЛУПУСТЫНЯХ КАЗАХСТАНА И ПЕРСПЕКТИВЫ ИХ ИСПОЛЬЗОВАНИЯ

Пустыни и полупустыни Казахстана долгое время считались безводными. Однако наши исследования показали, что эпизодически и концентрированно выпадающие здесь атмосферные осадки, миграция воды из горных областей обуславливают формирование больших запасов подземных вод. Для их выявления использованы поисковые признаки подземных вод, установленные У.М.Ахмедсафином и др.: растительность, рельеф, геологическое строение.

Растительность, особенно ксерофиты, тесно связана корневой системой с неглубоко залегающими грунтовыми водами; черный саксаул хорошо растет при оптимальных глубинах 5-8 м и наличии слабосолоноватой подземной воды; тополь-туранга-при глубинах 3-5 м и наличии в основном пресной подземной воды и т.д.

Рельеф определяет глубину залегания грунтовых вод. На высоких дренированных террасах, плато обычно распространены пресные воды с большими глубинами залегания. Низкие террасы, низменные межгрядовые понижения благоприятствуют накоплению неглубоко залегающих в разной степени минерализованных грунтовых вод. Эоловый сложный рельеф предопределяет частое изменение глубин залегания и качества вод даже на небольших участках.

Геологическое строение позволяет судить о водоносности отложений, их водоотдаче, минерализации подземной воды. Под плащем эоловых образований полупустынь нередко на небольших глубинах залегает комплекс песчаных, гравийно-галечниковых пород (особенно в погребенных и древних долинах, сухих руслах рек), служащих хорошими коллекторами для накопления доброкачественных грунтовых вод. В более глубоких слоях обнаружено немало геологических структур, выполнённых мел-палеогеновыми песчаными коллекторами, с которыми связаны обширные артезианские бассейны.

Большие ресурсы доброкачественных подземных вод, выявленные в результате привлечения вышеотмеченных поисковых критериев, открывают широкие перспективы их использования для коммунально-промышленного, сельскохозяйственного водоснабжения, оазисного орошения и обводнения пастбищ.

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GEOLOGICAL STRUCTURE AND WATER RESOURCES OF THE KARA-KUM DESERT

One of the biggest deserts of the world - the Kara-Kum desert is located within Turkmenistan. The geological structure is characterized by Mesozoic and Cenozoic deposits buried under Quaternary formations of different genesis. From the tectonic point of view the Kara-Kum is an epi- Hercinian platform. The basement of the platform consists of metamorphosed and magmatic rocks of Upper Paleozoic; the cover - of sedimentary (400-5000 m) Mesozoic and Cenozoic complexes. The hydrographic network here is weakly developed. The Amu-Darya river flows along the eastern slope of the Kara-Kum desert. The rivers Murgab and Tedjen are lost in the low-lying Kara-Kum, in the western Kopet-Dag the Atrek river flows. The Amu-Darya river feeds the main irrigation systems of Turkmenistan among which is the Kara-Kum canal named after V.I. Lenin - the tremendous project.

In piedmonts, valleys and deltas of rivers the landscapes of deserts are replaced by oases making green islands within the wast desert: Tashaus, Murgab, Middle Amu-Darya Tedjen, Pre-Kopet-Dag, Atrek-Sumbar.

At present as a result of hydrographic researches the main industrial districts, populated settlements and free-range animal husbandry are provided with fresh water. In the desert zone of Turkmenistan the following genetic types of subterranean fresh water occur: water which is connected with the formation of alluvial cone in piedmont plains; water of undersand lenses and water of lenses under takyr which plays an important role in water supply of free-range animal husbandry. The development of water resources in the Kara-Kum is closely connected with experimental and productive investigations on artificial construction of fresh water underground lenses.

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ГЕОЛОГИЧЕСКОЕ СТРОЕНИЕ И ВОДНЫЕ РЕСУРСЫ ПУСТЫНИ КАРАКУМЫ

В пределах Туркменистана располагается одна из больших пустынь земного шара - Каракумы. В геологическом строении широкое развитие принимают отложения мезозойской и кайнозойской эры, скрытые под четвертичными образованиями разного генезиса. В тектоническом отношении Каракумы представляют эпигерцинскую платформу. Фундамент платформы состоит из метаморфизованных и магматических пород верхнего палеозоя; чехол - из осадочных комплексов (400-5000м) мезозоя и кайнозоя.

Гидрографическая сеть развита очень слабо. Вдоль восточного склона Каракумов протекает река Амударья. В низменных Каракумах слепо оканчиваются реки Теджен и Мургаб, а на Западном Копетдаге протекает река Атрек. Основные системы Туркменистана берут начало от Амударьи, в их число входит грандиозное сооружение - Каракумский канал имени В.И.Ленина. В предгорьях, в долинах и в дельтах рек ландшафты пустынь сменяются оазисами, представляющими зеленые острова среди бескрайней пустыни: Ташаузский, Среднеамударьинский, Мургабский, Тедженский, Предкопетдагский и Атреко-Сумбарский.
В настоящее время в результате проведенных гидрогеологических исследований пресной водой снабжаются основные промышленные районы, насе-

ленные пункты и отгонное животноводство. В пустынной зоне Туркменистана встречаются следующие генетические типы подземных пресных вод: воды, связанные с образованиями конуса и выноса предгорных равнин; воды подпесчаных и подтакырных линз, имеющие существенное значение в водообеспечении отгонного животноводства. В освоении водных ресурсов Каракумов большое значение имеют опытно-производственные исследования по искусственному созданию линз пресных подземных вод.

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USE OF GEOTHERMAL METHODS IN EXPLORATION AND EXPLOITATION OF GROUNDWATER IN SEMI-ARID REGIONS OF BRAZIL

Conventional uses of temperature logs in water wells include determination of velocity and direction of groundwater movement as well as in-situ permeability. Regional geothermal gradient variations have also been found useful as an inexpensive auxiliary method in the determination of recharge and discharge zones, vital for urban and industrial planning in semi-arid regions.

Very little, however, is known about the use of geothermal techniques in the exploitation of groundwater. Studies carried out in wells drilled for groundwater in semi-arid regions of Brazil show that temperature logs can be used as an economical semi-quantitative method for defining the correct intervals for installation of filters. The technique is based on the fact that in layers with active groundwater movement mass transfer plays a key role in the heat exchange between drilling fluid and formation. On the other hand in impermeable strata this heat exchange is possible only through conduction. Hence temperature logs carried out soon after cessation of drilling reveal presence of thermal anomalies produced by groundwater movement. Results obtained so far show that installation of filters in intervals indicated by temperature logs have allowed increases of two to three times the extraction rates of groundwater in localities normally considered non-productive. In layers where flow is restricted by fractures installation of filters is critical in obtaining good flow rates. Detailed temperature logs are found useful in defining fractures but there is some difficulty in recognizing fractures that are hydrologically active from those that are passive and simply permit penetration of drilling fluid.

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APPLICATION OF GEOELECTRIC METHODS TO GROUNDWATER PROSPECTING IN NORTH EASTERN KANO STATE, NIGERIA

Geoelectric measurements (i.e. DC resistivity sounding and profiling, variable frequency EM depth sounding with horizontal coplanar coils system, SP and VLF-EM profiling) were carried out in two locations in a semi-arid area near Kano, Nigeria in order to identify the water bearing strata. This area is at the geologic boundary between the Quarternary Chad Formation (a loose sandy deposit in a sedimentary basin) and the Basement complex of Nigeria.
The results indicate that the depth to the water bearing layers varies from 20 to 60 m and their resistivities lie between 5 and 50 Ohm-m. The top layer consisting of dry loose sand which is about 0.4 to 6.0 m thick is highly resistive (about 1000 Ohm-m), this makes the variable frequency EM depth sounding technique more effective in this area of the investigation of deep seated conductors.

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WATER BALANCE MODELLING WITH EMPHASIS ON EVAPOTRANSPIRATION AND INFILTRATION

The paper deals with water balance modelling with emphasis on evapotranspiration and infiltration in examining the possibilities for determining recharge to groundwater. Other methods for determining recharge which may be considered more realistic approaches are also discussed. In summary, the paper outlines deterministic understanding of flow processes and points to shortcomings of this approach and concludes that recharge, being only a small fraction of the water balance is best estimated by direct measurement.

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HYDRO-GEOCHEMICAL INVESTIGATIONS OF GROUNDWATER ALONG WEST COAST OF INDIA - A CASE STUDY

Groundwater is one of the gifts of nature for the existence and propagation of life on the Earth. Fresh water resources being limited, man has naturally taken recourse of harnessing groundwater through open wells and bore wells.
The present studies on groundwater potential and quality cover an area of 4 km^2 along coastal Karnataka (South India). This area enjoys intensified farm activity, rapidly expanding industrialization and growing density of population. A small creek in the centre of the area slightly below the mean sea level often leads to salt water encroachment during high tides. A gated structure across the creek prevents sea water entry into the creek and on to the fields. The area experiences heavy rainfall from June to September. Yet it faces near drought conditions from February to May. The groundwater stored in sand layers, laterites and jointed and weathered gneisses, is the only dependable source of water for all needs.
Hydrogeological explorations reveal the presence of a potential unconfined aquifer suitable for all types of agricultural and civic needs. Many open wells are inventoried and several pump tests are conducted in order to determine aquifer parameters. Salt water ingression is noticed in wells deepened beyond the optimum depth of 10 m. The minimum spacing of 60 m between adjacent wells is found most favourable.
Well water samples and representative soil samples are analysed chemically to assess soil-water compatibility and to suggest appropriate cropping pattern.
Recommendations to develop, manage and harness groundwater are discussed in detail in the main paper.

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GENETIC TYPES OF FRESH GROUNDWATER OCCURRENCES IN TURKMEN DESERTS, ITS RESOURCES AND RATIONAL EXPLOITATION

Hydrogeological work shows, that fresh groundwater formation and origin occur in different natural conditions due to the unequal nourishment sources. Four genetic types are suggested:

The first genetic type is the footfield flat land fan fresh groundwater occurrences. Operating resources are formed by the seepage stream losses, infiltration of precipitation and underground runoff. Resources are estimated at ten thousands m^3/a day.
The second genetic type is the large undersand lenses fresh groundwater occurrences. They occur predominantly in sandy deserts. By genesis they are considered as relict with a recent nourishment through aeration zone. Operating resources are based on the relationship of natural (static) reserves and natural (dynamic) resources. Industrial water supply of the entire complexes may be organized by these reserves.
The third genetic type is subtakyr lenses of fresh groundwater occurrences. Fresh water resources are formed by immediate runoff from takyr watershed. On mode of occurrences they are similar to the large undersand lenses. Resources are used by distant animal husbandry.
The fourth genetic type is the river valley fresh groundwater occurrences and occurrences along the arterial canals. Resources are formed by infiltration losses and are able to satisfy industrial requirements. The question of rational exploitation has not been solved for a long time. In 1958 the reliable and effective method was worked out and inculcated. This method consists of simultaneous irrigation pumpage of fresh and mineralized water from adjacent wells.

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ГЕНЕТИЧЕСКИЕ ТИПЫ МЕСТОРОЖДЕНИЙ ПРЕСНЫХ ПОДЗЕМНЫХ ВОД ПУСТЫНЬ ТУРКМЕНИСТАНА, ИХ РЕСУРСЫ И РАЦИОНАЛЬНАЯ ЭКСПЛУАТАЦИЯ

Гидрогеологическими работами доказано, что формирование и происхождение ресурсов пресных подземных вод происходит в различных природных условиях и за счет неравноценных источников питания, что позволяет выделить четыре генетических типа месторождений.
I генетический тип - месторождения пресных подземных вод конусов выноса предгорных равнин. Эксплуатационные запасы формируются за счет потерь поверхностных водотоков, инфильтрации атмосферных осадков и подземного стока. Запасы их оцениваются десятками тыс.$м^3$/сут
II генетический тип - месторождения пресных подземных вод крупных подпесчаных линз. Они пользуются распространением преимущественно в песчаных пустынях. По генезису относятся к реликтовым с современным питанием через зону аэрации. Эксплуатационные запасы базируются на сработке естественных (динамических) запасов и естественных (динамических) ресурсов. На этих запасах можно организовать промышленное водоснабжение целых промышленных комплексов.

Ш генетический тип - месторождения пресных подземных вод подтакырных линз. Запасы пресных вод формируются за счет поверхностного стока с такырных водосборов. По условиям залегания они в миниатюре напоминают крупные подпесчаные линзы. Запасы их используются отгонным животноводством и жителями пустыни.

IУ генетический тип - месторождения пресных подземных вод речных долин и вдоль магистральных каналов. Запасы формируются за счет инфильтрационных потерь и способны удовлетворить потребность промышленных объектов.

Долгое время не был решен вопрос рациональной эксплуатации линз пустынь. В 1958 г. в Туркмении разработан и внедрен такой метод, который оказался весьма надежным и эффективным. Метод заключается в одновременном водоотборе пресных и соленых вод из рядом расположенных скважин.

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PECULIARITIES OF GROUNDWATER PROSPECTING IN AN ARID ZONE

Formation of groundwater in desert and semidesert zones is characterized by a number of peculiarities, consideration of which with prospecting allows to solve water-supply problems rather quickly and efficienly. These peculiarities are as follows: poor recharge, high evaporation, mosaic distribution of fresh- and slightly brackish water among salt water attributed to local recharge peculiarities, a greater role (as compared to humid and transition zones) of local conditions, such as relief, direction and strength of wet winds, the regime of precipitation in solid phase, etc., in the formation of ground water. All this predetermines the necessity and a greater importance of the use of non-conventional study methods: remote sensing, air photographs and aerovisual observations in the first place, indicative geobotany with phytocoenosis interpretation and quantitative determination of evapotranspiration, balance-hydrometric methods accompanied by snow surveys, flood runoff measurements and seepage coefficient determination, the use of ground geophysical methods. The use of this complex of methods allows to satisfy water-demands of various national-economic objects under desert and semidesert conditions in Western, Nothern and Central Kazakhstan, Kyzyl Kum and Turkmenistan. Thus, a water intake of fracture-karst ground water with mineralization of 1g/l was constructed and is now functioning (with a yield of $1m^3/s$) in Central Kazakhstan, given an evaporation value of 1000 mm and measured precipitation to 150 mm.

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ОСОБЕННОСТИ ПОИСКОВ И РАЗВЕДКИ ПОДЗЕМНЫХ ВОД В АРИДНОЙ ЗОНЕ

Формирование подземных вод в пустынных и полупустынных зонах характеризуется рядом особенностей, учет которых при поисках и разведке позволяет решать задачи водоснабжения относительно быстро и эффективно. К таким особенностям относятся: скудное питание и высокая испаряемость, мозаичность распространения пресных и слабосолоноватых вод среди соленых, обусловленная локальными особенностями питания, гораздо большая роль, по сравнению с гумидной и переходной зонами, в формировании подземных вод местных условий - рельефа, направления и силы влагоносных ветров, режима выпадения осадков в твердой фазе и т. д. Все это предопределяет необходимость использования и большее значение нетрадиционных видов иследований - применения дистанционных методов, прежде всего аэрофотоснимков и аэровизуальных наблюдений, индикационной геоботаники с расшифровкой фитоценозов и количественным определением эвапотранспирации, балансовогидрометрических с проведением снегомерных съемок, замерами паводкового стока и определением коэффициента просачивания, применения различных видов наземной геофизики. Применение такого рационального комплекса методов позволяет успешно удовлетворять потребности в воде различных народнохозяйственных объектов в условиях пустынь и полупустынь Западного, Северного и Центрального Казахстана, в Кызылкумах и в Туркмении. Так, в Центральном Казахстане при испаряемости около 1000 мм и измеренных атмосферных осадках 150 мм был разведан, построен и эксплуатируется водозабор грунтовых трещинно-карстовых вод с минерализацией 1 г/л и с производительностью до 1 м^3/с.

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GROUND WATER USE FOR ECONOMIC DEVELOPMENT OF SEMIARID ZONES

Semiarid and arid zones occupy a considerable part of the earth in the Temperate zone of the North hemisphere and Subtropical and Tropical zones of the North and South hemispheres. Arid conditions of moistening (precipitation less than 200 mm a year under extra-arid conditions less than 50 mm, humidity factor - 0 - 0.15) predetermine extremely unfavourable conditions of ground water forming. It is possible to conditionally subdivide groundwater reserves in the arid zone into local, phreatic as a rule, characterized by insignificant volumes (first litres or tens of litres per second, seldom first hundreds l/sec) and "transit", usually confined, originating in the marginal parts of artesian basins and slowly flowing to discharge areas, for instance, to the Aral Sea within Turanian artesian region, USSR. These "transit" groundwater reserves amount to considerable quantities (m^3/sec and first tens of m^3/sec) though this water is brackish as a rule and mineralization amounts to 1.5 - 3 g/l and more. Developing of semiarid and arid territories - pasturable cattle-breeding, mineral resources mining and irrigation cause the increasing demand for groundwater and its withdrawal. In the recent years groundwater occurring in the form of lenses developed due to rainfall and snowmelt runoff from takyrs is extensively used for cattle watering pastures in the arid zone of the USSR. There on the territory of Ustyurt and Plain Mangyshlak (to the West of the Aral Sea) more than 1700 takyrs are taken account of, the total area of their watersheds being 466 and 164 sq.km. Runoff of 1 sq.km of watershed amounts to 11,000 m^3, so total quantity of takyr runoff involved in subtakyr lens development comes up to about 7 mln.m^3/y in these two regions. With allowance for takyr rejection through negative factors (semipermeable deposits, high thickness of aeration zone etc.) more than 2 mln.m^3 of fresh and semibrackish water can be used for cattle watering annually.

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ИСПОЛЬЗОВАНИЕ ПОДЗЕМНЫХ ВОД ДЛЯ ЭКОНОМИЧЕСКОГО РАЗВИТИЯ ПОЛУПУСТЫННЫХ ЗОН

Полупустынные и пустынные зоны занимают значительную часть суши земного шара в умеренном поясе Северного полушария, субтропических и тропических поясах Северного и Южного полушарий. Аридные условия увлажнения (осадки меньше 200 мм в год, в экстрааридных условиях меньше 50 мм, коэффициент увлажнения 0-0,I5) предопределяют крайне неблагоприятные условия формирования подземных вод. Их ресурсы в аридной обстановке условно можно подразделить на местные, как правило, грунтовые, характеризующиеся небольшим объемом (первые литры или десятки литров в секунду, редко первые сотни л/с) и транзитные, обычно напорные, формирующиеся в краевых частях артезианских бассейнов и медленно движущиеся к зонам разгрузки, например, в пределах Туранской артезианской области СССР в сторону Аральского моря. Ресурсы таких "транзитных" подземных вод достигают значительных величин - $м^3$/с и первые десятки $м^3$/с, хотя эти воды, как правило, солоноватые с минерализацией I,5-3 г/л и более. Освоение полупустынных и пустынных территорий - пастбищное животноводство, добыча полезных ископаемых, орошение земель-обуславливают рост потребности и отбора подземных вод. Для водопоя скота на пастбищах в аридной зоне СССР в последние годы все шире применяются подземные воды, формирующиеся в виде линз за счет стока дождевых и снеготалых вод с такыров. Так, по территории Устюрта и Равнинного Мангышлака (западнее Аральского моря), учтено более I700 такыров с общей площадью такырных водосборов соответственно 466 и I64 км^2. Сток с I км^2 водосбора составляет II тыс.м^3, таким образом общая величина такырного стока, поступающего на формирование подтакырных линз в этих двух районах, составляет около 7 млн.м^3/год. С учетом отбраковки такыров по негативным факторам (слабопроницаемые отложения, большая мощность зоны аэрации и т.д.) для водопоя скота может использоваться более 2 млн.м^3 пресной и слабосолоноватой воды в год.

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GROUNDWATER IN THE EASTERN SUDAN

The eastern part of the Sudan is one of the richest natural potentialities in the country. Vast agricultural areas and potentials of minerals and petroleum in the region made it essential to develop this region for increasing the economic resources of the country as a whole. The present as well as forthcoming developments will be substantiated by existence of water resources that is sufficient to coup with such developments. Part of the present needs of this region is covered by surface water resources and the majority is covered by groundwater resources. The real development is related to the amount of groundwater released. Groundwater resources in the region are summarized in the following:

1 - Fan and alluvial deposits.
2 - Fractured and weathered Basement Complex.
3 - Nubian or Gedaref Sandstone formation.
4 - Fractured or weathered Basalts.

The purpose of this paper is to investigate the groundwater potentialities of these aquifers. The dimensions, quality and quantity of water and problem related to the aquifers are also discussed. Investigation for discovery of new aquifers and productivity of the major aquifers has been attempted.

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GEOPHYSICAL METHODS IN GROUNDWATER PROSPECTING AND EXPLORATION IN DESERTS

Efficiency of groundwater prospecting and exploration can be improved using field geophysical methods. Given various types of groundwater reservoirs in arid zones, the problems to be solved with geophysical methods fall in the groups: immediate prospecting of shallow fresh water lenses, study of the hydrochemical zoning of ground water in plan and section, lithological subdivision of a profile, studying the degree of jointing and karsting, as well as fissure filler of carbonate reservoirs, mapping of filtration properties in producing aquifers, evaluating the depth of groundwater table, control of mineralized water front migration during test-production pumpage. Area or multiple profile measurements carried out using a complex of methods of electrical prospecting with direct current, induced polarization and seismic prospecting provide the solutions to the above problems. Geologic-hydrogeological data interpretation is based on correlations and nomograms reflecting interactions between the geophysical and hydrogeological parameters and rock characteristics. Induced polarization is a more informative method. Studying the interrelations between polarizability and electrical resistivity enables immediate prospecting of fresh water lenses, as well as mapping of aquifer filtration properties and lithological composition of rocks. Polar diagram analysis of apparent polarizability and electrical resistivity allows to estimate fissure filler. The results of application of the developed technique in different areas of the arid zone in the USSR illustrate its high efficiency.

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ГЕОФИЗИЧЕСКИЕ МЕТОДЫ ПРИ ПОИСКАХ И РАЗВЕДКЕ ПОДЗЕМНЫХ ВОД В ПУСТЫНЯХ

Повышение эффективности поисково-разведочных работ на воду возможно путем применения методов полевой геофизики. При всем многообразии типов месторождений подземных вод в аридных областях задачи, решаемые геофизическими методами, объединяются в следующие группы: прямые поиски неглубокозалегающих линз пресных вод; изучение гидрохимической зональности подземных вод в плане и разрезе; литологическое расчленение разреза; изучение трещиноватости, закарстованности и материала заполнителя трещин карбонатных коллекторов; картирование фильтрационных свойств продуктивных горизонтов; оценка глубины залегания

уровня подземных вод; контроль за продвижением фронта минерализованных вод в процессе опытно-эксплуатационных откачек. Решение перечисленных задач обеспечивается выполнением площадных либо повторных профильных измерений комплексом методов электроразведки постоянным током, вызванной поляризации и сейсморазведки. Основой геолого-гидрогеологической интерпретации данных являются корреляционные зависимости и номограммы, отражающие взаимосвязь геофизических и гидрогеологических параметров и показателей горных пород. Наиболее информативен метод вызванной поляризации. Изучение взаимосвязи величин поляризуемости и удельного электрического сопротивления позволяет выполнить прямые поиски линз пресных вод, картировать фильтрационные свойства водоносного горизонта и литологический состав пород. Анализ полярных диаграмм кажущихся величин поляризуемости и электрического сопротивления позволяет оценить материал заполнителя трещин. Опыт работ в различных районах аридной зоны СССР показал высокую эффективность разработанной методики.

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FRACTURE TRACE ANALYSIS AS A TOOL FOR ASCERTAINING KINEMATICS OF MANIKPUR AREA OF BANDS DISTRICT, UTTAR PRADESH (INDIA)

Analyses of fracture traces observed in consolidated rock formations around Manikpur town of Banda district, India have been carried out to infer the kinematics of the area. The terrain is characterised by the presence of Kaimur Sand stone belonging to the Vindhyan supergroup (1400 - 900 million years). The rock formations exhibit conspicuous microfractures along N135 - 315°, N120 - 300°, and N45 - 225°, and also less prominently along North-South and East-West directions. The photolinears (fracture traces and lineaments) delineated from the aerial photographs show a fairly good agreement with the microfractures. The fracture trace map of the area has revealed occurrence of a ENE-WSW trending shear zone (Manikpur Shear Zone) characterised by the development of related Displacement and Riedel Shears, Conjugate Riedels, and the tension fractures. The probable direction of the maximum horizontal compressive stress (σ_{max}) seems to be along East-West, with the minimum horizontal stress (σ_{min}) being along North-South. The release of the stresses consequent to the formation of different types of slip surfaces may have resulted in the reactivation of NW-SE trending shears as tension joints. In some places,

within the shear zone, shear lenses are also observed.
In the framework of regional tectonic setup comprising Narmada Sone lineement, the Manikpur shear Zone can be considered to have originated by a stress pattern similar to the one operative in the whole region and may be an off short of the system of fractures, exhibited in the Narmada-Sone area.

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APPLICATION OF GEOPHYSICAL METHODS TO GROUNDWATER EXPLORATION IN PARTS OF NORTHERN NIGERIA

Since 1973 the Graduate Programme in Applied Geophysics of Ahmadu Bello University Zaria has been undertaking geophysical surveys for groundwater around selected villages in the semi-arid region of Northern Nigeria. These surveys have sought to provide the various State Waterboards with relevant geophysical data to aid the siting of productive water boreholes.

Results of electrical and seismic refraction methods used in three different localities show that in the crystalline basement areas, typical geological section consists of top soils, laterite, clay and sand, and quartz with gravel overlying the basement complex rocks. The water bearing layers never exceeded 12 m in depth and the thickness range from 1-30 m. Resistivity values for these layers are between 6 - 115 m with corresponding seismic velocities of between 1200 - 2500 ms^{-1}.

In general both methods proved effective in delineating the presence of groundwater. However comparisons with borehole data showed that the seismic method was more effective than the resistivity method in differentiating between intermediary beds and often gave more reliable estimates to depths to the water table.

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PETROGENETIC STUDIES ACROSS A PROTEROZOIC BOUNDARY IN NORTH SWEDEN

Petrogenetic shudies have been carried out within the northern part of the Baltic Shield, along the line of the Fennolora Profile and the northernmost segment of the European Geotraverse. The area studied contains three distictly different crustal regions: (1) an area of continental affinity in the north (southern Norrbotten) comprising heterogeneous complexes of gneisses, granites and supracrusal rocks with relatively few sediments, (2) a volcanic arc (the Skellefte District) and (3) an area of marine affinity in the south comprising marine metasediments and granites. The region may represent an example of early Proterozoic plate tectonics with a northerly dipping subduction zone being responsible for an "Andinotype" orogeny around 1900 - 1850 Ma followed by continental thickening and a "Hercynotype" event (1800 - 1700 Ma).

Geochemical and isotope studies (Nd & O) in the area indicate that (a) none of the Proterozoic granites yet sampled contain a significant component of Archaean material, (b) the granites in the southern "marine" area are peraluminous and have high oxygen isotope values similar to sediments, (c) the granites in the northern area have normal igneous oxygen isotope compositions, (d) the mantle from which the precursors of the granitic rocks was derived was depleted in LREE relative to CHUR.

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ON METALLOGENY OF PRECAMBRIAN GRANITOIDS

There is no difference between the types of Precambrian ore deposits relating to granitoids and the similar types of deposits which relate to Phanerozoic granitic rocks. This allows judgment concerning the preservation in the history of the lithosphere from Archaean to Mesozoic of certain conditions in the formation and development of ore-producing granitoids.

The macrostructures of greenstone belts had an exceptional significance for metallogeny of the Precambrian granitoids. The vast majority of occurrences of Cu and Mo of the porphyry-copper type, Au and Ag containing massifs of granitoids, and the most productive fields of rare-metal granite pegmatites are located within the greenstone belts of the ancient shields.

The processes of repeated melting and fractional crystallization of granitoids were the most important in formation of potentially ore-productive varieties. The weakest manifestations of the metallic ores accumulation are characteristic for the processes of metasomatic granitization, when a tendency to depletion of granitized rocks in base metals is prevailing over concentration under an influence of the residual solutions produced in the process of granitization.

Late- and post-orogenic silicic varieties of allochtonous granitoids, which underwent several stages of fractional melting and crystallization, are the most productive in precambrian for rare metals. For deposits of Cu and Cu-Mo ores, as well as for Au, relations to early- and syn-orogenic granitoids, often low in SiO_2, are more typical.

Ore concentrations connected with the Precambrian granitoids are heterogenous. Existing geological and geochemical data allow to judg that processes of assimilation from country rocks of the greenstone belts followed with mobilization of ore components were the leading ones in formation of ore mineralization of the porphyrycopper type and also of gold-bearing massifs of granitoids. The geological position of rare metal deposits of the pegmatite and metasomatite types, their close relations to deep-seated faults with probable mantle roots, allow to assume the participation of undercrustal granitizing solutions in the primary inflow of rare metals.

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МЕТАЛЛОГЕНИЯ ДОКЕМБРИЙСКИХ ГРАНИТОИДОВ

I. Принципиальная разница между типами рудных месторождений, связанными с докембрийскими гранитоидами, и аналогичными типами месторождений, связанными с гранитоидами фанерозоя, отсутствует. Это позволяет судить о сохранении в течение длительного времени определенных условий формирования и становления рудопродуктивных гранитоидов в истории развития литосферы от архея до мезозоя.

2. Макроструктуры зеленокаменных поясов играли исключительную роль для металлогении гранитоидов докембрия. Подавляющее большинство мес-

торождений и рудопроявлений Cu и Mo порфирового типа, Au и Ag , а также наиболее продуктивные поля редкометальных пегматитов располагаются в пределах зеленокаменных поясов.

3. Процессы многостадийного фракционного выплавления и кристаллизации играли важную роль в формировании потенциально рудопродуктивных разностей гранитоидов. Наиболее слабо явления рудогенеза проявлены в процессах метасоматической гранитизации, когда в широком диапазоне условий проявлялись тенденции к выносу рудных компонентов растворами, остаточными после гранитизации.

4. Наиболее продуктивными в докембрии для редких элементов являются позднеорогенные и посторогенные кислые разности аллохтонных гранитоидов, как правило, претерпевших несколько стадий фракционного переплавления и кристаллизации. Для рудопроявлений медных и медно-молибденовых руд, а также золота более характерна связь с до-, ранне- и синорогенными *гранитоидами, часто повышенной основности.*

5. Рудные концентрации, связанные с докембрийскими гранитоидами, имеют гетерогенное происхождение. Процессы ассимиляции из вмещающих пород зеленокаменных поясов и последующей мобилизации были решающими при формировании рудных концентраций меднопорфирового типа, а также рудопроявлений Au и U. В то же время геологическое положение редкометальных пегматитов и метасоматитов, их тесная связь с глубинными разломами, для которых в ряде случаев доказывается мантийное заложение, позволяют предполагать участие подкоровых гранитизирующих растворов в изначальном привносе редких элементов с последующей концентрацией в процессах многостадийного плавления и дифференциации гранитного субстрата.

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TECTONIC REGIMES IN THE PROTEROZOIC OF BRAZIL

Concerning litho-structural types and tectonic regimes it is possible to identify three different evolutionary stages during the Proterozoic of Brazil. Therefore, essential modifications in the geodynamic conditions have to be taken into consideration.

The folding systems of the Early Proterozoic have been preserved as narrow and scattered linear belts (Jacobina, Minas, Maroni-Itacaiunas). Nevertheless, the formation of granitic rocks, the tectonic reworking and isotopic rejuvenation of the older crustal basement were rather extensive. It has been very difficult to draw out convincing geodynamic models for such wide and vestigial mobile belts.

Intracratonic regimes seemed to be preponderating during the Middle

Proterozoic. Noteworthy sedimentary, volcanic and volcanic-sedimentary covers were formed in repeated tectonic-magmatic cycles, side by side with the intrusions of subvolcanic granites. These formations cover areas of several hundreds of thousands of square kilometers, and their development were done during a span of time of at least 800 m.y. The fold belts played a secondary role in such stage, as a subordinated type of tectonic regime.
The Upper Proterozoic evolution exihibit the more characteristic fold belts, proximal (limestone troughs) and distal (terrigenous) types, disposed among older and reworked fragments (massifs) of high grade terranes. Most of the internal and external subdivisions of these fold belts are made by polycyclical geofractures. The mosaic like arrangement belts-massifs-geofractures is rather complex. The plausible application of plate tectonic models for these regions has faced some difficulties that will be discussed.

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PROTEROZOIC TECTONIC ELEMENTS OF NORTH AMERICA MAPPED BY COCORP DEEP SEISMIC PROFILING

An extensive buried basin in the southern midcontinent, an asymmetric rift in northeastern Kansas, bimodal graben stratigraphy in central Michigan, a distinctly layered lower crustal wedge - perhaps highly conductive - beneath the Adirondacks, and a high-angle shear zone possibly representing a continental suture in southeastern Wyoming are among the Proterozoic crustal features discovered or detailed at depth for the first time by COCORP seismic profiling. The buried basin in southern Oklahoma and northern Texas is particularly well-defined: persistent and underformed layering, 7 to 10 km thick and extending to depths of 10 to 13 km, appears to cover an area of 2500 sq. Km or more. Based on synthesis of reflection character with the scant surface geologic observations, this layering has been interpreted as clastic sedimentary and felsic volcanic rocks deposited or intruded about 1200 to 1400 m.y.a. The distinctive layering does not extend north of the Wichita Uplift, where it is tectonically truncated by Proterozoic faults which have been reactivated as late Paleozoic thrusts. To the north and a little later (1100 m.y.a.), an abortive attempt to break apart the Proterozoic crust began, forming the Keweenawan rift. COCORP surveys across this rift in Kansas reveal a highly asymmetric graben, 8 km thick, formed by domino-style block rotation along moderately-dipping, planar normal faults. The graben fill exhibits a distinctly bimodal reflection character, attributed to a lower unit of interlayered volcanic flows and clastics overlain by an upper unit of immature clastic material . Similar seismic stratigraphy is also evident on a branch of the Keweenawan rift buried beneath the Paleozoic Michigan basin. While rifting was active in the midcontinent, the Grenville orogeny was underway in the eastern U S COCORP surveys in the Adirondack dome, an erosional window of Grenville-age metamorphic rocks, reveal a lower crustal wedge of layered reflections which may correspond to a high conductivity zone. Possibly a layered igneous body, perhaps related to an overlying anorthosite massif, it has also been interpreted as a tectonically emplaced metasedimentary wedge, underthrust during Grenville collisional orogeny and retaining sufficient water, graphite, or sulphides to be conductive. Further west, COCORP surveys across the Mullen Creek-Nash Fork shear zone, which juxtaposes Archaean basement and Proterozoic metasedimentary cover against Proterozoic basement, indicate a steeply dipping (55 degree) discontinuity separating crust of differing thickness and reflection character. This shear zone, interpreted variously as part of a Proterozoic wrench fault system and as a continental suture, may well have influenced later Laramide crustal deformation. In addition to filling important gaps in our knowledge of Proterozoic crust in the U S , much of which is hidden beneath Paleozoic cover, these results provide a new perspective from which to view the issue of Proterozoic (not to mention Archean) versus Phanerozoic tectonics. For example: the overall crustal reflection character of the crust in the south and central midcontinent contrasts markedly from that dominated by Phanerozoic detachment tectonics, suggestive of possible differences in style of continental accretion.

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THE EVOLUTION OF THE METAL CONTENTS IN PROTEROZOIC BLACK SHALES

1. The expedience of physico-chemical analysis of the metal contents evolution in Proterozoic black shales is conditioned by their great economic importance.

2. Beginning with early diagenesis and catagenesis up to low steps of the regional metamorphism the ore elements admixtures of shales do not leave their main carrier - organic matter. Only the nature of chemical bonds between metals and organic matter is changed. The por-

phirine textures representing fragments of past biomolecules indicate to these transformations. Under the late catagenesis and greenschist step of the regional metamorphism metalloporphirines incorporate into the texture of kerogen reflecting the highest level of the background metaliferous concentrations in the geological history of the concrete blocks of the Lithosphere.
3. During the progressive metamorphism the rocks enriched especially by organic matter generate aqueo-carbonated solutions which desorb the ore admixture. Under the processes of metamorphic growth of minerals the admixture is released by the mechanism of the Ostwald's recrystallization. The graphite which is crystallized at the expence of the metaliferous geopolymers under the metamorphism is purified from the ore admixture. All these processes call the rise of the trend migration of the scattered admixture towards the upper layers of the Lithosphere, i.e. to the less strained zones of the Earth's crust which has a lower P-T^{o} parameters.
4. Under the tectonic activization the regressive metamorphism is accompanied by the ore admixture fractionating between mineral and organic phases of the rock. At the activizated blocks the admixtures pass through a number of levels of the concentration: from background contens through metaliferous secondary bitumenoids to sulphide mineral forms for Au, Ag, Cu and oxide ones for U and V. Thus, if the regional catagenetic and metamorphic processes cause the forming of the background contents of the metals in the geopolymers and their dispersion then the local regressive phenomena under the late activization cause fractionating of the admixtures to the secondary organic matter and under its destruction the ore minerals will be directly formed.

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ЭВОЛЮЦИЯ МЕТАЛЛОНОСНОСТИ ЧЕРНЫХ СЛАНЦЕВ ПРОТЕРОЗОЯ В СВЯЗИ С МЕТАМОРФИЗМОМ ИСКОПАЕМОГО ОРГАНИЧЕСКОГО ВЕЩЕСТВА

I. Большое экономическое значение черных сланцев протерозоя как носителей промышленных концентраций благородных и редких элементов,меди, полиметаллов определяет целесообразность физико-химического подхода к анализу эволюции металлоносности этих пород.
2. Начиная с раннего диагенеза и катагенеза вплоть до регионально-метаморфических процессов низких ступеней примесь рудных элементов в сланцах не покидает своего главного носителя - органическое вещество. Меняется лишь характер химической связи металлов с органическим веществом. Индикатором таких преобразований являются порфириновые структуры, представляющие фрагменты былых биомолекул. При глубоком

катагенезе и на зеленосланцевой ступени регионального метаморфизма ископаемые металлопорфирины входят в структуру геополимеров (керогенов), отражая наиболее высокий уровень фоновой осадочно-катагенетической металлоносности в геологической истории конкретного блока литосферы.

3. На прогрессивной линии регионального метаморфизма рудная примесь десорбируется фильтрующимися водно-углекислыми растворами, генерируемыми самой породой, особенно обогащенной органическим веществом. В процессах метаморфического роста минералов примесь освобождается по механизму оствальдовской перекристаллизации, а также при растворении минерала-носителя. Кристаллизующийся при метаморфизме за счет металлоносных геополимеров графит от рудной примеси очищен. Все эти процессы обуславливают возникновение направленной миграции рассеянной примеси в верхние слои литосферы, т.е. в зоны земной коры с менее напряженными Р- и Т-параметрами.

4. Регрессивный метаморфизм при тектонической активизации сопровождается фракционированием рудной примеси между минеральной и органической фазами породы. В активизированных блоках примесь проходит ряд уровней концентрирования: от фоновых содержаний через металлоносные вторичные битумоиды до сульфидной формы нахождения Au, Ag и окисной формы U или V .

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TECTONOTHERMAL EVOLUTION OF THE LOWER TO MIDDLE PROTEROZOIC CONTINENTAL CRUST

Whereas some Proterozoic orogenic regions have characteristics of Andean-type continental margins, other large regions world-wide appear to have an ensialic type of orogeny unrepresented in the modern tectonic setting. Throughout much of Australia, the lower to middle Proterozoic (2000-1400 Ma) is typified by a remarkable consistency of tectonic style of the latter type. The main features are:

1. Broad, shallow sedimentary basins with laterally extensive facies and little evidence for substantial tectonic relief.
2. Deformational histories initiated by thrusting and/or recumbent folding of considerable extent, overprinted by one or more upright fold events, the first of which is generally penetrative, near peak grade and involves substantial shortening, and the later of which are more restricted in extent and retrograde.
3. Low pressure metamorphic facies, with P-T-t paths atypical of modern collisional orogenic terrains.

4. Large volumes of I-type, K-rich felsic magma, apparently derived from a mafic igneous parent of somewhat unusual composition and short crustal residence time. The major felsic igneous avent at about 1850 Ma separates the two main sedimentary.
These constraints imply that during the protracted period of high heat flow in these regions, extensional crustal motions were limited, precluding the formation of large ocean basins. The implications for mantle-crust interactions are discussed.

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EVOLUTION OF PROTEROZOIC LITHOSPHERE OF SIBERIAN PLATFORM

The end of the Archaean tectogenesis was marked by the formation of granulitic protocrust. The matrix of the early Proterozoic tectonosphere was determined at the beginning of this megachron by the emerged gigantic and ramified system of riftogenic mantle structures (greenstone belts) several thousand kilometres long. They split the protocrust into large segments (protocontinents). The evolution of the lithosphere is considered here at the example of this system's superstructure: the Principal (Baikal-Vitim) Belt (volcanogenic-sedimentary and ferruginous-siliceous formations) and the marginal zone of the protocontinent adjacent to the Principal Belt. The marginal zone granulitic basement, segmented by satellite belts of the first stage rifting, accumulated sequences of the shelf type. Parallelly, volcanism was effecting the Principal Belt.

Heat and fluid flows whose shape was controlled by rift zones brought about regional Barrovian zone metamorphism (from chlorite-sericite to sillimanite zones), granitization, together with the formation of muscovite-biotite granites and transcontinental blastomylonite sutures. There is much evidence of secondary metamorphism and granitization of granulitic protocrust. Formation of the mature continental crust with "granite" layer was over by no earlier than the end of the early Proterozoic. To this testify the appearance of volcano-plutonic association with K alkalinity and red molasses 1.65 b.y. old.

On the whole, the style of the early Proterozoic evolution is characterised by maximum continentalization of the Archaean protocrust. At the same time, central parts of the protocontinents, being far away from rift zones and unexposed to secondary metamorphism and granitization, have preserved their structures of newly formed continental crust in a form of relict segments.

The late Proterozoic shows the stbilizing tectonics and global accumulation of sedimentary sequences of the platform type. The base of the platform cover reveals rift structures (aulacogenes). There is a distinct discordance between the cover and the structure of the basement.

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ЭВОЛЮЦИЯ ПРОТЕРОЗОЙСКОЙ ЛИТОСФЕРЫ СИБИРСКОЙ ПЛАТФОРМЫ

Архейский тектогенез завершился формированием гранулитовой протокоры. Матрица раннепротерозойской тектоносферы была задана в начале этого мегахрона возникновением гигантской и разветвленной системы рифтогенных структур мантийного заложения (зеленокаменных поясов) протяженностью в несколько тысяч километров. Они расчленили протокору на крупные сегменты (протоконтиненты). Эволюция литосферы рассматривается на примере суперструктуры этой системы - Главного (Байкало-Витимского) пояса (вулканогенно-осадочная и железисто-кремнистая формации) и краевой зоны протоконтинента, прилегавшей к Главному поясу. В краевой зоне на гранулитовом фундаменте, расчлененном поясами-сателлитами первого этапа рифтинга, накапливались толщи шельфового типа. Синхронно им в Главном поясе продолжался вулканизм.
С тепловыми и флюидными потоками, контуры которых регулировались зонами рифтогенеза, связаны региональной зональный метаморфизм барровианского типа (от хлорит-серцитовой до силлиманитовой зон), гранитизация с образованием мусковит-биотитовых гранитов и формированием трансконтинентальных бластомилонитовых швов. Мощно проявлены процессы повторного метаморфизма и гранитизации гранулитовой протокоры. Окончательное становление зрелой континентальной коры с "гранитным" слоем произошло лишь к концу раннего протерозоя. Об этом свидетельствует появление вулкано-плутонической ассоциации с калиевой тенденцией щелочности и красноцветных молассс с возрастом I,65 млрд.лет.

В целом стиль раннепротерозойской эволюции - максимальная континентализация архейской протокоры. Вместе с тем центральные части протоконтинентов, удаленные от зон рифтогенеза и не затронутые повторным метаморфизмом и гранитизацией, сохранились в структуре новообразованной континентальной земной коры в виде реликтовых сегментов.

Поздний протерозой - тектоническая стабилизация и повсеместное накопление осадочных толщ платформенного типа. В основании платформенного чехла обнаруживаются рифтовые структуры (авлакогены). Отчетливо проявлена общая дискордансия чехла в структуре фундамента.

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WORLD WIDE EARLY TO MID-PROTEROZOIC CORRELATIONS

Early to Mid-Proterozoic systems with ages between 2.4 and 1.6 Ga exhibit striking similarities on the global scale. Correlating features are pointed out in the following orogenies: Svecokarelian (Baltic Shield), Ukrainian (USSR) , Circum Ungava (E Canada), Woopmay (W Canada), Penokean (USA), Transamazonian (Brazil), Eburnian (Africa), Wutai (China), Aravalli (W India), Singhbhum (E India) and Capricorn (Australia).
The correlations suggest a world-wide orogenic system evolved by manyfold plate-tectonic processes. The individual orogenies can be classified into three types, the continental margin type, the continent-continent collision type and ensialic type. Although the Early to Mid-Proterozoic systems are well comparable to the Alpine-Himalaya-Circumpacific orogenies both by scale and by processes, several dissimilarities are pointed out and discussed.

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ASSEMBLY AND GROWTH OF THE NORTH AMERICAN CRATON IN PROTEROZOIC TIME

Applying Helwig's (1974) concept of tectonic "collage" to the contiguous Precambrian of North America as a whole gives powerful insights into the formation of the craton in terms of lithospheric plate tectonics. Clustered about the present shield are at least three independent Archean cratons (Superior, North Atlantic, and composite Slave-Northwest Churchill-Wyoming) that converged and were consolidated between 1.9 and 1.8 Ga, based on U/Pb zircon chronologies of the enclosing Penokean, Trans-Hudson and Wopmay orogens. These linear orogens preserve passive margin depositional prisms, foreland thrust-fold belts and associated foredeeps, "calc-alkaline" magmatic arcs, obducted oceanic crust (in Cape Smith Klippe), allochthonous microcontinents, and other features indicating the existence of former oceans between the Archean cratons. The multiple collision events recorded in these orogens are closely spaced in time but not synchronous, and may be compared with the grand assembly of much of Eurasia in Permo-Triassic time. Between 1.8 and 1.7 Ga, the southern midcontinent grew by southward accretion of juvenile crust--island arcs, periarc basins and outer-arc accretionary prisms. From 1.6 to 1.1 Ga, the present-day southeast side of the new continent was intermittently perforated by shallow-level "anorogenic" plutonic complexes (syenogranite, anorthosite, etc) and related volcanics, suggesting an active (Andean?) margin on that side. At about 1.1 Ga, this margin experienced extreme crustal thickening and erosion, transgressing older Proterozoic and Archean crustal elements, during terminal Grenvillian collisional orogeny. Subsequently, the size of the continent was reduced by very late Proterozoic rifting that formed the Cambro-Ordovician margins of Paleozoic North America. It is noteworthy that the Canadian Shield is not representative of the North American Precambrian as a whole, being heavily biased in favour of Archean crust. The location and persistence of the shield about the old Archean cratons suggests a positive correlation between the buoyancy of cratonic lithosphere and its antiquity.

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CRUSTAL EVOLUTION OF THE KIBARAN BELT IN EAST-CENTRAL AFRICA

The section of the Kibaran fold belt which in exposed in Burundi, **is** composed of supracrustal rocks which have been metamorphosed mainly in the greenschist, locally in the amphibolite facies.

An intense granitic magmatism has occured during the entire evolution of the belt : besides less important pre-tectonic biotite granites, numerous intrusions of two-micas granites are emplaced synkinematically with an early (D1) phase of deformation, responsible for an intense foliation and local isoclinal folds. The granitic magmatism started around 1350 Ma, probably shortly after the deposition of the sediments. This D1 tangential deformation, associated with granitic intrusions lasted until ± 1200 Ma.

During a D2-deformation, consisting in open upright folds other peraluminous granites are emplaced. The paroxysm of this last deformation is a lateral shear, contemporaneous with the intrusion of other granite bodies as well as mafic and ultramafic bodies.

A model for the crustal evolution of the belt is proposed, in which the evolution of the belt is entirely ensialic. Granitic and basic magmatism occuring during a long period of time is considered to be related with lithospheric thinning and extension, but without rupture. The main deformation, ending with local shear around 1100 Ma, and accompanied by mafic and ultramafic intrusives is supposed to be connected with continental collision in a southern branch of the Kibaran belt.

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LATE PRECAMBRIAN OPHIOLITES AND CONTINENTAL ACCRETION IN NORTHEAST AFRICA AND ARABIA

The Pan-African evolution of the Arabian-Nubian shield has been interpreted in terms of quasi-continuous horizontal accretion, since about 950 Ma ago, of oceanic island-arcs, closure of marginal seas and eventual collision of the emerging juvenile crustal segments with the African "Nile Craton" of presumed Archaean to lower Proterozoic age at the end of the Precambrian.

Early tonalitic plutons in the southern Red Sea Hills of the Sudan are geochemically and isotopically akin to their counterparts in the southern Arabian shield and have an age of c. 900 Ma, thus confirming that Pan-African evolution began virtually simultaneously on both sides of the present Red Sea.

Extremely well preserved ophiolites in the Eastern Desert of Egypt and in the Red Sea Hills of the Sudan contain sheeted dyke complexes and testify to the operation of sea-floor spreading in the late Precambrian (c. 800 Ma ago). In southern Egypt the Wadi Ghadir ophiolite reveals a complete succession of ancient ocean crust that has been thrust over a continental margin type sequence of metasediments and granitoid gneisses. In Wadi Onib, Sudan, the ophiolite is tectonically dismembered but all elements of the suite can be recognized. The ultramafic portion of the complex is exceptionally well preserved,and Sm-Nd isotopic systematics on primary clinopyroxenes will be reported. Remnants of strongly dismembered ophiolites are found throughout the southern Eastern Deseet of Egypt and in the Red Sea Hills of the Sudan and mainly consist of tectonic mélanges composed of ultramafic rocks.

Broad regional correlations suggest that all these ophiolites or fragments mark ancient sutures comparable to those in Saudi Arabia, where large oceans and/or marginal basins closed during the Pan-African episode.

Structural data indicate large-scale overthrusts in Egypt and the Sudan implying extensive horizontal shortening and nappe emplacement to the west and northwest. Major tectonic boundaries in the shield appear to delineate several tectonic provinces or tectonic belts that are distinct from each other in terms of age, rock type, metamorphism and style of deformation. These crustal segments may constitute a collage of previously independent exotic terranes that accreted by oblique convergence and strike-slip translation rather than by right-angle collision following continuous subduction.

The generally low degree of regional metamorphism in the suture belts, anomalously high ages in several segments of the Arabian shield and palaeomagnetic data on gabbros in the Sudan and the Wadi Ghadir ophiolite in Egypt support this view of mixed microcontinent and arc accretion. This model is also more in line with crustal growth rates during the Pan-African event than previous suggestions involving accretion of only juvenile crust.

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THE REWORKING OF THE NORTH CHINA CRATON DURING PROTEROZOIC TIME AND ITS IMPLICATION FOR THE EVOLUTION OF THE LITHOSPHERE

Major crustal forming events occurred at the end of the Archean (2.5 Ga ago) through which large crustal segments centering around North China came into existence. This craton was subsequently disrupted during extensive Proterozoic reworking, which is characterized by the formation linear shear belts, different types of ensialic basins, mobile belts and strong ensialic orogeny. However, general consolidation of the basement was again brought about at the end of early Proterozoic (1.85 - 1.7 Ga ago). The middle Proterozoic initiated an era of rigid continental platform, that produced aulacogens, rifted margins and the coeval emplacement of anorthosites, rapakivi granites potassium acid volcanics and basic dyke swarms, which suggest an intracontinental rifting event occurred at a particular time in the cooling history of the Earth, a time that roughly coincides with the changeover to the modern plate tectonic process.

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THE CHARNOCKITE-QUARTZO-FELDSPATHIC GNEISS-KHONDALITE SUITES OF ROCKS OF SOUTH KERALA, INDIA AND THEIR INTERRELATIONSHIP

The Precambrian crystalline rocks of Kerala, formed of the Charnockite-Quartzo-feldspathic gneiss-khondalite suites of rocks exhibit records of the major tectonic and thermal events relating to the crustal evolution of southwest India. Imprints of four phases of deformation are discernible in the structural styles of these rocks. The ages for these crystalline rocks and the associated intrusives cluster around 2700 m.y., 1600 m.y., 1000 m.y., 700 m.y. and 500 m.y. The interrelationships of these diverse suites of rocks are not yet clear due to widespread migmatization caused by anatectic melting at depth during granulite facies metamorphism and due to magmatic activity along the deep crustal fractures. Varieties of gneissic rocks in the region have developed due to migmatization aided by shearing. The geochemical and mineralogical data suggest the basic and ultrabasic charnockites to be of igneous (proto-crust.) and the Khondalites to be of sedimentary parentages.

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PROTEROZOIC AND LATE-ARCHAEAN GRANULITE TERRAINS AS COLLISIONAL OROGENS

Extensive tracts of granulite-facies rocks have been described on every continent. Their ages are mostly 2700 to 900 my. Almost all well-described occurrences have the following features:
Early large-scale nappes, flat thrusts, and flat foliation parallel to layering. Dominant horizontal-type deformation early in the meta-

morphic history is documented in at least 17 terrains. Commonly, high-grade metamorphism outlasted overthrusting.

Supracrustal rocks. All granulite terrains have, in addition to massive pyroxene gneisses, isofacial assemblages of layered rocks which may include quartzites, calcsilicates and marbles, metapelites, and amphibolites. The lithology suggests a continental shelf or passive margin environment. In some terrains, the layered sequences may be dominant.

Gradational metamorphism. Most granulite provinces have at least one margin where amphibolite-facies rocks grade into granulite-facies rocks over distances of ten to hundreds of km. The inferred paleotemperature change may be 100°C to about 800°C in the highest grade areas. The transition interval commonly contains migmatites, a more-or-less well-defined orthopyroxene isograd, patchy charnockitic mottling of gray gneiss, and, in some cases, especially abundant supracrustals. Often, a structural discontinuity, as a shear zone or thrust, separates the highest-grade area from its surroundings. Southern Karnataka and the Broken Hill, Australia, area are examples of unbroken transition regions.

In addition, many granulite terrains also show the following features:

Large-ion lithophile (LIL) depletion. This is shown in the highest grade terrains. Transition-zone granulites that have been studied have not shown great depletion of U or Rb.

CO_2-rich fluid inclusions in quartz and feldspar. Many studies have revealed high-CO_2 (75 mol %) inclusions in transitional charnockites and high-grade granulites. Evidence for high CO_2 activity exists indirectly in mineralogically-deduced decrease of H_2O activity with increasing grade.

Pressure increase across the transition zone. This has been well-documented for the Adirondacks, southern Karnataka and Broken Hill. Five to six kbar is characteristic of the transition zone and seven to ten kbar of the highest grade zone.

The foregoing features are all consistent with continent-continent or island-arc-continent collision as a fundamental cause of granulite metamorphism. The horizontal structures imply some form of plate tectonics. Shelf sediments overridden in continental collision are a plausible source of deeply-buried CO_2, although limestone subducted prior to collision, with carbonation of the mantle wedge, is also plausible. A number of recent studies have implicated a shelf or cover sequence, perhaps with evaporites, as a lubricating surface for continent-scale overthrusting. Stratigraphic sources of Be, F and B, characteristic of the chemistry of many granulites, are more plausible than mantle sources. Destabilization of biotite by rising CO_2 probably best explains Rb depletion. The ubiquitous 7 - 10 kbar pressures of the highest-grade terrains is equivalent to burial beneath an overriding continent of 25 - 35 km thickness. The old age of most granulites suggests that the temperatures prevailing at the base of continents were higher in the Precambrian than at present. Even so, an additional source of heat, such as magmatism, is probable needed to account for most Proterozoic granulites.

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LOCALIZATION OF CRUSTAL ADDITION IN T'E PRECAMBRIAN

The applicability of modern plate tectonic and crustal growth processes to the Precambrian is assessed by comparing Phanerozoic crustal addition rates and patterns to the formation rates and geometries of certain Precambrian terrains. Phanerozoic crustal addition along magmatic arcs occurs at the average rate of about 30 km^3 per Ma per km of arc. This gives a worldwide addition rate of about 1.1 km^3 per year and an efficiency ratio of about 0.07 between continental crust produced and oceanic crust subducted. Other addition processes such as hotspot volcanism raise the total Mesozoic-Cenozoic addition rate to about 1.7 $km^3\ a^{-1}$. The Late Proterozoic Arabian Shield and Archean Superior Province, as well as other Proterozoic North American provinces of similar size, have rates of addition on the order of 1 $km^3\ a^{-1}$. To form these terrains one needs to concentrate in one area arc systems comparable in total length to the present-day global network of trenches. This requirement can be seen by calculating the addition rate of these Precambrian terrains per km of length along their structural grains. One obtains 300-400 $km^3\ km^{-1}\ Ma^{-1}$, an order of magnitude larger than the Phanerozoic arc addition rate. The present-day distribution of arc systems and plate movements will not result in a localization of arcs. Instead, long narrow belts of material will be welded to the continents. The final stages in the cratonization of the Precambrian terrains is often characterized by widespread intrusion of granites. This is difficult to explain in terms of modern plate margin processes. We conclude that the evolution of the Precambrian crust is characterized by localization of crustal addition by processes which have not been operating during the last few hundred million years.

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PROTEROZOIC LITHOSPHERE OF THE EAST EUROPEAN PLATFORM (COMPOSITION, STRUCTURE, EVOLUTION)

Geophysical investigations of the East Europenian platform deep structure suggest that the lithosphere thickness is 150-250 km, with MOHO discontinuity located at 30-65 km beneath the surface. The upper mantle shows a significant inhomogenity in density and composition; lithosphere is divided into geoblocks by broad zones (30-70 km width) of deep-seated faults. Development of the Proterozoic platform basement resulted in formation of a certain age succession of structure with different tectonic regimes, that marked the cycles of geoenergetic reactivation of the lithosphere. Conditions of development of the endogenic processes exhibited an unidirectional trend from one cycle to another due to the structural and compositional evolution of the lithosphere. The following three episodes of reactivation occurred during the Proterozoic gegachrone (about 2,0 b.y. duration). The Karelian episode (2,7-2,3 b.y.) is documented by fault zones controlling the location of the superimposed mogeosynclinal troughs and also by evidences of ultrametagenic granitization in geoblocks of the Archean crust that resulted in thickening of the granite-gneiss layer and reactivation (2,1-1,7 b.y.) resulted in formation of the extensive mobile belt along the western platformal margin accompanied by faults of various depths outside the belt and, in addition, by numerous orthomagmatic intrusions including ore-bearing ones. The stabilization by the end of the episode is accounted for the formation of the Early Proterozoic crystalline basement. During Dalslandian-Baicalian episode (1,3-0,8 b.y.) the Riphean folded frame of the platform and the block-faulted structure of the lithosphere under aulacogen-platformal regime were formed, the latter being preserved up to the present time.

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ПРОТЕРОЗОЙСКАЯ ЛИТОСФЕРА ВОСТОЧНО-ЕВРОПЕЙСКОЙ ПЛАТФОРМЫ (СОСТАВ, СТРОЕНИЕ, ЭВОЛЮЦИЯ)

По данным комплексного геофизического изучения глубинного строения Восточно-Европейской платформы мощность современной литосферы составляет I50-200 км с разделом Мохо на глубинах от 30 до 65 км; верхняя мантия имеет существенную плотностную и вещественную неоднородность; литосфера разбита широкими зонами (30-70км) глубинных разломов на геоблоки (В.А.Дедеев, Л.Е.Шустова). Анализ истории геологического развития фундамента платформы в протерозое свидетельствует о формировании в определенной возрастной последовательности структур различного геотектонического режима, отмечающих периоды (циклы) геоэнергетической активизации литосферы. Условия проявления эндогенных процессов при этом направленно менялись от цикла к циклу вследствие структурной и вещественной эволюции литосферы. В течение протерозойского мегахрона (длительность около 2,0 млрд.лет) проявились три эпохи активизации, разделенные периодами покоя и накопления энергии: карельская (PP^{I}_{I}) в интервале 2,7-2,3 млрд.лет, свекофеннская (PP^{2}_{I})- 2,I-I,7 млрд.лет, дальсландская-байкальская (PP_2) - I,3-0,8 млрд. лет. От карельской эпохи в современном строении фундамента сохранились отдельные зоны разломов, контролировавших местоположение наложенных прогибов миогеосинклинального типа, а также признаки ультраметагенной гранитизации архейской коры геоблоков, обусловившей увеличение мощности гранито-гнейсового слоя и последующую общую стабилизацию литосферы. Свекофеннская эпоха активизации характеризовалась формированием обширного подвижного пояса на западной окраине платформы и разломов разной глубинности за его пределами, а также многочисленных, в том числе рудоносных, интрузий глубинного происхождения. Стабилизация в конце эпохи сформировала единый раннепротерозойский кристаллический фундамент платформы. В дальсландско-байкальскую эпоху образовалось рифейское складчатое обрамление платформы и в условиях авлакогенно-платформенного режима сформировалась разломно-блоковая структура литосферы, сохранившаяся до наших дней.

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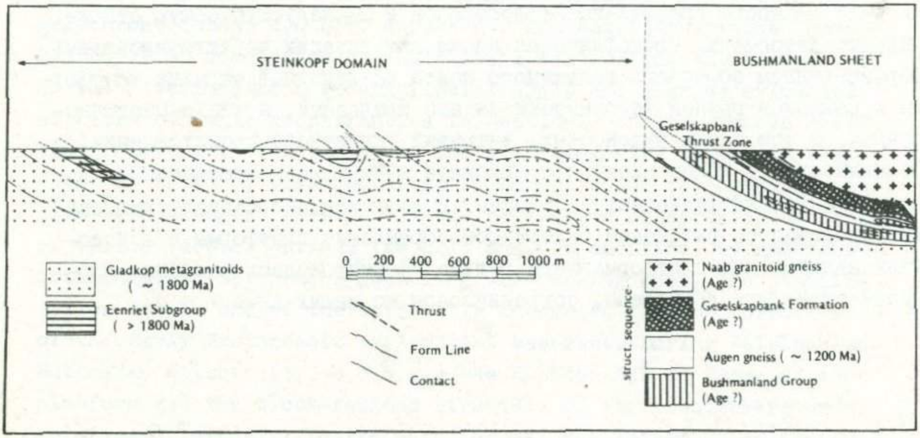
A CONTRIBUTION TO THE TECTONIC AND STRATIGRAPHIC CORRELATION OF PROTEROZOIC ROCKS IN NAMAQUALAND AND BUSHMANLAND, SOUTH AFRICA

The Proterozoic region of Bushmanland and Namaqualand presents severe problems of correlation because of horizontally disposed extreme deformation and associated metamorphic transformation of plutonites, volcanites and sedimentary rocks. Ever since the discovery in the previous decade of large stratabound sulphide ore deposits (Aggeneys, Gams), the correlation problem has been highlighted because of the necessity of effecting functional stratigraphic correlation between structurally separated metasediments. The predominantly horizontal disposition of lithologic types seems simple, but is shown by detailed investigation to be in part the result of complex structural relations involving low angle thust sheets, which were themselves deformed.

Mapping of critical areas in Bushmanland were carried out simulataneously with structural and stratigraphic analyses since 1978. The first synthesis of these results is in good agreement with the model previously developed for the adjacent

Namaqua Geotraverse. According to this model the main Namaqua orogeny involved large scale movement of regional thrust sheets in the order of 100 km. The thrust sheets were rendered ductile by the emplacement of large volumes of granitoid rocks today represented by augen gneisses.

The illustrative section shows the relationship between the Bushmanland thrust sheet and the Steinkopf domain. These two structural units are in contact along the Geselskapbank thrust zone, interpreted as a ramp zone of regional significance. The example illustrates the stratigraphic correlation problems encountered in this area. Does the Eenriet Subgroup belong to the economically important Bushmanland Group or not?



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EARLY PROTEROZOIC OROGENIC PROVINCES IN THE CENTRAL UNITED STATES

U-Pb geochronology, with other studies, permits improved understanding of Early and Middle Proterozoic evolution of the southern portion of North America. The Archean Superior Province is truncated south of Lake Superior by 1.8 to 1.9 Ga old orogenic suites that may be remnants of accreted arc systems. To the west, the Wyoming craton is flanked on the south by 1.7 to 1.8 Ga old orogenic suites that may also include remnants of arcs. Subsurface samples between these two regions indicate general continuity of units about 1.8 Ga old. Data from the southwestern United States and from basement samples from the continental interior indicate that the 1.7 to 1.9 Ga old provinces are flanked to the south by igneous rocks 1.6 to 1.7 Ga old. This younger province may represent lateral accretion to the south or may be partially developed upon older Proterozoic basement. These Early Proterozoic terranes have been intruded by Middle Proterozoic plutons, with volcanic units locally preserved. The largest suite is 1.45 Ga old, but a 1.36 Ga old suite occurs in the southcentral U.S. These suites probably formed by partial melting of Early Proterozoic and may not represent lateral growth.

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COMPARATIVE CHARACTERISTICS OF THE LITHOSPHERE OF THE RUSSIAN PLATE, THE SIBERIAN PLATFORM AND THE WEST-SIBERIAN PLATE FROM SEISMIC OBSERVATIONS ON LONG-RANGE PROFILES

During the last decade, deep seismic sounding observations on the profiles 3000 km and more long were carried out in the USSR. These observations provide data on the deep structures of the platforms of different age down to depth of several hundred kilometers. The most abundant data were obtained for the old Siberian platform and the young West-Siberian plate. The main results of the comparison between the structures of these regions are as follows. While the elevations of the Earth surface and the thicknesses of the sedimentary layer are almost the same in the both regions, the crust-mantle boundary of the Siberian platform is deeper by 4-5 km. The average ratio of velocities of the compressional and shear waves in the lower crust is somewhat higher in the Siberian platform and there is a difference in the distributions of this ratio with depth. In the upper mantle of the regions considered, continuous low-velocity layers and numerous indications of lateral heterogeneity were found. The seismic data will be interpreted in terms of composition and dynamics of the lithosphere.

В последнем десятилетии на территории СССР выполнены работы ГСЗ на ряде профилей длиной до 3000 км и более. Эти наблюдения позволяют, в частности, сравнить строение литосферы платформ различного возраста. При этом наиболее полные данные имеются для древней Сибирской платформы и молодой Западно-Сибирской плиты. Основные результаты сравнения структуры литосферы этих регионов заключаются в следующем.

I. При близкой высоте рельефа дневной поверхности и близких мощностях осадочного чехла глубина границы Мохо Сибирской платформы на 4 - 5 км больше, чем в пределах Западно-Сибирской плиты.

2. Среднее значение отношения скоростей продольных и поперечных волн в консолидированной части коры для Западно-Сибирской плиты несколько ниже, чем для Сибирской платформы. Наблюдаются различия в изменении этого отношения с глубиной.

3. В обоих регионах на глубине до 400 км прослеживаются слои пониженной скорости продольных волн и имеются многочисленные свидетельства латеральных изменений структуры верхней мантии.

Будет сделана попытка интерпретации сейсмических данных в терминах состава и динамики литосферы.

ГЕОЛОГИЯ СОВЕТСКОГО СОЮЗА
GEOLOGY OF THE USSR

Conveners: L.I.Krasny, V.M.Volkov

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GEOLOGY OF KAZAKHSTAN AND CENTRAL ASIA

The generalized information is presented on the geology and geological history of Kazakhstan and Central Asia which include large fold mountains belonging to the Ural-Mongolian and Mediterranean fold belts, and the North Caspian basin of the East-European craton. The principal features of the mosaic-shaped block structure, sedimentation, magmatism and metallogeny of major geosynclinal areas are discussed. The evolution of the crust is considered as a successive change from protogeosynclines to young platforms and tectonic reactivation.

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ГЕОЛОГИЧЕСКОЕ СТРОЕНИЕ КАЗАХСТАНА И СРЕДНЕЙ АЗИИ

Приводится обобщенная информация о геологическом строении и истории геологического развития территории Казахстана и Средней Азии, на которой расположены крупные складчатые сооружения, входящие в состав Урало-Монгольского и Средиземноморского складчатых поясов, а также Прикаспийская впадина Восточно-Европейской платформы. Дается харак-

теристика главнейших геосинклинально-складчатых областей, основных черт их мозаично-блокового строения, особенностей осадконакопления, магматизма и металлогении. Становление земной коры рассматривается на фоне последовательной смены тектонических режимов - от протогеосинклинального до режима молодых платформ и активизации.

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GEOLOGICAL STRUCTURE OF THE ALTAI-SAYAN FOLD AREA AND TRANS-BAIKAL REGION

The Altai-Sayan fold area and Trans-Baikal region were formed during the Baikalian and Caledonian orogenies and were later deformed by the Variscan ($D-T_1$), Pacific or Kimmerian (T_3-J), Alpine (K_1-P) and neotectonic movements. The resulting structures can be classified into the following types: (1) the marginal fold systems (Proterozoic pericratonic Yenisei-Sayan and Baikal-Patom fold systems) with marginal volcano-plutonic belts, uplifted blocks of the reactivated substratum, and zones of polymetamorphism; (2) the eugeosynclinal Baikalides formed on the Karelian substratum (Baikal-Vitim and East Sayan-Tuva fold systems); (3) the Caledonides with a geoanticline style of geosynclinal development formed on the Stanovides and Baikalides substratum (Selenga-Yablonovyi fold area) and transformed to orogenic plutonic (D-C) and volcanic ($P-T_1$, T_3-J) belts; (4) the mosaic-shaped Caledonides with geosynclinal depressions of different types (early geosynclinal carbonate-siliceous-volcanogenic; late geosynclinal and inverted terrigenous, carbonate-terrigenous and terrigenous-molassic; orogenic inherited and superimposed volcanogenic-molassic and variegated molassic).
The diversity of structures is attributed to deep-seated inhomogeneities and to differences in the substratum and in the geodynamic environment. Optimal conditions are established for the localization of endogenic mineralization of the siderophile, siderophile-chalcophile and sialic types.

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ГЕОЛОГИЧЕСКОЕ СТРОЕНИЕ АЛТАЕ-САЯНСКОЙ СКЛАДЧАТОЙ ОБЛАСТИ И ЗАБАЙКАЛЬЯ

Области байкальской и каледонской складчатостей, по-разному преобразованные в эпохи варисского ($D-T_1$), тихоокеанского (киммерийского - T_3-J), альпийского (K_1-P) и неотектогенеза, являются ведущими для Алтае-Саянской складчатой области и Забайкалья. Различаются следующие типы и ранги структур. I. Складчатые системы ограничения платформы (перикратонные системы протерозоид - Енисейско-Саянская, Байкало-Патомская) с краевыми вулкано-плутоническими поясами, выступами ремобилизованного субстрата, зонами полиметаморфизма. 2. Байкалиды эвгеосинклинальные, заложенные на субстрате карелид (Байкало-Витимская и Восточно-Саяно-Тувинская системы). 3. Каледониды с геоантиклинальным стилем геосинклинального режима, развившиеся на субстрате становид и байкалид (Селенгино-Яблоновая область); со среднего палеозоя преобразованы в орогенные плутонические (D-C) и вулканические ($P-T_1$, T_3-J) пояса. 4. Мозаично построенные каледониды с шестью типами геосинклинальных прогибов (раннегеосинклинальные карбонатно-кремнисто-вулканогенные; позднегеосинклинальные и инверсионные терригенные, карбонатно-терригенные, терригенно-молассоидные; орогенные унаследованные и наложенные вулканогенно-молассовые, молассовые пестроцветные). Многообразие типов структур связано с глубинными неоднородностями литосферы, различиями субстрата и геодинамических обстановок. Показаны оптимальные обстановки локализации эндогенных проявлений минерализации сидерофильного, сидерофильно-халькофильного и салического типов.

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GEOLOGY OF THE URALS

A polycyclic development of the intracontinental Ural fold system is established. The most characteristic feature of the system is the presence of parallel linear zones reflecting a heterogeneous structure of the pre-Uralian basement and the specifics of the tectonic development of these zones. Based on this structural subdivision, a systematic description of the geology and development of the Ural foredeep and the West Ural, Greenstone, Ural-Tobol and Transuralian megazones is given. It is stated that these megazones were formed in different times. The effect of tension faults, overthrusts and nappes on the development of the megazones and of the Ural fold system as a whole is emphasized.

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ГЕОЛОГИЯ УРАЛА

Обосновывается полициклическое развитие внутриконтинентальной Уральской складчатой системы, наиболее характерной чертой которой является наличие продольных линейных зон, отражающих гетерогенное строение доуральского субстрата, а также специфику тектонического режима в период их формирования и последующего развития. На основе проведенного структурного районирования дается систематизированное описание геологического строения и развития Предуральского краевого прогиба, Западноуральской, Зеленокаменной, Урало-Тобольской и Зауральской магазон. Обосновывается асинхронность заложения линейных зон Урала, роль раздвигов, надвигов и шарьяжей в развитии отдельных мегазон, а также Уральской складчатой системы в целом.

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GEOLOGY OF THE USSR FAR EAST AND SURROUNDING SEAS

The USSR East is a north-western part of the Pacific belt where the lithosphere was subject to active movements in the Mesozoic and Cenozoic. It is divided into the Western continental segment and the Eastern transitional segment by the East-Asiatic volcanic belt. The zone bordering the ocean is extremely variable in structure. It includes a complex seismofocal region extending to a depth of 700 km and consisting of the upper low-velocity and the lower high-velocity lay-

ers, and the Kuril-Kamchatka island arc with its deep-sea trenches and marginal oceanic ridges.
The Precambrian basement of the continental segment is broken into *median* and *marginal masses* which were repeatedly regenerated in the Phanerozoic by igneous and tectonic adjustments. The segment includes the Verkhoyansk-Kolyma, Mongolia-Okhotsk, Sikhote-Alin, and Alazea-Oloi mobile systems. Three more mobile areas are confined to fault blocks: Chukotka, South Anyui, and Ilin-Tas.
New results have been recently obtained in the Eastern segment: (a) blocks of abnormal density and velocity were located in the mantle, and conductive layers were traced in the asthenosphere at depths of 80-100 km (Sakhalin) and 60-70 km (South Kurils); (b) heat flow was found to vary greatly from high values in the marginal seas to low in deep-sea trenches; (c) the continuously traceable acoustic basement indicates that the basement beneath the marginal seas is heterogeneous, folded and faulted, and variable in age; it is not compensated by young sediments.

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ГЕОЛОГИЧЕСКОЕ СТРОЕНИЕ ВОСТОКА СССР И ОКРАИННЫХ МОРЕЙ

Восток Советского Союза, составляющий северо-западную часть Тихоокеанского подвижного пояса, - регион с активными движениями в литосфере в мезозое и кайнозое. Граничным элементом, делящим его на *Западный континентальный сегмент и Восточный - переходный к Тихому океану* - служит Восточно-Азиатский вулканогенный пояс. Весьма контрастна полоса сочленения с океаном, включающая сложную сейсмофокальную зону (глубиной до 700 км) с верхним низкоскоростным и нижним - высокоскоростным слоями, Курило-Камчатскую островодужную систему с глубоководными желобами и периокеанскими валами. В результате раздробления неоднородного докембрийского фундамента в континентальном сегменте сформировались массивы (срединные и краевые), подвергавшиеся в *фанерозое неоднократной* тектоно-магматической регенерации. Главные подвижные системы этого сегмента - Верхояно-Колымская, Монголо-Охотская, Сихотэ-Алинская и Алазейско-Олойская, а также приуроченные к разломным ограничениям крупных блоков: Чукотская, Южно-Анюйская и Илинь-Тасская. Для Восточного сегмента получены принципиально новые результаты: а) в мантии прослеживаются блоки с аномальными значениями плотностей и скоростей и токопроводящие (астеносферные) слои на глубине 80-100 км (о.Сахалин), 60-70 км (Южные Курилы); б) выявлены сильно варьирующие значения теплового потока, максимальные в окраинных морях, минимальные - в глубоководных желобах; в) повсеместно прослеженный акустический фундамент свидетельствует о неоднородном разновозрастном складчато-глыбовом основании краевых морей с молодым некомпенсированным осадконакоплением.

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STRUCTURE AND TECTONIC HISTORY OF SIBERIAN CRATON

Deep structure and geotectonic subdivision of the Siberian craton and Taimyr are given. Evolution of the Earth crust of the region in more than 3.5 billion years is discussed, and a stage-by-stage sequence in the formation of the folded metamorphic basement, sedimentary complexes and arch-block and riftogenic structures is established. An originally heterogeneous nature of the crust and directional-polycyclic formation of the volcano-sedimentary cover concurrent with large-scale global movements are demonstrated. It is stated that the craton was subjected in Mesozoic and Cenozoic times to different deformation processes caused, to a certain degree, by horizontal movements. Specific metallogenic features of the development of the region at all the stages are discussed.

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ГЕОЛОГИЧЕСКОЕ СТРОЕНИЕ СИБИРСКОЙ ПЛАТФОРМЫ

Охарактеризованы главные черты глубинного строения и дано геотектоническое районирование Сибирской платформы и Таймыра. Рассмотрена эволюция земной коры региона на протяжении более 3,5 млрд.лет с обоснованием стадийности складчато-метаморфических областей фундамента, плитных комплексов чехла платформы, сводово-глыбовых и рифтогенных структур активизации. Устанавливаются изначальная неоднородность земной коры, направленно-полициклическое образование вулканогенно-осадочного чехла, синхронизированное с крупными глобальными движениями, а также разнотипные явления разрушения платформы в мезозое и кайнозое, обусловленные в определенной мере горизонтальными движениями. Изложены типичные особенности металлогении всех стадий развития региона.

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STRUCTURE AND GEOLOGICAL HISTORY OF THE MEDITERRANEAN FOLD BELT IN THE USSR

The principal stages of the complex cyclic geosynclinal development of the fold belt are discussed. The effects of Riphean, Early Paleozoic and Alpine tectonic adjustments are considered. It is shown that the Alpine orogeny, accompanied by tholeiite volcanism, embraced, in the second half of the Triassic period, nearly all the Mediterranean belt and produced complex but regularly zoned structures of the oceanic and island arc types, as well as median masses, in-

termontane basins, and platforms. The structure and evolution of large segments of the belt, such as the Carpathians, Crimea, Great Caucasus, and Pamirs, are briefly outlined. Different versions of the origin of the Caspian, Black Sea and other basins are considered.

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ОСНОВНЫЕ ЧЕРТЫ ГЕОЛОГИЧЕСКОГО СТРОЕНИЯ И РАЗВИТИЯ СРЕДИЗЕМНОМОРСКОГО СКЛАДЧАТОГО ПОЯСА В ПРЕДЕЛАХ СССР

Рассмотрены основные этапы сложного полициклического геосинклинального развития Средиземноморского складчатого пояса. Охарактеризованы роль и значение рифейской, раннепалеозойской и альпийской деструкций в его становлении и развитии. Показано, что альпийская с толеитовыми вулканизмом деструкция во второй половине триаса охватила почти весь Средиземноморский пояс и явилась причиной образования сложных, но вместе с тем подчиненных закономерной зональности, сочетаний структур океанского и островодужного типов, а также срединных массивов, межгорных впадин и платформ. Кратко охарактеризованы современные структуры и эволюция наиболее крупных сегментов пояса (Карпаты, Крым, Большой Кавказ, Памир), рассмотрены различные варианты образования Каспийской, Черноморской и других впадин.

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SOME ASPECTS OF GEOLOGY AND GEOLOGICAL HISTORY OF USSR TERRITORY ACCORDING TO NEW GEOTECTONIC CONCEPTS

On the basis of the Early Precambrian geodynamics and the theory of Neogean plate tectonics, the authors demonstrate a mechanism of the formation and history of Early and Late Precambrian geological structures (Aldan and Anabar shields, Baikalian mountain system and others), of the Siberian Craton, West Siberian Platform, and Neogean fold belts (Paleozoic Ural-Mongolian, Mesozoic Verkhoyano-Kolyma, Mesozoic-Cenozoic Alpine-Himalayan, and recent East Asian belts). Using new data on the deep structure of the USSR territory, different theoretical models of the lithosphere are discussed and a conclusion is made on the importance of spreading (with the absence of subduction) in the formation of major Early Precambrian structures; it is shown that apart from the cores of the tonalite protocrust and greenstone belts (paleorifts), these structures incorporate granulite belts, and also (in Early Proterozoic) ancient shelves. The formation and evolution of the Neogean structures were strongly affected by intensive subduction and rifting. The role of these processes in the formation and distribution of mineral deposits is illustrated.

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НЕКОТОРЫЕ АСПЕКТЫ ГЕОЛОГИЧЕСКОГО СТРОЕНИЯ И ИСТОРИИ РАЗВИТИЯ ТЕРРИТОРИИ СССР С ПОЗИЦИЙ НОВЫХ ГЕОТЕКТОНИЧЕСКИХ КОНЦЕПЦИЙ

С позиций геодинамики раннего докембрия и теории тектоники литосферных плит (для неогея) рассматриваются механизм образования и история развития геологических структур раннего и позднего докембрия (Алданский и Анабарский щиты, Байкальская горная область и др.), древней Сибирской платформы, Западно-Сибирской плиты и складчатых поясов неогея (палеозойский Урало-Монгольский, мезозойский Верхояно-Колымский, мезозойско-кайнозойский Альпийско-Гималайский, современный Восточно-Азиатский). С привлечением новых данных о глубинном строении территории СССР рассмотрены различные теоретические модели развития литосферы и сделан вывод о ведущем значении спрединга при отсутствии субдукции при формировании основных структур раннего докембрия, показано, что в составе последних наряду с ядрами тоналитовой протокоры и зеленокаменными поясами (палеорифтами) существенную роль имеют гранулитовые пояса, а в раннем протерозое и древнейшие шельфы. Обосновано широкое развитие субдукции и рифтинга в формировании и развитии структур неогея, на отдельных примерах показана их роль в образовании и размещении полезных ископаемых.

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GEOLOGY OF EAST EUROPEAN CRATON

The results of deep seismic sounding are used to demonstrate the horizontal and vertican heterogeneity of the Earth crust, which is manifested by a layer-block structural pattern of the craton basement. It is shown that individual basement blocks are separated by narrow mobile belts which have given rise to systems of faults still living at the present time. Specifics of the geology and evolution of the Vendian-Phanerozoic sedimentary cover are discussed, and the effect of numerous aulacogens and pericratonic depressions on the evolution of the sedimentary strata is emphasized. This is confirmed by the presence in the sedimentary cover of a smaller number (as compared to the other cratons, e.g. North American and African) of circular slightly depressed syneclises and by the absence of young orogenic uplifts. Epochs of activization and quiescence with inherent types of tectonic stresses and mineral associations are described.

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ГЕОЛОГИЧЕСКОЕ СТРОЕНИЕ ВОСТОЧНО-ЕВРОПЕЙСКОЙ ПЛАТФОРМЫ

С учетом новых материалов, полученных при проведении глубинного сейсмического зондирования, обосновывается горизонтальная и вертикальная неоднородность земной коры, находящая выражение в слоисто-

блоковом строении фундамента платформы. Показано, что отдельные блоки фундамента разделены узкими подвижными поясами, с которыми связано образование систем разрывных нарушений, не потерявших свою подвижность и в настоящее время. Выявлены особенности геологического строения и развития вендско-фанерозойского осадочного чехла платформы, в частности показано, что на его развитие большое влияние оказывали получившие широкое распространение авлакогены и перикратонные прогибы. В структуре чехла это находит отражение в меньшем, по сравнению с другими древними платформами (Северо-Американская, Африканская), развитии округлых пологих синеклиз и отсутствии молодых орогенических поднятий. В развитии платформы выделены и охарактеризованы эпохи активизации и успокоения со свойственными им типами тектонических напряжений и комплексами полезных ископаемых.

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GEOLOGY OF WEST SIBERIAN PLATFORM

This paper describes the main geological features and evolution of the West Siberian Platform - a gigantic depression filled with thick Mesozoic and Cenozoic strata of coastal-continental and marine sediments. Based on the latest data on the deep structure of the platform, the geology of its basement and distribution of Paleozoic sedimentary basins are discussed, and a general structural pattern and sedimentary succession are characterized. New data are demonstrated on the geology of regional segments of the platform (outer marginal belt, Middle Ob mega-anticlise, and Yamal-Taz megasyneclise) and on major structures of the platform cover: marginal slopes (monoclises), hemi-anticlises, internal closed uplifts (anticlises, arches, swells), and depressions (syneclises, basins and megadeeps).

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ГЕОЛОГИЧЕСКОЕ СТРОЕНИЕ ЗАПАДНО-СИБИРСКОЙ ПЛИТЫ

Рассмотрены основные черты геологического строения и история геологического развития Западно-Сибирской плиты - гигантской платформенной впадины, выполненной мощными толщами мезозойских и кайнозойских прибрежно-континентальных и морских отложений. С учетом

новейших материалов по глубинному строению плиты приводится систематизированное описание геологического строения фундамента и закономерностей размещения палеозойских седиментационных бассейнов, а также общая характеристика структуры и разреза платформенного чехла. Приводятся новые данные по строению региональных сегментов (Внешний прибортовой пояс, Среднеобская мегаантеклиза и Ямало-Тазовская мегасинеклиза) и крупнейших структур платформенного чехла: прибортовых склонов (моноклиз), гемиантеклиз, внутренних замкнутых поднятий (антеклиз, сводов, мегавалов) и депрессий (синеклиз, впадин, мегапрогибов).

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METALLOGENY OF THE USSR

A total of 87 types of metallogenic zones of stratified, intrusive and metamorphic complexes and residue layers have been identified and characterized with respect to their mineral potential, as is seen in new metallogenic maps of the USSR territory. Metallogeny of crustal structures is shown to be related to the specific development of shields, fold areas, platform cover, regions of orogeny and tectonic and igneous adjustments, rifts and aulacogens. Regularities in the evolution of ore formation are discussed, and major metallogenic epochs are identified and described. Principal types of metallogenic zones reflecting the trends of directional development of ore formation processes during the evolution of the lithosphere have been established.

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МЕТАЛЛОГЕНИЯ СССР

При составлении новой серии металлогенических карт на территории СССР выделено и с позиций рудоносности охарактеризовано 87 типов металлогенических зон, связанных с формированием стратифицированных, интрузивных и метаморфических комплексов, а также с корами выветривания. Металлогения структур земной коры увязана с основными закономерностями развития щитов, складчатых областей, платформенного чехла, областей орогенеза и тектоно-магматической активизации, рифтов и авлакогенов. Рассмотрены закономерности эволюции рудообразования, выделены и охарактеризованы главнейшие металлогенические эпохи, намечены важнейшие типы металлогенической зональности, отражающей закономерности направленного развития процессов рудогенеза в ходе эволюции литосферы.

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DEEP CRUSTAL STRUCTURE AND GEODYNAMICS OF THE LITHOSPHERE OF THE USSR TERRITORY

As a result of the integrated studies of the deep crustal structure of the USSR territory, new data have been obtained on geophysical fields, age, composition and structure of the sedimentary and granite-metamorphic layers (to a depth of 5-7 km), on the Earth's crust as a whole (to a depth of 30-60 km), and on the lithosphere and upper mantle layers (to depths of 300-700 km). On the basis of the geodynamic zoning, geodynamic systems have been singled out differing in energy and active geodynamic forces, in structure, composition and age. Principally new tectonic units (deep non-compensated depressions, marginal geosutures, rifts and tension fault structures) have been described, and a series of scientific concepts on geodynamic models of the Earth elaborated.

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ГЛУБИННОЕ ГЕОЛОГИЧЕСКОЕ СТРОЕНИЕ И ГЕОДИНАМИКА ЛИТОСФЕРЫ ТЕРРИТОРИИ СССР

При комплексном изучении глубинного геологического строения территории СССР получены новые материалы по физическим полям, возрасту, составу и структуре осадочного и гранитно-метаморфического слоев (до глубины 5-7 км), земной коры в целом (до глубины 30-60 км), литосферы и подкоровых астеносферных горизонтов верхней мантии (до глубины 300-700 км). Проведено геодинамическое районирование с выделением геодинамических систем, классифицированных по их энергетическому обеспечению и действующим геодинамическим силам, структурно-вещественным особенностям и возрасту слагающих пород. Охарактеризованы принципиально новые тектонические подразделения (глубокие нескомпенсированные впадины, пограничные шовные зоны, структуры раздвигов и растяжения), разработан ряд научных положений о геодинамических моделях Земли.

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MAJOR TRENDS OF GEOLOGICAL STUDIES IN THE USSR

This paper gives a brief account of the major achievements made in the basic disciplines of the geoscience in the USSR for the last 10-15 years, particularly, in stratigraphy, lithology, petrography, formational analysis, geochemistry, hydrogeology, tectonics, and geological cartography. Problems and progress in metallogeny, petroleum geology, and offshore geological exploration are discussed. Integration of the geoscience and geological practice is emphasized as a major tool of improving the effectiveness of geological exploration.

ОСНОВНЫЕ НАПРАВЛЕНИЯ ГЕОЛОГИЧЕСКИХ ИССЛЕДОВАНИЙ В СССР

Кратко охарактеризованы особенности развития основных отраслей геологической науки в СССР за последние 10-15 лет. Показаны отдельные важнейшие достижения в области стратиграфических, литологических и петрографических исследований, формационного анализа, геохимии и гидрогеологии, тектоники и геологической картографии. Освещены проблемы и успехи металлогении, геологии нефти и газа, морских геологических исследований. Подчеркнуто значение интеграции геологической науки и геологической практики как главнейшего условия эффективности геологоразведочных работ.

ЭНЕРГЕТИЧЕСКИЕ РЕСУРСЫ МИРА
ENERGY RESOURCES OF THE WORLD

Conveners: M.Halbouty, R.W.Hutchison, R.A.Sumbatov
Co-Conveners: F.Gutierez, I.Kapolyi, E.V.Karus, V.V.Semenovich

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CIRCUM-PACIFIC MAP PROJECT: ENERGY- AND MINERAL-RESOURCES MAPPING OF MORE THAN HALF THE WORLD

The Circum-Pacific Map Project is a cooperative international effort to depict the relation of known energy and mineral resources to major geologic features of the Pacific Basin. The project area extends from the Indian Ocean eastward to include western North and South America, and from the Arctic Ocean southward to include Antarctica. Innovative approaches to the compilation of resource and geologic data are being developed by participating geoscientists from some 35 countries.

The project operates through five regional panels representing the four quadrants of the Pacific (Northwest, Southwest, Southeast, Northeast) and Antarctica. Basic mapping is on five ocean-centered 1:10,000,000-scale equal-area maps. Basinwide syntheses are on 1:20,000,000- and 1:30,000,000-scale maps.

Now in its 11th year, the project has already completed 21 of 47 planned maps. Geographic, Base, and Plate-Tectonic Series are published. Initial Geologic and Mineral Resources Maps were printed late in 1983. Publication of Energy Resources and Geodynamics Maps will commence late in 1984. Basinwide manganese-nodule, seafloor-sediment, and tectonostratigraphic-terrane maps are in preparation. Compilation of larger scale maps in regions of major resource programs is under consideration as a Phase II effort.

The Map Project is an actifity of the Circum-Pacific Council for Energy and Mineral Resources. Project coordination and cartography are by U S Geological Survey, and the maps are being issued by the American Association of Petroleum Geologists.

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NEW DEVELOPMENTS ON GEOTHERMAL ENERGY ESPLORATION IN TURKEY

Turkey is located on the Alpine active tectonic belt. There are many grabens, wide spread asidic volcanism, hydrothermal alteration, fumeroles and a lot of springs 100°C temperature depend on the young tectonic activities. These data indicate that Turkey has very important geothermal energy potential. According to completed geological, geophysical and geochemical studies total 4500 MWe energy potential and at least 31000 MWt non-electrical uses have been expected. This amount is close to installed capacity of Turkey in 1982. This potential is very important for Turkey since energy shortage have been increased rapidly and the half of energy which is used in Turkey provided by imported petroleum .

The first economic geothermal field was discovered at Denizli-Kızıldere in Turkey in 1968. 20 MW of power plant has been constructed in this field. Drilling operations are increased and high enthalpy of two geothermal fields have been discovered in 1982. One of them is Aydın-Germencik field drilled in the first time and reached at 1002 m depth and found the first reservoir that has 200°C temperature and 13% steam in Miocene conglomerates . The second explatory well drilled in the same area and reached at 975 m depth in the second reservoir which consist of quartzite, gneiss and schists of Paleozoic age. Temperature is 231°C and steam content 20%. Third well completed at 1196 meters and BHT temperature is % 213°C. Total flow rate of the well is 235 tons/h steam and water mixture. According to Preliminary test results it has a 5 MWe capacity. The other field is Çanakkale-Tuzla. The first reservoir at 330 m depth and which has 173°C temperature and steam ratio is 13%. The second exploratory drilling is still continuing for the description of the second reservoir characteristics.

According to the field explorations of İzmir-Seferihisar area which has been expected high enthalpy of geothermal fields, in which deep exploratory drilling has began in 1982. In addition to these Nemrut, Süphan, Tendürek and Zilan areas which have effected by the young volcanism in the Eastern Anatolia are interesting for dry steam.

Non-electrical uses have also begun in 1982. İzmir-Balçova geothermal field has scaling problem. For this reason down-hole heat exchanger system has tested and shown thousand houses can be heated by one well. At the first step heating and cooling systems of the thermal and touristic buildings are connected to this down-hole heat exchanger in the vicinity. Determination of the geothermal energy possibilities of Balçova area are continuing for district and greenhouse heating. Testing down-hole heat exchanger and out-hole heat exchanger system successfully been done in Afyon geothermal area so that thermal buildings greenhouses and swimming pool heating have begun.

At the end of these results high and low enthalpy geothermal areas are useful for cover up energy shortage and therefore it will help country economy.

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LES REALISATIONS FRANCAISES DANS LE DOMANE DE LA GEOTHERMIE BASSE ENERGIE

Première partie: Presentation des Realisations Françaises

Dans cette partie sont abordés:

- le rappel historique du développement de l'énergie géothermique en France

  1970: première opération française

  1983: 40 opérations en service: 85 000 Tep économisées.

- le conditions géologiques, technico-économiques et juridiques qui ont permis son développement

  - les inventaires de ressources et de consommateurs: la détermination du potentiel géothermique français
  - la loi française: un atout majeur de ce développement.

- l'originalité des caractéristiques techniques des réalisations françaises comparativement aux techniques hongroises et islandaises

- le développement actuel et les perspectives d'avenir: 800 000 Tep économisées en 1990: les moyens à mettre en oeuvre pour atteindre cet objectif ambitieux

Deuxième partie: Presentation Détailée d'une Realisation Particulière: le Gas de Meaux

La plus importante opération géothermique française est présentée en détail depuis la genèse du projet jusqu'à l'exploitation.

Quelques chiffres caractéristiques: 20 000 Tep économisées annuellement grâce à 8 forages exploitant plus de 11 000 m3/h d'eau à 76 °C.

L'ensemble des caractéristiques techniques des installations sont détaillées dans cette partie. La question de la modélisation du déplacement des fronts thermiques et de la disposition optimale des puits fait l'objet d'une analyse spécifique.

Les différents aspects du montage juridique et financier de l'opération sont abordés et cet article conclut sur une analyse des premiers bilans économiques.

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MAIN TRENDS IN SOLID FOSSIL FUELS UTILIZATION

The development of public production and the increase of population lead to the constant growth of the requirements of organic fuel and the products of its processing. So, the world output and energy resources production in 1970 accounted for 4700 billion tonnes of coal equivalent fuel, in 1980 - 11000 billion tonnes of coal equivalent fuel. The quantity of energy resources to 2000 is proposed to achieve

25 billion tonnes of coal equivalent fuel, 30% being solid fuels.

Over a long period of time coal is a power-generating fuel and raw material for many branches of industry.

In future the significance of coal as a power-generating fuel and a raw material will be steadily increasing. Coal was and will be one of the main kinds of fuel for power plants. Coal requirements are increasing for the production of metallurgical coke. In addition to the blast-furnace coke production the coke production for non-blast-furnace processes will be increased (electrothermic production, the production of calcium carbide, ferroalloys, zinc, yellow phosphorus, copper and others).

Coal will be used on larger and larger scales for producing a wide assortment of materials (carbon graphite, carbon black, adsorbents and others), liquid and gaseous fuels as well as chemicals.

To extend the sphere of coals utilization it is desirable to process them on the basis of new technologies - hydrogenation under the pressure of 10 MPa, fluidized gasification, oil shale processing in gasifiers with a daily capacity of 1000 t and the processes in the presence of a solid heat carrier (УТТ-500).

The suitability of coals for either utilization trend shouls be estimated with regard for their matter composition and properties on the basis of commercial and genetic classification (GOST 2543-82).

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ОСНОВНЫЕ НАПРАВЛЕНИЯ ИСПОЛЬЗОВАНИЯ ТВЕРДЫХ ГОРЮЧИХ ИСКОПАЕМЫХ

Развитие общественного производства и увеличение численности населения приводят к постоянному росту потребности в органическом топливе и продуктах его переработки. Так, мировая добыча и производство энергетических ресурсов в 1970 г. составили 4700 млрд.тут, в 1980 г. - 11 000 млрд.тут. Ожидается, что к 2000 году количество вырабатываемых энергоресурсов достигнет 25 млрд.тут, из которых около 30% составят твердые виды топлива.

Уголь в течение длительного времени служит энергетическим топливом и технологическим сырьем для многих отраслей промышленности.

В перспективе значение угля как энергетического топлива и технологического сырья будет неуклонно возрастать. Уголь был и останется одним из основных видов топлива для энергетических установок. Возрастает потребность в углях для производства металлургического кокса. Кроме производства доменного кокса, в перспективе увеличится производство кокса для недоменных процессов (электротермические производства, производство карбида кальция, ферросплавов, цинка, желтого фосфора, меди и др.).

Уголь все в больших масштабах будет использоваться для получения широкого ассортимента углеродистых материалов (углеграфита, сажи, адсорбентов и др.), жидких и газообразных топлив, а также химических продуктов.

Для расширения сферы использования углей нецелесообразно осуществлять их переработку на основе новых технологических методов - гидрогенизации при давлении 10 мПа, газификации в кипящем слое, переработку сланцев в газогенераторах производительностью 1000 т/сут и переработку с использованием твердого теплоносителя (УТТ-500).

Оценку пригодности углей для того или другого направления использования целесообразно проводить с учетом их вещественного состава и свойств на основе промышленно-генетической классификации (ГОСТ 2543-82).

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THE WORLD OIL SHALE RESOURCES, ITS PRODUCTION AND UTILIZATION

According to the formation conditions the oil shales are divided into 2 large groups: sea and lake oil shales. The most oil shale deposits were formed during the platform and orogenic stages of crust development because geosynclinal conditions are less favourable for their formation. There exist several maxima of oil shale formation - in Cambrian, Ordovician, Permian, Jurassic and especially in Paleogene and Neogene where the oil shales of unique Green River formation are believed to date from. There are 14 oil shale provinces in the world. Many sources give different and often difficult to comparison figures of world oil shales and oil shale tar reserves. Taking into consideration the previous calculations the world oil shale tar reserves account for 550 billion tons. The large and unique deposits contain the majority of known reserves and are notable for low combustion heat (1,4 - 6,3 M Joule/kg) and low tar seep (5 - 10%-. The two thirds of oil shale reserves are characterized by low sulphur content (up to 2%). Taking into account the quick depletion of natural petroleum resources perhaps it is high time to evaluate seriously the world oil shale resources and on its base to develop the perspectives of synthetic liquid and gaseous fuel production. For this purpose in the first place it is necessary to develop common evaluation criteria of its world resources and make the corresponding calculation to the following 28th International Geological Congress.

The USSR and China have highly developed oil shale industry and the USA, Australia, Brazil and Morocco are actively trying to organize it. There are two main ways of oil shale utilization: as a fuel and the production of synthetic oil and gas based on their thermal processing. Energy-technological and energy-clinker use of oil shale is also possible as well as the recovery of rare and dispersed elements from them. Although many problems connected with oil shales are far from their solving the heightened interest and the proposed considerable exploration, exploitation and processing of them in the world are quite natural and justified.

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РЕСУРСЫ ГОРЮЧИХ СЛАНЦЕВ МИРА, ИХ ДОБЫЧА И ИСПОЛЬЗОВАНИЕ

По условиям образования горючие сланцы делятся на две большие группы: морские и озерные. Большинство сланцевых месторождений образовалось в платформенную и орогенную стадии развития земной коры; геосинклинальные условия менее благоприятны для их образования. Отмечается несколько максимумов сланцеобразования в кембрии, ордовике, перми, юре и особенно в палеогене и неогене, куда относятся сланцы уникальной формации Грин-Ривер. На земном шаре выделяется I4 сланценосных провинций. В различных источниках приводятся разные и часто трудносопоставимые цифры мировых запасов сланцев и сланцевой смолы. С учетом всех предыдущих подсчетов, мировые запасы сланцевой смолы оценены в 550 млрд.т. Большинство известных запасов содержится в крупных и уникальных месторождениях и отличается невысокой теплотой сгорания (I,4-6,3 МДж/кг) и низким выходом смолы (5-I0%). Две трети запасов горючих сланцев характеризуется низким содержанием серы (до 2%). Учитывая быстрое истощение ресурсов природной нефти, видимо, настало время серьезно подойти к оценке мировых ресурсов горючих сланцев и перспектив развития на их базе производства синтетического жидкого и газообразного топлива. Для этого, в первую очередь, необходимо разработать единые критерии оценки их ресурсов в мире и к следующему 28-му Международному геологическому конгрессу произвести соответствующий подсчет.Высокоразвитая сланцевая промышленность имеется в СССР и КНР, активную деятельность по ее организации ведут США, Австралия, Бразилия и Марокко. Имеются два основных пути использования горючих сланцев: непосредственно в качестве топлива и термическая переработка их в синтетическую нефть и газ. Возможны также энерготехнологическое и энергоклинкерное использование сланцев, извлечение из них редких и рассеянных элементов. Хотя многие проблемы, связанные с горючими сланцами, еще далеки от разрешения, повышенный интерес к сланцам и планируемые значительные объемы работ по их разведке, освоению и переработке в мире являются закономерными и оправданными.

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GEOTHERMAL RESOURCES OF CALIFORNIA

California depends on oil and natural gas for 90 percent of its total energy needs, and seeks to reduce this dependence to 79 percent by the year 2002 through conservation and increased development of alternative energy sources such as wind, biomass, solar, and geothermal. California contains about 60 percent of the US geothermal resources suitable for electric power generation. At the Geysers, a 240°C. vapor-dominated field, 1127 megawatts of capacity are installed, and 693 megawatts are under construction. The California Energy Commission estimates that installed geothermal capacity statewide will be from 3700 to 5000 megawatts by 2002.
The Public Utilities Commission has approved S89 million in ratepayer funding for the world's first commercial-sized binary geothermal powerplant at Heber in the Imperial Valley, where a 65-megawatt hydrocarbon turbine will produce power from a 180°C. water-dominated reservoir. The state is promoting greater diversity in new geothermal technology to enable development of additional geothermal reservoirs through organic Rankine cycle, single and double flash and total flow systems, and small wellhead generators from 100 kilowatts to 3.5 megawatts in size. Direct uses of geothermal resources of 50° to 150°C are displacing natural gas in space heating, aquaculture, greenhouses, snow melting, food processing, and dehydration of agricultural products.

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GEOTHERMAL ENERGY RESOURCES IN HUNGARY

A considerable amount of low enthalpy geothermal resources occurs in the sedimentary formations of the intermontane Pannonian basin. This area is characterized by a regional geothermal anomaly where the mean terrestrial heat flux is of 90,4 mW/m^2. Two reservoir systems of regional extent and dimension contain the most prolific and richest thermal water resources. One is the multiunit resevoir system consisting of a vast sequence of sand and sandstone layers of Pliocene age, the other is the Mesozoic fractured carbonate rock complex. After an intense exploration and development drilling program in the last two and half decades a continuous thermal water exploitation is going on. As a result, a highly developed thermal water utilization is taking place in various branches /e.g. balneology, agriculture, horticulture, space and district heating, sanitary water, industry, etc./. At some places it is in the form of multipurpose utilization. A total of 650 thermal water well was completed until now and about 500 are production wells. Among them 190 wells are of geothermal value where the outflowing water temperature is more than 60 °C. The average annual use of geothermal energy is approx. 330 MW. The geothermal energy is playing a complementary role in the country's energy budget. Locally it is of great importance, especially within the hydrogeologically most favorable areas in SE-Hungary at the surrounding of Szenetes and Szeged.

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GEOTHERMAL RFSOURCES OF THE USSR AND PROSPECTS FOR THEIR USE

Two types of geothermal resources are developed in natural dynamic carriers of the subsurface heat energy: hydrogeothermal resources (water, steam, water-steam mixtures) originating from geothermal water, and petrogeothermal resources issuing from water impermeable heated rocks.At the recent stage of developing the technique and technology of geothermal resources extraction, the scales of their practical use are defined by the value of the safe yield and heat-power potential of geothermal water. Some rather complex technical scientific problems of designing and constructing extraction systems should be solved to facilitate the utilization of huge petrogeothermal resources. Geologic-economic assessments of hydrogeothermal resources performed the results of which are shown in the Atlas of geothermal water resources in the USSR, as well as the analysis of the Soviet and foreign experience in their industrial development and heat-power use indicate that these resources can greatly contribute to a fuel-power country balance after implementing intensive methods of their production. In a flowing well production potential fuel savings are assessed to be 5-6 mln. tons of fuel equivalent (t.f.e.) per year as compared to 60 mln. t.f.e./year during pumpage production. Development of only 1-5% of reserves (in various regions) by extraction with injection of the used thermal water in producing aquifers can save 130-140 mln. t.f.e. per year. In the latter case, an effect of strata pressure maintenance is reached providing a long-term flowing of high-yielded wells, as well as an effective solution to the problems of environmental protection from thermal and chemical pollution. Implementation of this method requires a complex of research and test studies to be carried out. Problems concerning the development and heat-power use of low-potential geothermal water (with temperature of 40-45°C) by applying heat pumps are becoming of great importance due to large power potential and shallow depth of this water (300-1200 m).

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ГЕОТЕРМАЛЬНЫЕ РЕСУРСЫ СССР И ПЕРСПЕКТИВЫ ИХ ИСПОЛЬЗОВАНИЯ

Геотермальные ресурсы связаны с природными динамическими носителями тепловой энергии недр - геотермальными водами (вода, пар, пароводяные смеси - гидрогеотермальные ресурсы) и с практически безводными (водонепроницаемыми) нагретыми горными породами (петрогеотермальные ресурсы). На современном этапе развития техники и технологии извлечения геотермальных ресурсов масштабы их практического использования определяются в первую очередь размерами эксплуатационных запасов и теплоэнергетическим потенциалом геотермальных вод. Использование колоссальных петрогеотермальных ресурсов связано с необходимостью решения ряда весьма сложных научно-технических проблем проектирования и создания систем их извлечения. Выполненные геолого-экономические оценки гидрогеотермальных ресурсов, результаты которых отражены на демонстрируемом Атласе карт ресурсов геотермальных вод СССР, анализ накопленного в СССР и за рубежом опыта их промышленного освоения и теплоэнергетического использования показывают, что при внедрении интенсивных методов извлечения они могут обеспечить заметный вклад в топливно-энергетический баланс страны. Если при отработке скважинными водозаборами при фонтанном режиме эксплуатации возможная экономия топлива оценивается в 5-6 млн. тонн условного топлива (тут .) в год, то при переходе на принудительную эксплуатацию водозаборов скважинными насосами эта цифра увеличивается до 60 млн. тут /год, а освоение только I-5% запасов (по различным регионам) путем извлечения с обратной закачкой термальных вод после использования их полезных свойств в продуктивные горизонты может обеспечить экономию 130-140 млн. тут /год. В последнем случае достигается эффект поддержания пластового давления, обеспечивающий длительное фонтанирование скважин с высокими дебитами, а также эффективное решение вопросов защиты окружающей среды от теплового и химического загрязнения. Внедрение этого способа требует проведения комплекса научно-исследовательских и опытно-экспериментальных работ. Важное значение приобретают вопросы освоения и теплоэнергетического использования с применением тепловых насосов низкопотенциальных геотермальных вод (с температурой до 40-45°С), энергетический потенциал этих вод велик, глубины залегания незначительны (300-1200 м).

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WORLD COAL RESOURCES

General evaluation of World coal resources had been carried out for the first time in 1913, confined to the XII Session of IGC. Their total amount at depths of 1800 m (for bituminous coals) and 1200 m (for brown coals) was 7397 billion tons. After 70 years the volume of estimated resources increased two times as much, and according to presently defined generalized data (1982) it comprises 14810 billion tons (or 12012 billion tons of conventional fuel), including anthracites, bituminous and carboniferous coals (9440 billion tons or 8677 billion tons of conventional fuel), and subbituminous brown coals and lignites (5370 billion tons or 3336 billion tons of conventional fuel); the amount of preliminary estimated and prospected reserves (and their analogues) comprised correspondingly 4298, 2903 and 1395 billion tons (or 3695, 2866, 829 billion tons of conventional fuel). In Europe there are 9% of proved coal resources and 13% of coal reserves of the World, in Asia - 55 and 26%, in America - 29 and 4%, in Africa - 2 and 2%, and in Australia - 5 and 18%. The shortcoming of presentday evaluations of coal resources over the countries and the whole World is the nonidentity of calculation parameters, evaluation principles of prospecting and predicting totality. As the result, evaluated resources and reserves are difficult to compare in different countries. In order to improve and unificate the World coal resource evaluation, the authors propose the conduction in 1984-1988 of the International calculation of coal resources by common standarts and principles, which should be confined to the 28-th Session of the IGC. It is suggested that coal resources be calculated up to the maximum depths and thicknesses of coal seams: 1800 m and 0,5 m - for anthaacites and subbitominous coals, 600 m and 0,7 m - for subbituminous coals and 300 m and I m - for lignites, with dividing resources into 4 coal types - according to their quality (anthracites, bituminous and subbituminous coals and lignites) and 3 categories (prospected, preliminary estimated and presicted resources).

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РЕСУРСЫ УГЛЕЙ МИРА

Общая оценка ресурсов углей мира впервые проведена в 1913 г. к XII сессии МГК: общее их количество до глубин 1800 м для каменных и 1200 для бурых углей оценено в 7397 млрд.т. За 70 лет величина оцененных ресурсов возросла в 2 раза и по обобщенным в настоящем докладе данным (1982 г.) определилась в 14810 млрд.т (12012 млрд.тут), в т.ч. антрациты, битуминозные и каменные угли 9440 млрд.т (8677 млрд.тут); суббитуминозные бурые угли и лигниты 5370 млрд.т (3336 млрд.тут); количество предварительно оцененных и разведанных запасов (и их аналогов) составило соответственно 4298, 2903, 1395 млрд.т (3695, 2866, 829 млрд.тут). В Европе сосредоточено 9% учтенных ресурсов и 13% запасов углей мира, в Азии-55 и 26%, Америке-29 и 40%, Африке-2 и 2%, Австралии-5 и 18%. Недостатком существующих оценок ресурсов угля по странам и миру в целом является неидентичность параметров подсчета, принципов оценки разведанности и полноты прогнозирования, в результате чего оцененные ресурсы и запасы в разных странах трудносопоставимы. В целях совершенствования и унификации оценок ресурсов углей мира авторами вносится предложение провести в 1984-1988 гг.к 28-йсессии МГК международный подсчет ресурсов углей по единым нормативам и принципам. Предлагается оценку ресурсов производить до предельных глубин и мощностей угольных пластов; для антрацитов и суббитуминозных углей - 1800м и 0,5 м;для суббитуминозных углей - 600 м и 0,7 м; для лигнитов - 300 м и 1 м с разделением ресурсов на 4 типа углей по качеству (антрациты, битуминозные угли, суббитуминозные угли и лигниты) и 3 категории по степени достоверности (разведанные, предварительно оцененные запасы и прогнозные ресурсы).

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SYSTEM ANALYSIS IN REASONING THE SEARCH FOR OIL AND GAS FIELDS

Such analysis predetermines development of the three main blocks: the structural model of sedimentary basin structure, the functional model of oil and gas accumulation processes, the technogenic model of exploration process. The structural model establishes spatial relations between different geologic bodies, allows to divide the sedimentary cover into oil and gas bearing objects, shows substantial uniformity of sedimentary basins and allows to divide them into classes depending on the history of their formation and destruction, downwarping intensity, etc. The deposit formation processes are studied by functional models of different hierarchic level. According to geochemical data the unique law of kerogen element composition variation during catagenesis was established, allowing to estimate intensity of oil-gas formation processes. On the basis of this law and with regard for hydrocarbon migration and accumulation models quantitative laws of resource concentration changes versus DOM classes, temperature, structural, tectonic, lithologic factors were established for regional objects. Technogenic models show the unity of exploration process parameters in different regions. If the process is aimed at discovery of deposits larger than q, half of the deposits has the dimension less than q and contains 5% of resources. Probability of deposit discovery is controlled both by geologic and technogenic conditions. Combining structural, functional and technogenic models we obtain reliable estimates of hydrocarbon resources, estimates of their quality, detectability, optimal strategy of search for new fields.

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СИСТЕМНЫЙ АНАЛИЗ ПРИ ОБОСНОВАНИИ ПОИСКОВ МЕСТОРОЖДЕНИЙ НЕФТИ И ГАЗА

Системный анализ нефтегазоносности предопределяет разработку трех основных блоков: структурной модели строения осадочнопородного бассейна, функциональной модели процессов нефтегазонакопления, техногенной модели поисково-разведочного процесса. Структурная модель устанавливает пространственное соотношение геологических тел различной протяженности, позволяет однозначно разделить осадочный чехол на нефтегазоносные объекты, показывает существенную однотипность развития осадочнопородных бассейнов и позволяет разделить их на классы в зависимости от истории их формирования и разрушения, интенсивности прогибания и т.п. Процессы формирования залежей изучаются функциональными моделями для объектов различного иерархического уровня. По геохимическим данным установлен единый закон изменения элементного состава керогена при метаморфизме, позволяющий оценивать интенсивность процессов нефтегазообразования. Для региональных объектов на базе этого закона и с учетом моделей миграции и аккумуляции УВ установлены количественные закономерности изменения концентрации ресурсов в зависимости от классов РОВ, температуры, структурных, тектонических, литологических факторов, позволяющие оценивать по ним изменение концентрации ресурсов нефти, газа и конденсата в недрах. Техногенные модели показывают единство параметров поисково-разведочного процесса в различных регионах. Если процесс настроен на выявление залежей, больших некоторого размера, то половина залежей имеет размер меньше заданного и содержит 5% ресурсов. Вероятность выявления залежи на площади контролируется, наряду с геологическими условиями, плотностью сети профилей, расстоянием между скважинами и т.д. Объединяя структурную, функциональную и техногенную модели, получаем надежные оценки ресурсов УВ, оценки их качества, выявляемости, оптимальную стратегию поиска новых месторождений.

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WORLD ENERGY RESOURCES AND THEIR DISTRIBUTION IN TIME AND SPACE

If the estimated total energy resource potential of the world is reduced to a common denominator, then the total resources are estimated at 20 615 Terrawatt years (TWyr). Assuming that all these resources are recoverable, and applying today's technology, they would suffice for 1 718 years under no-growth conditions and 133 years assuming an annual growth rate of 3%.

It should, however, be borne in mind that only about 15% (or / 093 TWyr) of the world's resources can be regarded as proved or partly proved and recoverable at current price levels and technology. Assuming a no-growth scenario, these resources will meet future energy requirements for a period of 257 years. At a 3% annual growthrate, resources will last for 72 years. The various resources would be depleted at the following rates: oil 32 years, gas 39 years, uranium 52 years, with coal bringing the total life expectancy of energy resources to 72 years. If due allowance is made for improved technology, a 15% stretch-out could possibly be attained. This however, could, be negated by an increased growth rate.

In considering which areas of the globe represent the most promising target areas for prospection, it should be noted that the distribution of energy minerals is distinctly time-bound and occurs in a series of clearly defined rhythms ranging from the early Proterozoic to the Recent.

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PRINCIPAL FACTORS ACCOUNTING FOR IRREGULAR DISTRIBUTION OF HYDROCARBON RESOURCES

In the world 426 petroleum-bearing and possible petroleum-bearing basins have been recognized. Onshore and offshore area, promising for oil and gas, totals, according to estimates, 93 million square kilometres. The volumetric density of the ultimate potential geological hydrocarbon resources (UPGR) averages 6.5 thousand tons per cubic kilometre, varying for the major types of basins as follows: intraplatform (intracratonic) - 5 Mt/cu km, marginal (pericratonic) - 7.6 Mt/cu km, intramontane (intrageosynclinal) - 4.4 Mt/cu km.

Besides, all the basins are classified into three groups according to the specific volumetric density of UPGR. The first group includes 42 basins of over 10 Mt/cu km specific volumetric density, the second group - 65 basins between 10 and 5 Mt/cu km, and the third group - 319 bains under 5 Mt/cu km.

The highest specific volumetric density of UPGR is characteristic of the following basins: Los Angeles (210 M t/cu km), Maracaibo (72M t/cu km), Suez Gulf (42 M t/cu km), Santa Maria (36 M t/cu km), Persian Gulf (30 M t/cu km). The principal factors, accounting for their higher specific petroleum potential, are as follows: presence of high-bitumen source rocks, higher rates of sedimentation, higher geothermal gradient, predominant marine and deltaic facies, and inherited character of downwarping.

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ОСНОВНЫЕ ФАКТОРЫ,ОПРЕДЕЛЯЮЩИЕ НЕРАВНОМЕРНОСТЬ РАЗМЕЩЕНИЯ РЕСУРСОВ УГЛЕВОДОРОДОВ

В мире выделяются 426 нефтегазоносных и возможно нефтегазоносных бассейнов. Общая площадь перспективных на нефть и газ территорий и акваторий оценивается в 93 млн. км^2. Средняя объемная плотность начальных потенциальных геологических ресурсов углеводородов (НПГР ув.) составляет 6,5 тыс. т/км^3.

По основным группам бассейнов она распределяется следующим образом: внутриплатформенные (интракратонные) - 5 тыс. т/км^3; пограничные (перикратонные) - 7,6 тыс. т/км^3, внутрискладчатые (интрагеосинклинальные) - 4,4 тыс. т/км^3.

По величине удельной объемной плотности НПГР ув. все бассейны также делятся на три группы. К первой относятся 42 бассейна с удельной объемной плотностью свыше 10 тыс. т/км^3. Вторая группа объединяет 65 бассейнов с плотностью от 10 до 5 тыс. т/км^3. В третью группу с удельной плотностью ресурсов менее 5 тыс. т/км^3 включены 319 бассейнов.

Наиболее высокими удельными объемными плотностями НПГР ув. обладают бассейны Лос-Анджелес (210 тыс. т/км^3), Маракаибо (72 тыс. т/км^3), Суэцкого залива (42 тыс. т/км^3), Санта-Мария (36 тыс. т/км^3), Персидского залива (30 тыс. т/км^3). Основными факторами, определяющими их высокий удельный нефтегазовый потенциал явились: наличие высокобитуминозных нефтематеринских толщ, высокая скорость седиментации, повышенный геотермический градиент, преобладание морских или дельтовых фаций и унаследованный характер прогибания.

ПАЛЕООКЕАНОЛОГИЯ
PALAEOCEANOGRAPHY

Conveners: K.Y.Hsü, A.P.Lisitsin

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THE TERMINAL EOCENE EVENT: CATASTROPHE OR THRESHOLD-PUNCTUATION IN A LONG TERM CLIMATIC COOLING TREND

Should the geological events associated with the Eocene/Oligocene Boundary be interpreted as the results of a catastrophic extraterrestrial event, as several authors have recently suggested, or rather in the classical terms of a late Eocene cooling? Calcareous nannofossil studies of middle Eocene through lower Oligocene oceanic deposits from DSDP sites drilled in the Atlantic, Pacific and Indian Oceans, and of the middle Eocene to Oligocene shallow water epicontinental deposits of Europe and the Gulf Coast, strongly support the hypothesis of a cooling trend initiated close to the middle/late Eocene boundary which intensified during the late Eocene and the early Oligocene - a trend otherwise deduced from various paleontologic as well as isotopic evidence. A major calcareous nannofossil renewal took place at the middle/late Eocene boundary (NP17/NP18). It is associated with the initiation of an equatorwards migration of high-latitude nannoflora and a regression of low latitude nannoflora. At the end of the Eocene, low-latitude calcareous assemblages, dominated by rosette-shaped discoasters and Reticulofenestra reticulata, disappeared. Mid-latitude assemblages with abundant Reticulofenestra umbilica reached equatorial regions, while high-latitude nannoflora with Chiasmoliths and Reticulofenestra gr. hampdenesis reached temperate regions. In the early Oligocene, elements from these latter assemblages also developed in equatorial areas. A trend towards well-marked provincialism increases during the early Oligocene and affects oceanic as well as epicontinental calcareous nannoflora.

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QUATERNARY PALAEOCEANOGRAPHY OF THE ATLANTIC

The Quaternary paleoceanographical evolution of the Atlantic was controlled by global climatic fluctuations which greatly affected the values and order of changes in the main paleoceanographical parameters: paleotemperature and oxygen-isotope composition of water, position of water masses, currents, hydrological fronts, propagation of drifting ice, upwelling activity and oceanic circulation on the whole, bottom circulation, sedimentation, paleobiogeography of planktonic foraminifera and other organisms, sea level.

No large-scale climatic changes were detected in oceanic sediments at the Pliocene-Pleistocene boundary. For the Eopleistocene (1.9 to 0.8 m.y.) parameter variations, in particular, of paleotemperature and oxygen-isotope water composition were relatively small. During the period of 0.9 to 0.7 m.y. the first sharp temperature lowering occurred and all paleoceanographical parameters changed. Further, these changes were of fluctuation character; they are correlated with the stages of continental glaciations.

The optimum regime during the last interglacial (about 125 th.y.) had similar parameters to those of the present time at the general slightly higher level of the heat balance. In the North Atlantic, latitudinal bands existed temperature differences of which was small (to 2°C) as compared to the present one. The oceanic circulation was weaker. During the maximum of the last glaciation (about 18 th.y.) the water temperature, in general, was 5°C lower than the present one, a large sub-arctic cyclonic gyre developed, the polar front and the drift-ice boundaries shifted for 2000 km towards the Equator, all climatic belts also shifted, anti-cyclonic sub-tropical gyres reduced, upwellings sharply activated as well as the whole oceanic circulation and processes of terrigenous sedimentation, bottom circulation considerably changed. In the interstadial period (about 40 th.y.) the temperature was, in average, 2°C lower than the present one. Other parameters had intermediate values between the glaciation and interglaciation ones, though closer to the latter the North Atlantic Drift occurred.

Paleooceanologic parameters of interglacial, stadial and interstadial periods of the last glaciation characterize limits of conditions and one of the intermediate state. That's why they help us to know about conditions of all Quaternary climatic periods in the Atlantic.

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ЧЕТВЕРТИЧНАЯ ПАЛЕООКЕАНОЛОГИЯ АТЛАНТИКИ

Палеоокеанологическая эволюция Атлантики в течение четвертичного времени определялась глобальными климатическими колебаниями, которые оказывали решающее влияние на количественные характеристики и последовательность изменений важнейших палеоокеанологических параметров: палеотемпературу и изотопно-кислородный состав воды, положение водных масс, течений, гидрологических фронтов, распространение плавучих льдов, активность апвеллингов и океанской циркуляции в целом, придонную циркуляцию, осадконакопление, палеобиогеографию планктонных фораминифер и других организмов, уровень моря.

У плиоцен-плейстоценовой границы в разрезах океанских осадков не обнаружено свидетельств крупных климатических перестроек. В течение эоплейстоцена (I,9-0,8 млн.л.н.) колебания параметров, в частности палеотемператур и изотопно-кислородного состава воды, были относительно небольшими. В период 0,9-0,7 млн.л.н. произошло первое резкое понижение температуры и изменились все палеоокеанологические характеристики. В дальнейшем эти изменения имели колебательный характер, они коррелировали с этапами материковых оледенений.

Условия оптимума последнего межледниковья (около I25 тыс.л.н.) по всем характеристикам были близки к современным при общем несколько более высоком уровне теплового баланса. В Северной Атлантике располагались широтные полосы небольших (до 2°С) отличий температур от современных. Океанская циркуляция была более вялой. В период максимума последнего оледенения (около I8 тыс.л.н.) температура в целом по океану была на 5°С ниже современной, развивался крупный субарктический циклонический круговорот, полярный фронт и граница плавучих льдов смещались к экватору на 2000 км, смещались также все климатические пояса, сокращались антициклонические субтропические круговороты, резко усиливались апвеллинги и активизировалась вся океанская циркуляция, усиливались процессы терригенного осадконакопления, существенно изменялась придонная циркуляция. В период межстадиала (около 40 тыс. л.н.) температура в среднем была на 2°С ниже современной. Другие характеристики имели промежуточное значение между ледниковыми и межледниковыми, ближе к последним. Существовал Северо-Атлантический дрейф.

Палеоокеанологические характеристики периодов межледниковья, стадиала и межстадиала последнего оледенения характеризуют крайние пределы условий и одно из промежуточных состояний, поэтому они позволяют судить об условиях всех четвертичных климатических этапов в Атлантическом океане.

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PHYSICAL PALAEOCEANOGRAPHY

The circulation of the ocean is a major governing factor in biologic, geochemical and sedimentary processes. For this reason the interpretation of physical processes in ancient oceans is a major element of paleoceanographic research. Several processes have been the subject of substantial interest and speculation: 1) the poleward oceanic heat transport and its effect on climate evolution, 2) the thermohaline circulation-particularly the role of cold polar sources, subtropical warm saline sources and the role of stratification, 3) the vigor or intensity of the oceanic circulation-particularly as to whether changes in the equator-to-pole surface temperature gradient have been a controlling factor in the intensity of oceanic currents, and 4) the role of gateways as controls on oceanic circulation and climate.

Traditionally these subjects have been investigated through the interpretation of geologic data and from analogy with modern oceanographic processes. More recently, atmospheric and oceanographic numerical models which are based on the physical laws thought to govern the circulation have become a new tool in paleoceanographic research. A hierarchy of such models from simple energy balance models to fully resolved oceanographic models have been applied to an investigation of the Cretaceous Period. The results suggest that many hypotheses on past ocean circulation should be reevaluated.

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ENVIRONMENT AND SEDIMENTATION IN THE LATE MESOZOIC AND CENOZOIC PACIFIC

Analyses of the new lithological-paleogeographical maps for the Pacific compiled by authors for the various age intervals, and maps of the distribution and mass-accumulation rates of the various sedimentary components convince in that the oceanic sedimentation mechanism of Mesozoic and, especially, of the Cenozoic was affinity that of the present time. Behavior of the most chemical elements in the oceanic sedimentation depends directly or indirectly upon the biochemical processes. One of principal causes of the changes in the composition and distribution of bottom sediments was climate evolution and associated changes in the vertical mixing of the oceanic waters and changes in the sea-level.

The Mesozoic ocean was characterized by the warm climate with weak differentiation of latitudinal zones. In the Paleogene considerable

cooling in high latitudes led to the increase in latitudinal contrast of climatic parameters and formation of glaciers in high latitudes in the Late Paleogene-Early Neogene.
In the Mesozoic latitudinal climatic zoning of sedimentation was not pronounced, whereas the Neogene was a period of global formation of latitudinal bands of biogenic sedimentation. During the Paleogene the bottom circulation system and its intensity were changed. In the Mesozoic and Early Cenozoic the aeration of the bottom waters was weak and anoxic conditions existed in some regions. In the Neogene aeration sharply increased. It was manifested in the preservation of the buried individual sedimentary components, and in the authigenic mineral formation.
Change in the intensity of sedimentary material input into ocean, resulted from the denudation evolution of continental blocks, flux of some elements by hydrothermal solutions within active mid-oceanic ridges, and variations in the sea-level was also resulted in the change of the composition of Mesozoic and Cenozoic sediments, mass-accumulation rates of some elements in sediments and sedimentary rocks, in particular, elements characterized by relatively short residence time. Changes in the pathes and intensity of the spreading of the bottom waters and also in the input and in the composition of sedimentary material on the surface of the bottom effected the distribution areas of nondeposition and erosion of the sediments, and the formation of hiatuses.

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ПРИРОДНАЯ СРЕДА И ОСАДКОНАКОПЛЕНИЕ В ТИХОМ ОКЕАНЕ В ПОЗДНЕМ МЕЗОЗОЕ И КАЙНОЗОЕ

Анализ новых литолого-палеогеографических карт Тихого океана, составленных авторами для разных возрастных срезов, карт распределения и абсолютных масс разных компонентов осадочного материала убеждает в том, что механизм океанского осадкообразования был близок к современному по крайней мере на протяжении мезозоя и в особенности кайнозоя. Поведение большинства химических элементов при седиментогенезе в океане прямо или косвенно было связано с биогеохимическими процессами. Одной из важнейших причин изменения состава и распределения донных осадков являются эволюция климата и связанное с ней изменение интенсивности вертикального перемешивания океана, изменения уровня океана. Мезозойский океан характеризовался теплым климатом, слабо дифференцированным по широтным зонам. В палеогене происходило существенное похолодание в высоких широтах, что привело в конце палеогена-начале неогена к увеличению широтной контрастности климатических характеристик, возникновению ледников в высоких широтах.

Если в мезозое широтная климатическая зональность осадконакопления проявлена слабо, то в неогене формируются глобальные широтные пояса биогенной седиментации. Палеоген был временем перестройки системы и интенсивности донной циркуляции. В мезозое и начале кайнозоя вентиляция придонных вод была ослаблена, в отдельных районах существовали условия стагнации, сероводородное заражение. В неогене она резко усилилась.Это отразилось на сохранности отдельных компонентов осадочного материала при их захоронении, особенностях аутигенного минералообразования.

Изменение интенсивности питания океана осадочным материалом, связанное с эволюцией денудации континентальных блоков, поставкой химических элементов с гидротермальными растворами в пределах активных срединно-океанических хребтов и колебанием уровня океана,также нашло отражение в изменении состава океанских осадочных образований мезозоя и кайнозоя, абсолютных массах химических элементов в осадках и осадочных породах, прежде всего элементов, характеризующихся относительно малыми временами пребывания в океане.

Изменение путей и интенсивности перемещения придонных вод, а также скоростей поступления и состава осадочного материала на поверхность океанского дна сказалось на формировании областей ненакопления и эрозии осадков, образовании перерывов в осадконакоплении.

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THE RECORD OF CHEMICAL CHANGES IN THE OCEAN

There are few unambiguous tracers of past ocean chemistry. For the more recent (Quaternary) period, $\delta^{13}C$ and Cd/Ca measurements on benthic and planktonic foraminifera and ice-core p_{CO_2} measurements place some quantitative constraints on changes in ocean circulation and of oceanic chemical inventories. This information is supplemented by more qualitative indicators such as bulk sediment chemistry and mineralogy (e.g. $CaCO_3$,organic C), aragonite preservation, and fossil organism assemblages. These indicators all point to significant changes in oceanic inventories and internal distributions on glacial/interglacial time scales. On longer time scales, these indicators are useful as well as several long residence time properties: Sr isotopes, Sr/Ca, and Li/Ca in foraminifera, and S isotopes in ancient evaporites. These indicators all show that there have been significant - although surprisingly subtle - changes in the input/output balance of the ocean. Since recent evidence suggests that hydrothermal sources probably have not varied significantly throughout the last 100 m.y., it appears that changes in continental fluxes to the ocean are responsible. These can originate from continental drift and orogeny (or lack thereof) and its influence on weathering, climate, and continental internal drainage, as well as from variations in sealevel which can produce depositional environments, which are rare today. Although plausible models for the observed changes can be constructed, constraints leave indeterminate the ocean chemistry system at remote times.

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TERMINAL MIOCENE EVENT

The terminal Miocene paleoceanographic event is connected with the salinity crisis that affected the Mediterranean, although the cause/effect relationships are still debated.
The hydrologic budget of the Mediterranean is, and presumably was, strongly negative, so that when the permanent connections with the Atlantic were severed, and then interrupted due to the relative motions of Africa and Europe, the basins became evaporitic. The Mediterranean paleogeography underwent drastic changes: the basin margins were subject to subaerial erosion, and the main rivers in the attempt to adapt their thalweg to the rapid fall in base level, incised deep and narrow canyons, subsequently filled by Plio-Pleistocene marine sediments.
Calculations show that over one million cubic kilometers of halite and other evaporitic minerals were laid down in the Mediterranean, thus lowering the salinity of the oceans by 2 per mil.
Looking for a response of the worlds ocean to the Mediterranean salinity crisis, paleoceanographers found (a) an extended regression on continental margins and (b) a sudden lightening of the isotopic composition of Carbon in oceanic sediments.
The regression is well expressed and results in the interruption of carbonate buildups; however, it is not well dated in most cases. The "carbon shift" instead is well calibrated, but its significance is still in part obscure; first discovered in the Indian Ocean, it was subsequently recorded in the Pacific and - to a lesser extent - also in the Atlantic. Its numerical age is 6.2-6.3 m.y., occurring just after (above) the FAD of <u>Amaurolithus primus</u> in the lower part of paleomagnetic Epoch 6.
Two attempts were made so far to correlate the various intramessinian sedimentary and erosional events recorded in the Mediterranean with the biostratigraphic, paleomagnetic and isotopic record of the Atlantic: one based on the expanded, high-sedimentation-rate succession recorded at DSDP Site 397 off NW Africa, the other one based on the condensed succession recorded at DSDP Site 519 on the Walvis Ridge. The correlations are still tentative because (1) the Mediterranean record itself cannot be investigated paleomagnetically, the

rock units being unsuitable, (2) the isotopic record is strongly affected by the major paleogeographic changes undergone by the Mediterranean and (3) the biostratigraphic record based on marine fossils can only be used to calibrate the sediments predating and postdating the salinity crisis, since the marine fauna was entirely destroyed.

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THE EOCENE/OLIGOCENE EVENT IN THE DEEP-SEA

The Eocene/Oligocene boundary marks one of the most important paleoceanographic events during the Cenozoic, and is marked by deep-sea fauna and floral turnovers, surface and deep water coolings, changes in surface and deep water circulation, and changes in sedimentation patterns. This paper reviews recent data from DSDP material to determine in more detail the nature of the Eocene/Oligocene event in the deepsea. Benthonic foraminiferal oxygen isotope data show an isochronous enrichment at the Eocene/Oligocene boundary at intermediate to abyssal depths, and a similar enrichment at the middle/late Eocene Boundary. Benthonic and planktonic foraminiferal and calcareous nannoplankton data from the middle Eocene to early Oligocene show no catastrophic change at the boundary, but rather a series of first and last appearances throughout the interval, creating the faunal and floral turnovers previously observed.
The benthonic foraminiferal data indicate that the most important faunal event during the middle Eocene-Early Oligocene interval was the isochronous last occurrence of Nuttallides truempyi, an important middle Eocene species throughout most of the deep ocean, coinciding with a 3°C deep-water cooling inferred from the oxygen isotope record. Geochemical analysis of DSDP cores reveals an iridium anomaly near the Eocene/Oligocene boundary associated with an extensive tektite layer, which have been suggested to be related to an extraterrestrial bolide impact. The assocation of the iridium and tektite data at the Eocene/Oligocene boundary are preliminary findings, since a) evidence has been presented for multiple tektite layers in Eocene-Oligocene time, and b) it has not been established if the iridium anomaly near the boundary is unique, or if other iridium peaks are present in Eocene-Oligocene sequences.
Sedimentation patterns dramatically changed at the Eocene/Oligocene boundary, marked by a deepening of the CCD in much of the ocean, and the deposition during the Oligocene of Braarudosphaera oozes in the South Atlantic. These sedimentation changes are suggested to be the result of either intensified pole to equator surface circulation or to an influx to the low and middle latitudes of cool, low-salinity

Antarctic intermediate water which was upwelled and caused increased carbonate production in the equatorial Pacific and the south Atlantic.

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GEOLOGIC EVOLUTION OF THE TETHYS CONVERGENCE ZONE FROM LIASSIC TO PRESENT BETWEEN THE ATLANTIC AND PAMIR

We present a set of nine coloured maps at 1/20.000.000 scale reconstructing the general history of the mountain belts resulting from the disappearance of Tethys inferited from Paleozoic, from the Atlantic to Pamir. These maps we published elsewhere. They were drawn using a kinematic frame, geological constraints and paleomagnetic data for intermediate blocks when available. The large body of geological observation, both on land and at sea, in tectonics, stratigraphy, petrology and sedimentology was critically examined. The first map (pliensbachian) is situated of the Triassic opening of the Tethyan ocean and the subsequent collission of Gondwanian fragments with Eurasia. From then on, the emphasis is on coherence on the relationship between East and West. We make an important distinction between young and old oceanic lithosphere in the evolution of the Tethyan basins and pay special attention to the opening of now oceanic basins. Tectonics are dominated by the progression from ocean basin subduction to obduction followed by continental collision which was going toward the East. Lateral motion along large strike-slip faults plays a very significant role especially during the continental collision stage. This report is an intermediate one in a long standing effort to better understand the evolution of the Tethyan belt.

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HISTORY OF THE OCEANS: AN OVERVIEW OF RESULTS FROM DEEP OCEAN DRILLING

The enormous progress made in our understanding of the history of the ocean and climate in the past 16 years can be largely attributed to the results obtained from deep ocean drilling. Cores and geophysical data obtained from the major ocean basins have contributed to a far reaching study of ocean paleoenvironment, paleoceanography and paleoclimatology that has produced a broad inventory of the major trends and events in the history of circulation, changes in geochemical balance and biologies and climatic evolution in the past 150ma of earth history. Important contributions to this paleoceanographic inventory have been the development of global stratigraphics based on fossil plankton, magnetic reversals and stable isotopes and the paleogeography of oceans and continents based on linear magnetic anomalies in the sea floor.

Our understanding of the Jurassic and Cretaceous oceans remains rudimentary because of meager core coverage, imprecise stratigraphies and unclear paleogeographics, especially in the Pacific and high latitudes. Fossil, sediment and limited stable isotope data suggest that global climates were warm and equable with low thermal gradients across latitude. The occurrence and distribuion of organic-carbon rich shales and associated geochemical results indicates periodic development of the wide spread anoxia in the Mesozoic ocean, possibly related to sea-level high stand and deep circulation. In the Mesozoic and early Tertiary, deep water formation and circulation may have been driven by warn, saline waters formed by evaporation in epi-continental seas.

Our understanding of the Cenozoic Ocean, especially the last 40 m years is extensive. With the development of the hydraulic piston core which permits high resolution stratigraphies, it is now possible to describe not only the general trends in ocean history but the detailed sequences, to related sequences from different portions of the ocean and to understand the mechanism which cause change in ocean climate systems. Cooling in polar regions in the late Eocene, possible earlier, signals a major change in the ocean-climate system with steeping thermal gradients across latitude and the onset of ice cover in Antartica. Except, for brief reversals in the late Oligocene - early Miocene and Pliocene, this trend dominates the Cenozoic and culminates in the glaciation of the Pleistocene. Accompanying this trend are major changes in ocean biochemistry, surface productivity, the distribution of biogenic sediments and the development of the cryosphere.

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THE PROCESS OF EVOLUTION

Evolution has been hotly debated since the day Darwin published THE ORIGIN OF SPECIES (Nov. 24, 1859). Much of the debate stems from failure to appreciate the role of extinction in the process of evolution.

Evolution is a time-dependent process and, therefore, can be assessed only if a fossil record that is demonstrably continuous through time is used. The fossil record of marine Protozoa and Protophyta in deep-sea sediment cores gathered in recent years by the drilling vessel GLOMAR-CHALLENGER is the first to meet this reguirement. An analysis of the deep-sea record and a comparison with similar, more patchy records from marginal marine areas and the continents indicates that evolution of abundant and widespread species (marine Protozoa and Protophyta in this case) involves two separate but complementary processes: COMPETITIVE EVOLUTION in the marginal marine environments of the world, where genetic pools are limited and ecological conditions highly variable; and EXTINCTIVE EVOLUTION in the major environment (the world ocean), where the genetic pools are huge and the ecological conditions more stable. In the marginal environment evolution proceeds along the classic lines of mutation, competition, natural selection, and survival of the fittest. The record is one of gradual change and transitional forms ("missing links") are common. In the major environment, the record is one of abrupt change, with new species replacing the older ones without any transitional forms. Here, species are seen to thrive and live in great abundance for hundreds of thousand to millions of years, only to become abruptly extinct often at the peak of their success.

The oceanic record shows that extinctions are not only abrupt, but normally affect individual species only, leaving undisturbed dozens of other species living in the same general environment. A possible cause is infestation by selective pathogens, that can spread across the ocean at a rate comparable to the rate of mixing of the ocean (about 1,000 years). The ecological domain vacated by the extinct species may be occupied by a new species from one of the innumerable marginal environments if the new species happens to have evolved in such a way as to be sufficiently adapted to the ecological conditions prevailing in the vacated domain. Replacement is non-competitive and, therefore, the new species need not be better adapted than the older one. A marginal species can be successful only if the extinction of a dominant species allows its diffusion into the major environment. Its spreading is not the cause, but the effect of extinction. As a result, the more successful groups are those exhibiting a high rate of extinction. Extinctive evolution is entirely discontinuous because it is both allopatric and non-competitive. There are no transitional forms and the "missing links" are necessarily missing. Competitive and extinctive evolution combine into a comprehensive model.

Mass extinction, defined as the simultaneous extinction of a number of diverse taxa in a number of diverse environments, follows major ecological shocks. A spectacular example is the mass extinction at the end of the Cretaceous, 65 million years ago, which was apparently triggered by the impact of a large extraterrestrial body on the ocean. The deep-sea record shows the abrupt extinction of a number of species and genera of marine Protozoa and Protophyta, and the survival of a few misfits. These rapidly expanded to occupy the world ocean but were rapidly replaced by a succession of increasingly better adapted species that apparently had independently and concurrently evolved in the marginal environments. The fossil record immediately following the shock is one of accelerated evolution. Mass extinction induced by global ecological shocks (not necessarily extraterrestrial) is a means by which the biosphere renovates itself, but the renovated biosphere is not necessarily better adapted than its predecessor.

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THE MESOZOIC-CAINOZOIC HISTORY OF CLIMATE CHANGE AND CAUSE OF GLACIATION

Over the interval since the late Permian, the Earth has seen a recovery from Paleozoic glaciation followed by an anomalously warm Mesozoic and a punctuated decline in mean global temperature in the late Cretaceous-Cenozoic. The main changes in thermal condition occured in the middle Triassic (strong warming = W); late Jurassic (W); post-Santonian late Cretaceous (strong cooling = C); late Paleocene-early Eocene (W); middle Eocene (C); end Eocene (C); middle Miocene (C); end Miocene (C); middle Pliocene (C) and end Pliocene (C). Intervening times were characterized by low amplitude fluctuations and/or gradual warming or cooling trends. Abrupt climate changes have been explained by a variety of mechanisms, including changes in paleogeography, oceanic circulation, structure of the water mass, volcanic dust input, and recently, volcanic-related CO_2 levels. From matching of a Phanerozoic curve of atmospheric CO_2 concentration, based on estimates of deposition of organic carbon on the continents, with a sub-parallel curve for abundance of continental volcanic rocks, Budyko and Ronov concluded that global climate changes are related to the variable output of CO_2 from volcanic activity. This conclusion is supported by most Phanerozoic climate trends. However, their CO_2-derived temperature curve suggests warming in the late Cretaceous and in the Miocene; these two trends are against the geological evidence. To explain the Miocene, a substantial though gradual warming in the early Miocene might be overly weighted in construction of the CO_2 curve. The known cooling in the late Cretaceous is not so easily explained, nor is the fact that CO_2-derived temperatures in the Tertiary are consistently higher than the present mean global temperature.

It is suggested that the warming effect of CO_2 produced by volcanism normally outweighs the cooling tendency arising from the dust veil index from volcanism. However, CO_2-induced warming was not effective in the post-Santonian Cretaceous, probably because of the long-term decrease in seafloor spreading and the consequent falls in sea level. The result was increased global albedo and hence cooling. It is likely that the general decline in oceanic volcanism related to slowed spreading also played a part, in that CO_2 input to the atmosphere-hydrosphere was lowered. It appears likely that elevated earth temperatures are maintained by atmospheric CO_2 except when concentration falls below about 0.20% (vs. the present value of 0.03%), when glaciation may ensue.

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PALEOOCEANOLOGY AND CLAY-SIZED MINERALS (ON THE EXAMPLE OF THE EAST PACIFIC OCEAN)

In the surface layers of the sediments in the EPR active ridge region a regular lateral change of high-dispersed minerals content was revealed in connection with decreasing of endogenic material deposit while removing from the ridge axis in the time of simultaneous increasing of the allothigene material deposit (terrigenous and volcanic).

For the clay-sized minerals from the deep-sea drilling cores in the studied region the analogous content change of these minerals along the vertical direction while removing from the basaltic bed is quite typical. The lower horison sediments of different geological age, situated on basalt (Site 323 - Maastrichtian, Site 329 - lower Miocene, Site 159 - middle Oligocene) contain high-dispersed mineral complex, which at the present stage is formed near the spreading centres (amorphous hydrous ferric oxide, goethite, Fe-montmorillonite). This complex is connected with the endogenic material, transformed from the active ridges, and with authigenous-diagenic processes, as well.

The amount of the endogenic material, transformed to the ocean bottom is irregular in time, and is dependent not only of the distance from the spreading axis, but also of its expanding rate and of its dilution by the detrital material (terrigenous, biogenic and volcanic). The relations and accumulation rates of endogenic and exogenous minerals were changed, but common regularities are revealed clearly enough. Sharp climate changes find their reflection in minerals sediment content, moreover, the camouflage influence of diagenesis doesn't make the paleoclimate development difficult in the period of Pleistocene-Oligocene. As far as the more ancient (Cretaceous) sedimentary rocks are concerned, these modifications are sometimes of great significance (Site 163). However, according to the newly-formed minerals we can reveal the source material to some reliable degree in this case as well.

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ПАЛЕООКЕАНОЛОГИЯ И ВЫСОКОДИСПЕРСНЫЕ МИНЕРАЛЫ (НА ПРИМЕРЕ ВОСТОЧНОЙ ЧАСТИ ТИХОГО ОКЕАНА)

В поверхностных слоях осадков в районе активного хребта Восточно-Тихоокеанского поднятия была выявлена латеральная смена состава высокодисперсных минералов в связи с уменьшением по мере удаления от оси хребта вклада эндогенного вещества при одновременном возрастании вклада детритного (терригенного и вулканогенного).
Для высокодисперсных минералов из кернов глубоководного бурения изученного района типична аналогичная смена состава этих минералов по вертикали по мере удаления от базальтов ложа. Нижние горизонты осадков разного геологического возраста, лежащие на базальте (скв.323 - маастрихт; скв.319 - нижний миоцен; скв.159 - средний олигоцен),содержат комплекс высокодисперсных минералов, который на современном этапе образуется близ центров спрединга (аморфные гидроокислы железа, гетиты, Fe-монтмориллониты). Этот комплекс связан с эндогенным веществом, поступающим из активных хребтов, а также с аутигенно-диагенетическими процессами. Количество эндогенного материала неравномерно во времени и зависит не только от расстояния от оси спрединга, но и от скорости его раздвижения, от разбавления его детритным материалом (терригенным, биогенным и вулканическим). Изменялись соотношения и темпы накопления эндогенных и детритных минералов, но общие закономерности выявляются достаточно четко. Крупные климатические события находят свое отражение в минеральном составе осадков, причем маскирующее влияние диагенеза не затрудняет палеоклиматические построения в пределах плейстоцен-олигоцен. Что касается более древних (меловых) осадочных толщ, то эти преобразования иногда существенны (скв.163).Однако с какой-то степенью достоверности по новообразованным минералам можно иногда восстановить исходный материал и в данном случае.

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SCHISTES LUSTRES IN PALAEO-OCEANOGRAPHIC RECONSTRUCTIONS

Schistes lustrés were for a long time considered the formations of the Alps, but those are now known to be also formed beyond the Tethyan limits.
Schistes lustrés and similar formations are characterized by monotonous geological columns with argillaceous and siliceous and calcareous rocks prevailing and all transitional varieties between them. Besides the slightly altered rocks, this formation occasionally contains green schists and crystalline schists of the amphibolite facies.

The most important characteristic of schistes lustrés is their extreme poverty in fossils. Other important characteristics are: nearly complete absence of remains of calcite- or aragonite-test organisms, sporadic occurrence of levels with radiolaria or conodonts, and frequent association with ophiolites.
The striking absence of any fossils with calcareous tests in schistes lustrés is their primary characteristic associated with the compensation depths of calcite (CCD) and aragonite (ACD) in the global sea and in each division of the Earth's history. On these grounds the conclusion has been drawn that schistes lustrés, by their principal characteristics, could have been formed only in the deepest parts of the ancient oceans and troughs with oceanic bottoms. Hence the study of the schistes lustrés in palaeo-oceanographic reconstructions is equally important as that of ophiolites.
All the above mentioned is in full conformity with the latest correlations of characteristics of schistes lustrés from the Alps and the deep-water formations of the Californian Bay which demonstrate a high similarity (K.Kelts, 1982).

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ARCTIC PALEOCEANOGRAPHY AND ITS RELATIONSHIP TO LATE NEOGENE ICE AGES

Sediment cores from the Arctic Ocean yield significant faunal and lithologic evidence of three major oceanic-climatic regimes (represented by stratigraphic units) during the last 4.5-5 m.y. The evolution of these regimes appears to have been linked to global climatic, hydrologic and tectonic events. The record commences near the time of a major global cooling phase. The oldest unit (III) comprises sediments deposited between 5 and 2.4 m.y.B.P. and consists of fairly well sorted, manganese concretions-bearing red clays. The low abundance of microfauna is attributed to their dissolutions during a period of elevated calcium carbonate compensation level (CCL); the Arctic Ocean was cold but free of perennial ice during this period. Unit II records a drastically altered oceanographic regime: a climatic threshold was crossed about 2.4 m.y. ago with the development of sharp salinity-density stratification. Reduced surface-water biological production was due to low availability of nutrients and decreased salinities. Another oceanic-climatic threshold was crossed 0.9 m.y. ago with the inception of a perennial sea ice cover: this event marks the deposition of sediments representing the third and most recent climatic-oceanic regime. Unit I is equivalent to the classical Pleistocene of the Alpine stratigraphic system, encompassing the time between the Donau glaciation and the Holocene and also corresponds to Selli's "Glacial Pleistocene".

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TERMINAL CRETACEOUS OCEAN

The paleontological record indicates accelerated turnover rates for many groups of organisms at the end of Cretaceous and/or the first few tens of thousand years of the Tertiary Period. Particularly remarkable are the extinction rates of calcareous planktons, which are estimated to be about a thousand times faster than the "normal evolutionary rates" found by Lyell for Tertiary molluscs. Appearance of new species has also been accelerated, early Danian new nannofosill species occurred at a rate of 20 to 40 per million years.
Studies of stable isotopes indicated sudden changes in ocean chemistry and in atmospheric temperatures at the end of Cretaceous. The $\delta^{13}C$ of plankton skeletons shows a shift of minus 1.5 to 3 pro mil and this anomaly has been considered an indication of drastically reduced plankton-fertility after a catastrophic event at the end of Cretaceous. The oxygen-isotope signals suggest fluctuating temperature, with an overall warming trend during the first few tens of thousand years of the Tertiary.
The common presence of a boundary clay, especially at localities on continental crust, may reflect the low production rate of calcareous planktons. The reduced supply of calcareous skeletons may have contributed to a rise of calcite-compensation depth in some regions, although increased dissolution may have also been a factor, especially in areas lying within the zone of oxygen-minimum, where much biogenic CO_2 was produced.
The boundary clay is almost everywhere enriched in siderophile elements such as Ir, Os, Pt, Au, etc. Spherules, which may represent diagenetically altered microtektites, have also been found at many localities. The geochemical anomalies are considered evidence that a large extra-terrestrial body (comet or asteroid), weighing some 10^{17} or 10^{18} grams, fell on earth at the end of the Cretaceous Period.

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PALEO-TEMPERATURES AND CIRCULATION OF THE INDIAN OCEAN

The Indian Ocean may be divided into three broad oceanographic regimes on the basis of its general circulation patterns and surface oceanography. During the Late Quaternary, these three regions showed unique responses to changing global climate. Reconstructions of past oceanographic features are possible through of examination of fossil

Planktonic Foraminifera in sedimentary sequences from deep-sea cores throughout the Indian Ocean. Oxygen isotope stratigraphy has been used to establish chronostratigraphic datums, such as the last Glacial maximum, approximately 18,000 Y.B.P. Statistically-based transfer functions enable precise sea-surface temperatures to be estimated from fossil assemblages. These techniques reveal that, during the last Glacial maximum, (1) the monsoon regime of the northern Indian Ocean was less pronounced than it is today, (2) the central water-mass region was relatively stable, and (3) the southern, circum-polar region underwent dramatic changes in temperature and circulation patterns.

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LATE QUATERNARY PALEOCEANOGRAPHY OF THE INDIAN OCEAN AND THE RED SEA

Maps of sea-surface temperature (SST) anomalies and deviations of $CaCO_3$ composition of planktonic foraminiferal tests from Recent ones in the Indian Ocean and the Red Sea were compiled for 6 time levels of Late Quaternary. Comparison of the maps allows to reveal evolution of SST, water circulation patterns and migrations of biogeographic zones.
At last interglacial optimum SST was 1° to 2°C higher than today on major part of the region studied. Climatic and biogeographic zones were shifted poleward. During early stadial of the last glaciation SST lowered almost all over the Indian Ocean and the Red Sea. The surface water circulation intensified. Increase in volume of ice and arid climate on the major part of surrounding continents led to heaviering of oxygen isotope content in planktonic foraminiferal tests. During interstadial SST were similar to Recent ones. At the last glacial maximum cooling in the region studied was most prominent in the Subantarctic and in the Red Sea, where SST were 4° to 6°C and at least 5°C lower than Recent ones correspondingly. Surface circulation and upwelling in the south tropical divergence of the Indian Ocean intensified. Climatic and biogeographic zones shifted equatorward. Dramatic decrease in water exchange through Bab-el-Mandeb Straits led to essential increase in Red Sea water salinity. Eustatic sea level elevation and pluvial conditions on the major part of surrounding land in Holocene resulted in lowering of salinity, especially in the Red Sea due to restortion of water exchange between the Indian Ocean and the Sea. The lower salinity promoted to rise in abundance of planktonic fauna and led to stable stratification of water column. In anoxic bottom water of the Red Sea sapropelic sedi-

ments were deposited. Paleoceanologic parameters of the two basins during the Atlantic period were similar to those of the last interglacial optimum.

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ПАЛЕООКЕАНОЛОГИЯ ИНДИЙСКОГО ОКЕАНА И КРАСНОГО МОРЯ В ПОЗДНЕЧЕТВЕРТИЧНОЕ ВРЕМЯ

Сравнение схем отличий температур поверхностной воды и изотопно-кислородного состава $CaCO_3$ раковин планктонных фораминифер от современных значений для 6 временных уровней позволило выявить позднечетвертичную эволюцию термического режима, особенности циркуляции Индийского океана и Красного моря и миграцию биогеографических зон.

Во время оптимума последнего межледниковья температуры поверхностной воды на большей части исследованной акватории на I-2°С превышали современные. Климатические и биогеографические зоны были смещены к полюсу относительно современного положения. В течение раннего стадиала последнего материкового оледенения температуры вод понизились почти на всей акватории Индийского океана и Красного моря, усилилась поверхностная циркуляция. Увеличение размеров оледенения и установление аридных условий на большей части континентального обрамления двух бассейнов способствовали утяжелению изотопно-кислородного состава раковин планктонных фораминифер. Во время межстадиала оледенения температуры поверхностных вод были близки к современным. Максимальное похолодание в пределах рассматриваемого региона особенно сильно проявилось в Субантарктике и в Красном море, где температуры поверхностных вод были соответственно на 4-6°С и по крайней мере на 5°С ниже современных.

Усиливались поверхностная циркуляция Индийского океана и подъем вод в южной тропической дивергенции. Климатические и биогеографические зоны смещались к экватору. В результате резкого сокращения водообмена через Баб-эль-Мандебский пролив значительно повысилась соленость красноморских вод. В послеледниковое время в результате эвстатического повышения уровня океана и установления плювиальных условий на большей части окружающей суши произошло распреснение поверхностных вод, особенно в Красном море, водообмен которого с Индийским океаном значительно увеличился. Распреснение поверхностных вод моря сопровождалось расцветом планктонной фауны и установлением устойчивой стратификации вод. На дне в анаэробных условиях накапливался сапропель. Палеоокеанологические характеристики оптимума голоцена в Индийском океане и Красном море были близки к аналогичным параметрам оптимума межледниковья.

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ANTARCTIC BOTTOM WATER PRODUCTION: SOURCES OF HIGH SALINITY WATERS TO THE ANTARCTIC PERIMETER

Three principal factors are potentially important in governing the initiation of Antarctic Bottom Water (AABW) flow through the deep ocean basins during the Paleogene, and subsequent fluctuations in its intensity during the Neogene and Quaternary: (a) The beginning of circumpolar flow, leading to thermal isolation of the Antarctic continent and decreasing surface water temperatures around the Antarctic perimeter; (b) Injection of high-salinity waters into the Antarctic region at intermediate depths; and (c) Rifting and subsidence of sills and passages below critical threshold depths. Of these factors, salinity has probably been the limiting one. Formation of bottom water in the northern Atlantic began near the Eocene/Oligocene boundary via overflow from the Norwegian Sea through deepening sills in the Iceland-Scotland Ridge. This overflow, or proto-North Atlantic Deep Water (NADW), injected high-salinity water into the central and southern Atlantic at intermediate depths, and was probably essential to AABW production. A prominent seismic discontinuity (Horizon A of Ewing) marks the initiation of AABW flow through the southwestern Atlantic; drilling through this discontinuity in the Brazil Basin at DSDP Site 515 shows thick, rapidly-accumulating (20 m/m.y.) bottom current deposits beginning in the middle Oligocene (32 Ma), and continuing through the Quaternary. The effects of AABW in the deep North Atlantic were also well established by the middle Oligocene (30 to 33 Ma), advecting older and ^{13}C-depleted bottom waters as far north as the Bay of Biscay. Beginning in the middle Miocene (16 Ma), an alternative source region developed in the northwestern Indian Ocean for supplying high salinity waters to high southern latitudes. The gradual closing of the eastern Tethyan seaways during the Neogene has dramatically altered the evaporation/precipitation budget of southwestern Asia, allowing the Arabian Sea and its marginal basins to become source areas for southward-flowing hypersaline intermediate and deep waters. During the climatic cycles of the late Neogene and Quaternary, the most recent episodes of intense AABW flow appear to precede the strongest glacial maxima at 50 Kyr and 150 Kyr BP. These episodes are not directly associated with maxima in NADW production, which may occur at a 40 Kyr period. Thus the production of high salinity deep water in the northernmost Atlantic (i.e., NADW) is not necessarily the only precondition to the formation of AABW, provided that an alternative source of hypersaline water (e.g. the northwestern Indian Ocean) is available.

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MIOCENE PALEOCEANOGRAPHY AND PLANKTON EVOLUTION

The development of the circum-Antarctic current near the end of the Oligocene (22 to 25 Ma) and related continued restriction of low latitude oceanic circulation set the stage for Miocene oceanographic and biotic evolution. Numerous workers of CENOP (Cenozoic Paleoceanography Program) and others have contributed towards better understanding of the Miocene Ocean; which existed between that of the still unfamiliar Oligocene Ocean and the familar latest Cenozoic. The Miocene also represents the time when the first major and permanent ice sheets formed in the late Phanerozoic.

Biogeographic patterns of planktonic microfossils underwent distinct change during the Miocene and have assisted in evaluating paleocirculation patterns. Earliest Miocene species tend to be distributed in the eastern and western sectors of the tropical Pacific. Oligocene elements tend to be distributed in the east. By the late Miocene, species distributions were more transtropical, forming more latitudinal rather than meridional provincialism. This increased latitudinal provincialism is tied to an intensification in polar to equatorial temperature gradients during the Miocene. The foraminiferal patterns imply that much of the gradient increase occurred during middle Miocene buildup of the cryosphere. Coincident with increased biogeographic latitudinal zonality was a strengthening of surface-water gyres (Kuroshio/California Currents), which was probably lined with global climatic cooling and the closure of the Indonesian Seaway. Temperate assemblages expanded towards the tropics at the expense of the Transitional Zone.

The middle Miocene (about 14 Ma) represents a crucial stage in the development of global paleoceanography, for at this time much of the Antarctic ice sheet formed. This event is marked by a sharp increase in the $\delta^{18}O$ values of calcareous plankton and of benthonic foraminifera. This increase certainly reflects in part a major period of ice-sheet growth, and a drop in surface temperatures at the Antarctic coast. Comparison of the oxygen isotopic records between high and low latitudes suggests that during the middle Miocene event, the planetary temperature gradient markedly steepened and temperatures at high and low latitudes became much less closely coupled. The existence of a widespread ice sheet from the middle Miocene is supported by the presence of common and persistent ice-rafted sediments around the Antarctic continent from that time. Cooler planktonic assemblages also became more important.

Part of the oxygen isotopic change resulted also from temperature change, as indicated by large changes at that time of deep-sea benthonic foraminiferal assemblages. Coincident with the isotopic change was the distinctive and rapid replacement of numerous species originating in the Oligocene or earlier that dominate the late Cenozoic and modern deep-sea environment.

The cause of development of Antarctic ice sheet in the Middle Miocene remains unexplained. No permanent ice sheet formed before this even though temperatures were cold enough since the latest Eocene. This was perhaps because of insufficient precipatation, until NADW was produced in sufficient quantities to influence the circum-Antarctic current and associated atmospheric conditions.

However some controversy still exists as to when Antarctic ice sheets became important on Antarctica. Some workers have reinterpreted oxygen isotopic data by assuming constant tropical sea-surface temperatures during the late Phanerozoic. They believe that major Antarctic ice sheets existed since the Eocene and perhaps during much of the Cretaceous, and that almost all ice volume was in place prior to the Middle Miocene. This is not well supported by independent sedimentologic and paleobiological evidence. However, little is still known about the Paleogene sediment record at high southern latitudes and further deep sea drilling is required to resolve these conflicts.

The discovery of a marked isochronous decrease of carbon isotopic ratio values (0.5 - 0.8 $^{o}/_{oo}$) in marine carbonates of the Indo-Pacific region at about 6.2 Ma has stimulated several speculations regarding the origin of this event and of its possible interrelations with the terminal Miocene event. Several workers have suggested that this decrease may reflect changes in circulation patterns and upwelling dynamics of an increase in the amount of particulate phosphorous reaching the deep ocean, while others have suggested that the shift reflected a sudden increase in the rate of supply of organic carbon from shallow water areas exposed by regression as well as changes in deep circulation patterns and ocean fertility.

An extraordinary number of important oceanographic changes are now known to have occurred during the latest Miocene in association with the carbon shift. These include a drop in sea level, cooling of surface waters, intensification of bottom-water circulation, increased biogenic productivity over large areas of the ocean, coupled with a decrease in biogenic silica deposition in the eastern equatorial Pacific, the isolation and dessication of the Mediterranean basin and increased Antarctic glaciation.

The intensification of oceanic circulation at this time is believed by some to have resulted from the development of the west Antarctic ice sheet and the formation of the first major production of true AABW which permanently altered global abyssal circulation.

The Oligocene/Miocene boundary is not marked by any crisis in Oligocene planktonic foraminiferal or other microfossil assemblages. Instead it is marked by the beginnings of a major evolutionary radiation leading to Neogene assemblages. The evolution of Neogene planktonic foraminifera occurred in three stages: a diversification stage (22.5 to 15.0 Ma, Early Miocene): an equilibrium stage (15.0 to 5.0 Ma, Middle and Late Miocene); and a declining stage (5.0 Ma to Recent, Pliocene and Quaternary). Early Miocene diversification reflects an initial exponential stage of phylogenetic radiation into new niches as the Miocene ocean conditions began to develop. Following this, the assemblages maintained approximate evolutionary equilibrium, although increased turnover rates reflect faunal reorganization during times of more intense paleoceanographic change. A diversity decline in the Pliocene and Quaternary seems to have resulted from adverse effects imposed by high-frequency paleoceanographic oscillations related to Northern Hemisphere glaciations.

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PALEOOCEANOLOGY OF THE INDIAN OCEAN

A sedimentological approach has been attempted to study paleooceanology of the Indian Ocean since the Late Jurassic. Paleolithological maps for the Late Jurassic, Neocomian, Middle Cretaceous, Senonian and Cenozoic sub-stages have been compiled. Plate tectonics reconstructions by Zonenshain and Savostin are used as a paleogeodynamic basis. Data on deep sea drilling and on drilling for oil, data from the Soviet and foreign geological and geophysical sea expeditions, materials on geological structure and paleogeography of islands and continental margins of the Indian Ocean are used in the research.
As the result, three stages can be distinguished in the geological history of the Indian Ocean, namely, Late Jurassic - Middle Cretaceous, Senonian-Paleogene, and Neogene-Quaternary. Three stages of the Indian Ocean development-Embrional, Early and Mature - correspond to these stages. The first period in question is the Late Jurassic as it was the period when formation of the oceanic crust and of most ancient pelagic sediments began in the Indian Ocean.
The Embrional stage is characterized by the dissection of Gondwana, formation of a number of shallow and narrow depressions between the major continental blocks, sedimentation in the northern part of the basin under the influence of the Tethys waters. Sedimentation rates were high, terrigenous and terrigenous-carbonate sedimentation predominated at the prograding continental margins. Concentration of C_{org} was high, especially in the Middle Cretaceous. Poor differentiation of the sedimentation patterns was typical of the period.

The Recent basic geological features of the Indian Ocean were formed at the Early stage. Sedimentation became more complicated. Sedimentation rates and concentration of C_{org} decreased. Hiatuses in the sedimentation often occurred and corresponded to the periods of sea level decrease.
The Mature stage is characterized by the origination of the recent circulation pattern. Facial variety in sedimentation reached its maximum. Inflow of terrigenous material increased; production of biogenic $CaCO_3$, silica and also C_{org} increased sharply. Silica accumulation played a very important role.

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ПАЛЕООКЕАНОЛОГИЯ ИНДИЙСКОГО ОКЕАНА

Для рассмотрения палеоокеанологии Индийского океана начиная с поздней юры применен седиментологический подход. Составлены палеолитологические карты для поздней юры, неокома, среднего мела, сенона и подотделов кайнозоя. Палеогеодинамической основой явились мобилистские реконструкции Л.П.Зоненшайна и Л.А.Савостина. В работе использованы материалы глубоководного и нефтяного бурения, данные советских и зарубежных геолого-геофизических морских экспедиций, сведения о геологическом строении и палеогеографии островов и континентального обрамления Индийского океана.
В результате в геологической истории этого океана удалось выделить три этапа: позднеюрско-среднемеловой, сенон-палеогеновый и неоген-четвертичный. Им соответствуют три стадии развития: эмбриональная, ранняя и зрелая. Рассмотрение начинается с поздней юры, поскольку именно в это время начинается формирование океанской коры и наиболее древних пелагических осадков Индийского океана.
Эмбриональная стадия характеризуется фрагментацией Гондваны, формированием ряда мелководных и узких прогибов между основными континентальными блоками, седиментацией в северной части бассейна под влиянием океана Тетис. Скорости осадконакопления высокие, преобладает терригенная и терригенно-карбонатная седиментация на проградирующих континентальных окраинах. Содержание С орг. повышено, особенно в среднемеловое время. Характерна слабая дифференциация седиментационных обстановок.
На ранней стадии формируются основные черты геологической структуры Индийского океана в его современных размерах. Седиментация усложняется. Скорости седиментации и концентрации С орг. уменьшаются. Широкое развитие получают перерывы в осадконакоплении, синхронные с периодами падения уровня океана.
Зрелая стадия характеризуется становлением современной циркуляционной структуры. Седиментация достигает наибольшего фациального разнообразия. Усиливается поставка терригенного материала, резко возрастает продук-

ция биогенных $CaCO_3$, кремнезема, а также С орг. Существенную роль играет кремненакопление.

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PALEOBIOLOGY OF EXTINCTION AND RADIATION EPISODES IN PELAGIC ECOSYSTEMS: PALEOCEANOGRAPHIC IMPLICATIONS

In the last 150 million years, three major extinction episodes occurred among open-ocean planktonic organisms. The Cenomanian/Turonian, Cretaceous/Tertiary, and Eocene/Oligocene episodes each reduced species diversity significantly. Biogeographic and trophic reorganization, and dominance by organisms with adaptations for vertical segregation took place. During radiations, following the extinctions, species became more numerous and were restricted in their biogeography, many had adaptations for vertical segregation, and others required an abundance of trophic resources.
Interpretation of the paleobiology of pelagic ecosystems indicates that periods of radiation were paleoceanographically heterogeneous with relatively stronger currents and more intense upwelling. Periods of extinction were paleoceanographically homogeneous both vertically and horizontally with biologically insignificant upwelling. This paleoceanographic reorganization may have been induced by known tectonic or extraterrestrial impact events that had enduring oceanographic effects.

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AVALANCHE SEDIMENTATION, SEA LEVEL VARIATIONS, HIATUSES AND PELAGIC SEDIMENTATION - GLOBAL LAWS

The global laws governing the process of a very rapid accumulation of sedimentary material on the floors of water basins, called avalanche sedimentation, are considered. The process results in the formation of unique properties of sediments, leads to isostatic downwarping of the earth's crust which, in turn, results in the creation of peculiar thermobaric conditions in a sediment-rock basin (SRB).
It should be emphasized that the very definition of avalanche sedimentary material in a small basin is not avalanche sedimentation, as we understand it, since the process should be long enough to be imprinted upon a geological section and of a sufficient scale to result in isostatic downwarping and a creation of a SRB. An important

feature of avalanche sedimentation lies in the fact that matter differentiation has usually no time to be completed under such a rapid accumulation. This process, like all other avalanche processes, is periodic rather than continuous.

In accordance with the main structural elements of the earth's crust, 3 global levels of avalanche sedimentation can be distinguished: upper (the first) - near the sea surface level (at the land-sea boundary), middle (the second) - at the continental rise, and lower (the third) - corresponding to the floor of the deep-sea trenches. All the levels are characterized in detail. It is shown that the major part of the Earth's sedimentary material is and was accumulated at the two first levels which correspond to the continental crust regions. As a result of this an enormous deficiency of sedimentary material is characteristic of the pelagic ocean - no more than 7.8-12% of river suspended matter penetrates it.

The sea level variations are the cause of the global hiatuses and cyclicity of sedimentation at the 1-3 levels of avalanche sedimentation the peculiarities of which are considered in the paper. The avalanche sedimentation regions are shown to be areas of high concentrations of organic matter and associated elements, deposition areas of oil, gas and other mineral resources.

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ЛАВИННАЯ СЕДИМЕНТАЦИЯ, ИЗМЕНЕНИЯ УРОВНЯ ОКЕАНА, ПЕРЕРЫВЫ И ПЕЛАГИЧЕСКОЕ ОСАДКОНАКОПЛЕНИЕ - ГЛОБАЛЬНЫЕ ЗАКОНОМЕРНОСТИ

Рассматриваются глобальные закономерности процесса очень быстрого накопления осадочного материала на дне водоемов, названного автором лавинной седиментацией. Этот процесс приводит к возникновению уникальных свойств отложений, ведет к изостатическому прогибанию земной коры, что,в свою очередь,приводит к созданию особых термобарических условий в осадочно-породном бассейне (ОПБ). Важно подчеркнуть, что само определение лавинной седиментации предполагает сочетание ряда критериев, а не одного, взятого в отдельности, Так, кратковременное накопление осадочного вещества в небольшом бассейне не есть лавинная седиментация в нашем понимании, поскольку этот процесс должен быть достаточно длительным, чтобы запечатлеться в геологическом разрезе, и достаточно масштабным, чтобы он привел к изостатическому прогибанию с созданием ОПБ. Важной особенностью лавинной седиментации является также то, что при столь быстром накоплении вещества не успевает обычно завершиться его дифференциация. Этот процесс, как и все лавинные процессы, не постоянный, а периодический.

В соответствии с основными структурными элементами земной коры выделя-

ется 3 глобальных уровня лавинной седиментации: верхний (первый) близ уровня океана (на границе суша-море), средний (второй): у основания континентального склона (на границе континентальной и океанской коры) и нижний, соответствующий дну глубоководных желобов (третий). Дается подробная характеристика всех уровней. Показано, что главная часть осадочного вещества Земли накапливалась и накапливается на первых двух уровнях, которые соответствуют областям развития континентальной коры. В результате в пелагиали образуется огромный дефицит осадочного вещества : проникновение речной взвеси в пелагиаль составляет не более 7,8-12,8%.
В связи с изменениями уровня океана возникают в глобальном масштабе прерывистость и цикличность осадочного процесса на 1-3 уровнях лавинной седиментации, особенности которых рассмотрены в докладе. Подчеркивается, что к областям лавинной седиментации приурочены концентрации органического вещества и связанных с ним элементов, здесь главные месторождения нефти и газа, а также ряда других полезных ископаемых.

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EVOLUTION OF THE ACTIVE MARGINS OF THE TETHYS (CAUCASIAN EXAMPLE)

In the Paleozoic and Alpine time the northern structural domain of the Caucasus, situated north of the Lesser Caucasian ophiolitic suture, evolved as the northern active margin of the Tethys. Geological record of the Caucasus provides unique information on the persistence of the Great Caucasian and Lesser Caucasian basins in the Paleozoic-Mesozoic, which implies continuity between the Paleozoic and Alpine Tethys in its Caucasian part. The southern structural domain of the Caucasus, Nakhichevan bloc, was detached from the northern shelf of Gondwana in the Late Paleozoic and appeared near the southern margin of Eurasia towards the Late Triassic. In the Mesozoic it represented a passive sialic microblock in the northern Tethyan realm and only in the Paleogene it adjoined the Iranian active margin. Paleomagnetic evidence indicates that the major Alpine orogenetic stages correlate with plate and microplate collision. In the Misozoic the most mobile boundary extended through the Black sea-Caspian basin, that divided microplates moving with different velocities and-at times- in opposite directions. The Pyrenean tectonic stage seems to be related to collision of the Caucasian and Iranian active margins in the Late Eocene. The present-day topography and structure of the Caucasus results from direct interaction of the latter with the Arabian plate in the Late Miocene-Quaternary.

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ЭВОЛЮЦИЯ АКТИВНЫХ ОКРАИН ТЕТИСА (НА ПРИМЕРЕ КАВКАЗА)

В палеозое и альпийское время северная структурная область Кавказа, расположенная к северу от Малокавказского офиолитового шва, развивается как северная активная окраина океана Тетис. Геологическая летопись Кавказа сохранила уникальные сведения о сквозном развитии Большекавказского и Малокавказского океанических бассейнов в палеозое-мезозое, что подразумевает унаследованный характер кавказской части Мезотетиса. Южная структурная область Кавказа, Нахичеванский блок, отделяется от северного шельфа Гондваны в позднем палеозое и уже к концу триаса оказывается у южного края Евразии. В мезозое он представляет собой пассивный сиалический микроблок в северной части Тетиса и лишь в палеогене причленяется к Иранской активной окраине последнего. Палеомагнитные данные показывают, что в альпийское время основные орофазы коррелируются с коллизией плит и микроплит, причем в мезозое наиболее подвижная граница, разделяющая микроплиты с различной скоростью и иногда с различным знаком движения, проходит через Черноморско-Каспийский бассейн. Существование последнего подтверждается палеомагнитными данными и результатами глубокого бурения. Пиренейская орофаза, по-видимому, связана со столкновением Кавказской и Иранской активных окраин Тетиса в позднем эоцене.Современный рельеф и структура Кавказа - результат взаимодействия последнего с Аравийской плитой в позднем миоцене-плейстоцене.

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THE NERITIC, SOUTHERN EXTRATROPICAL, FORAMINIFERAL RECORD ACROSS THE EOCENE/OLIGOCENE BOUNDARY: THE TEE IS NOT ET

The Late Paleocene-Early Eocene, the later Middle to Late Eocene, and the Early to Middle Miocene are three warm, transgressional intervals in the stepped deterioration of global climate. Each interval is spiked by its own set of oscillations. The middle interval is bracketed neatly by the major Middle Eocene transgression and the Terminal Eocene Event. On the Southern Australian passive margin, in facies ranging from oceanic, through open-neritic facing the nascent Southern Ocean, to restricted-neritic in intracratonic basins, there are "warm spikes" corresponding to planktonic foraminiferal Zones P13, low P15, high P15, and low P17. Interspersed among them are other interbasinal stratigraphic configurations and disjunct foraminiferal ranges that reinforce the sense of rapid, far-reaching, iso-

chronous oscillation that is based in climatic changes and shifts in watermasses.

Species ranges and the relative abundances of genera and higher taxa have been compared for open and restricted neritic sections from early Late Eocene to Early Oligocene. They are remarkably parallel and reveal no catastrophe in the TEE. Plots of incomings and outgoings among benthonic foraminifera are entirely consistent with background extinction. Profiles of relative abundances are entirely consistent with transgression-regression, with problems with salinity and oxygen, and with climatic change, for -briefly-lowered salinity, and for some overturn among neritic taxa.

That is all. There is no mass extinction. Indeed, the paleoceanographic significance of the TEE has been overstressed at the expense of the Early/Middle Eocene boundary.

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EVOLUTION OF OCEANS AND GEOCHEMISTRY OF CONTINENTS

The Earth's tectonic activity is determined by intensity of convective mass exchange in the mantle generated by gravitational differentiation of the mantle matter. This process is likely to be based on decay of solid silicate solutions and barodiffusion of iron oxides from the mantle's silicates to the intergranular space. At the mantle foot, liquid (melted) iron oxides are separated from solid silicates and flow into the core, whereas the mantle matter that has lost part of iron oxides starts outflowing in the Earth's gravity field thereby giving birth to convective currents in the Earth's mantle.

Proceeding from the above mechanism of the Earth's matter differentiation and the present-day concepts of planetary origins, the Earth's tectonic activity and degassing rate of its mantle can be determined. Based on this, calculations are made of water mass accumulation in the hydrosphere and hydration rate of the oceanic crust rocks. It is assumed that the outflow rate of many ore and lithophylic elements to the sialic "layer" of the continental crust is proportional to the dehydration rate of the oceanic crust in subduction zones. The abovementioned theoretical premises serve as a basis to explain the nature and apecific features of the Early Archean and Early Proterozoic metallogenic epochs in the Earth's history. The former of the stages (4-3 b yr ago) is associated with a sharp outburst of the Earth's tectonic activity in the Early Archean caused by an avalanche-type separation of the Earth's core embryo. The origin of the Early Archean metallogenic epoch accompanied by a transfer to the continental crust of the maximum volumes of iron, gold, uranium, potassium, rare earths and other ore and lithophylic elements is attributed to the saturation of the oceanic crust with water after in the Early Proterozoic the growing ocean water covered the rift zones of mid-oceanic ridges (2.6-2 b yr ago). Lowering of the metallogenic potential of the subsequent geological epochs is accounted for by both a decrease of the Earth's tectonic activity and a gradual exhaustion of the mantle. During water cycles in the Earth the hydrospheric water was repeatedly filtered through subduction zones. Altogether for the Earth's lifetime 16 x 10^{24} g of water passed through the subduction zones, which is II times as great as water content of the present hydrosphere.

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ЭВОЛЮЦИЯ ОКЕАНОВ И ГЕОХИМИЯ КОНТИНЕНТОВ

Тектоническая активность Земли определяется интенсивностью конвективного массообмена в мантии, генерируемого процессом гравитационной дифференциации мантийного вещества. В основе этого процесса, по-видимому, лежит распад твердых силикатных растворов и бародиффузия окислов железа из силикатов мантии в межгранулярные пространства. На подошве мантии расплавленные окислы железа отделяются от нерасплавленных (жестких) силикатов и стекают в ядро, а мантийное вещество, потерявшее часть окислов железа, начинает всплывать в гравитационном поле Земли, порождая тем самым в ее мантии конвективные течения.

Исходя из описанного механизма дифференциации земного вещества и современных представлений о происхождении планет, удается определить тектоническую активность Земли и скорость дегазации ее мантии. На этой основе рассчитывается накопление массы воды в гидросфере и скорость гидратации пород океанской коры. Принимается, что скорость выноса многих рудных и литофильных элементов из мантии в сиалический "слой" континентальной коры пропорциональна скорости дегидратации океанской коры в зонах поддвига плит.

На основе этих теоретических посылок удается объяснить природу и специфику раннеархейской и раннепротерозойской выдающихся металлогенических эпох в истории развития Земли. Первая из этих эпох (4-3 млрд.лет назад) связана с резким всплеском тектонической активности Земли в раннем архее, вызванным лавинообразным процессом выделения зародыша земного ядра. Происхождение раннеархейской металлогенической эпохи, сопровождавшейся выносом в континентальную кору максимальных объемов железа, золота, урана, калия, редких земель и других рудных и литофильных элементов, связано с насыщением океанской коры водой после того, как в раннем протерозое воды растущего океана перекрыли собой

рифтовые зоны срединно-океанских хребтов (2,6 - 2 млрд. лет назад). Снижение металлогенического потенциала последующих геологических эпох объясняется как уменьшением тектонической активности Земли, так и постепенным истощением мантии.
В процессе круговорота воды в Земле воды гидросферы многократно фильтровались через зоны поддвига плит. Всего за время жизни Земли в зонах поддвига плит выделилось $I6 \cdot I0^{24}$ г воды или примерно в II раз больше, чем ее содержится в современной гидросфере.

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SEA LEVEL CHANGES: UPSETTING FACTS

The new theory of eustasy and global sea level changes realizes that two different sea levels are never fully parallel over the globe because of the disturbance of the geoid configuration. These "paleo-geoid" changes are shown to have had a considerable effect through time; some 3-4 meters within some hundred years in Holocene time, several tens of meters in some thousand years in Late Pleistocene time and some hundred meters for longer times (maybe, some 200-400 m in some hundred thousand years time). Rates of 10 mm/yr seem common (and up to 30 mm/yr have been recorded). We can see several different mechanisms for such paleogeoid changes.
The well-known "Exxon Eustatic Curve" claims that there, during the last 200 Ma, were numerous large and very rapid (not to say "instantaneous") regressions and that these were simultaneous and globally recognizable. The curve has even been claimed to be a "Geological Index" for recognision and dating of submarine horizons.
The amplitudes and rates of the regressions can, however, in no way be physically combined with a global synchroneity. Obviously, it is the global validity that has to be sacrificed. By this, however, also the importance of the curve as a "geological index" must be completely revised.
Paleogeoid changes are natural effects of the high-dynamic Earth we know today. The esperation of expressing the eustatic changes in one globally valid curve is an illusion; each region needs its own eustatic curve. This simple fact, now starting to become generally recognized among Quaternary geologists, must also be accepted by scientists working with pre-Quaternary sea level analyses (the opposit will only cause farther retardations).

15. Зак. 1548

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PACIFIC PLEISTOCENE PALEOGEOGRAPHY

A complex research of deep-sea sediment cores of the Pacific was carried out according to the project of "Paleooceanology", which is aimed at recording Pleistocene climatic cycles, determining their absolute age and reconstructing of their paleogeographic environments for extreme phases of some cycles. Using the methods of the theory of information transmission (the technique of signal accumulation) to treat the results of the research allowed to distinguish 6 coolings of the first order (which may correlate to the epochs of glaciations of the North hemisphere) for the last million years: more ancient than 960, from 850 to 740, from 660 to 540, from 420 to 330, from 260 to 175 and from 80 to 10 thousand years ago. The most part of the distinguished climatic stages is complicated by the oscillations of the second order. The joint application of the oxygen-isotopic and micropaleontological analyses created a possibility to reconstruct the evolution of thermal structure of the surface water layer (0 - 200 m) in the south-eastern part of the Pacific for the last 400 thousand years. The vertical thermal gradients decreased in cold stages and increased in warm ones in the temperate zone and in Equatorial latitude, the water thermal structure almost didn't change in the tropical zone. The schemes of average annual temperatures of surface waters are made for the extreme phases of the Last Interglacial and Last Glacial of the Pacific and their differences from the modern values. The character of the flora is reconstructed on the territory of the land encircling the Pacific. The temperatures and water circulation in the optimum of the Last Interglacial were close to the modern ones. The increment of the interlatitude thermal contrast was established for the maximum of the Last Glacial, and, as the result, the intensification of the ocean water circulation.

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ПАЛЕОГЕОГРАФИЯ ТИХОГО ОКЕАНА В ПЛЕЙСТОЦЕНЕ

По проекту "Палеоокеанология" проведено комплексное исследование колонок глубоководных осадков Тихого океана с целью выявления климатических циклов плейстоцена, оценки их абсолютного возраста и реконструкции палеогеографических условий для экстремальных фаз некоторых из этих циклов. Использование методов теории передачи информации (техника накопления сигналов) для обработки результатов исследований позволило выделить 6 похолоданий первого порядка (вероятно, сопоставимых с эпохами оледенений северного полушария) за последний миллион лет: древнее 960, от 850 до 740, от 660 до 540, от 420 до 330, от 260 до I75 и от 80 до I0 тысяч лет назад. Большинство выделенных климатических этапов осложнено колебаниями второго порядка. Совместное применение изотопно-кислородного и микропалеонтологического анализов создало возможность для реконструкции эволюции термической структуры поверхностного водного слоя (0-200 м) в юго-восточной части Тихого океана за последние 400 тысяч лет. В холодные эпохи уменьшались, а в теплые увеличивались вертикальные термические градиенты в умеренной зоне и в экваториальных широтах, в тропической зоне термическая структура вод почти не менялась. Для экстремальных фаз последних межледниковья и оледенения составлены схемы среднегодовых температур поверхностных вод Тихого океана и их отличий от современных значений. На обрамляющей Тихий океан суше реконструирован характер растительности. Температуры и циркуляция вод в оптимум последнего межледниковья были близки к современным. Для максимума последнего оледенения установлены увеличение междуширотных термических контрастов и, как следствие, усиление циркуляции поверхностных вод океана.

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THE HYDROLOGICAL PALEOENVIRONMENT IN THE MESOGEAN SEA FROM THE CRETACEOUS-TERTIARY CRISIS TO THE YPRESIAN STAGE: A PALEOOCEANOGRAPHIC OUTLOOK OF THE NORTH ATLANTIC - MESOGEAN CONTEXT

A new method analysis conducted on ostracodes of open marine environment (PEYPOUQUET et al., in press) from three north Tunisian geological sections (El Kef, Elles, Sidi Kralif) led to a better understanding of the evolutive paleooceanographic processes of the north tunisian margin during the period covering the Maestrichtian to Ypresian stages.

The aim of this paper is sevenfold:

1° - to set an "ecostratigraphy" intercalibrated with chemostratigraphy and biostratigraphy of various other results obtained from previous studies in order to arrive at the "systemic stratigraphy" defined by BERGER and VINCENT (1981).

2° - to show that the Cretaceous-Tertiary transition is a relatively short, unforseeable, "crisis" which hit unevenly the ostracod fauna. This transition is reflected on the continental shelf, by an increase of the oxygen minimum zone which must have reached: O_2 1.5 ml/l at bottom level.

3° - to examine closely the O.M.Z. and its evolution throughout time.
4° - the phosphate deposits of Thanetian-Ypresian age in north tunisia is the final result of a specific paleohydrological history which began to take form as soon as the Danian stage (Trinidadensis zone).
5° - north equatorial oceanic upwelling which characteri e the southern mesogean coast are due to local physiography but above all to general climato-oceanic context which prevailed at the time over the northern hemisphere.
6° - the comparison of the present results with those obtained during leg 43 shows the extent of which the Mesogean and Atlantic oceans are climatically and hydrologically linked.
7° - a discussion on the theoretical models by VAIL et al. (1977), and FISCHER and ARTHUR (1977)enforces the arguments forwarded in the paper.

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MESOZOIC PALEOGEODYNAMICS AND PALEOGEOGRAPHY OF THE ARCTIC REGION

We attempted to reconstruct the mesozoic paleogeodynamic and paleogeographic patterns of the entire Arctic region located north off 60°N from three independent data sources, namely, kinematics, paleomagnetism and geology. On this basis, reconstructions were made for four time intervals: Early Triassic (230 MY), Late Jurassic (150 MY), Early Cretaceous (115 MY) and Late Cretaceous (70 MY). In the first reconstructions the West Europe, Greenland and most North America comprise the single East-North American plate. Slight motions which practically did not change Laurasia geometry occurred between this plate and the rest of Eurasia. In the following reconstructions the pattern changed considerably; relative motions between individual blocks were so great that formation of the oceanic crust began. In the western part of the Arctic region the main geological events were controlled by relative motions of the large Laurasian fragments. In the east, the geological pattern was governed by the interaction of small lithosphere blocks. Part of them as North Alasca, Chukotka, Novosibirsk and Polousny-Khroma blocks were also Laurasian fragments; the other as Omolon microcontinent, Koryakiya, Kamchatka, South Alasca, Wrangellia and so on, might belong either to Gondwana, or to the Pantalassa continent, which is now completely destroyed.
The geological history of the Arctic has been controlled by two opposite processes. The first led to the breakup of the former single continental domains, to the formation of the oceanic crust and passive co-

ntinental margins of the Atlantic type; the second led to the origination of active continental margins of the Pacific type, where subduction of the crust of former and newly originated oceans took place, and accretion of the continental crust and formation of fold belts occurred.

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МЕЗОЗОЙСКАЯ ПАЛЕОГЕОДИНАМИКА И ПАЛЕОГЕОГРАФИЯ АРКТИЧЕСКОГО РЕГИОНА

В настоящей работе рассмотрена палеогеодинамика и палеогеография арктической области, расположенной к северу от 60° с.ш. Исследование опиралось на три независимых источника данных: кинематику относительных перемещений литосферных плит, палеомагнетизм и геологию. На этой основе составлены реконструкции для четырех временных интервалов: раннего триаса (230 млн.лет), поздней юры (I50 млн.лет), раннего мела (II5 млн.лет) и позднего мела (70 млн.лет). На первых двух реконструкциях Западная Европа, Гренландия и бо́льшая часть Северной Америки входят в состав единой Восточной Северо-Американской плиты. Между этой плитой и остальной частью Евразии происходит лишь незначительное перемещение, которое практически не меняет конфигурации Лавразии. На последующих реконструкциях ситуация меняется коренным образом; относительные движения между отдельными блоками достигают таких размеров, что сначала в Лабрадорском море, а затем в Норвежско-Гренландском бассейне начинает формироваться океаническая кора. Если на западе Арктического региона основные геологические события определялись перемещением крупных фрагментов Лавразии, то на востоке важная роль принадлежала малым литосферным блокам. Часть из них, такие,как Северо-Аляскинский, Чукотский, Новосибирский и Полоусненско-Хромский блоки, также являлась осколками Лавразии; другие,- как Омолонский континент, Корякия, Камчатка, Южная Аляска и Врангелия,могли принадлежать либо Гондване, либо Панталассе - ныне полностью разрушенному континенту внутри Палео-Тихого океана.Реконструкция перемещений малых блоков и их положения относительно системы координат, образованной главными литосферными плитами, осуществлялась прежде всего на основании палеомагнитных данных.

Геологическая история Арктики в мезозое определялась двумя разнонаправленными процессами. Один из них приводил к расколу ранее единых континентальных массивов, формированию между ними пространств с океанической корой и пассивных континентальных окраин Атлантического типа, другой - к возникновению активных окраин Тихоокеанского типа, где в зонах субдукции поглощалась кора ранее существовавших и вновь образованных океанов, происходило наращивание континентальной коры, формировались складчатые пояса континентов.

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NUMERICAL MODELLING OF THE WORLD OCEAN PALEOCIRCULATION

Numerical modelling of the global ocean circulation makes it possible to reconstruct the schemes of the currents and hydrological fields of the oceans of the geological hystory of the Earth using the equations of hydrothermodynamics of the ocean and the paleoclimatological data.

A mathematical model for simulation studies of ocean hydrophysics with an arbitrary geometry has been proposed and tested. Temperature, salinity and currents fields are adjusted to specified and stationary fields of the air temperature(or ocean surface), winds and precipitations. Numerical experiments with the aim to study modern circulation and to reconstruct the Mesozoic and the Cenozoic (from the Jurassic to Late Miocene) paleocirculation have been carried out. There have been shown that the main cause for the circulation patterns on the geological time scale is the continental drift, which produces the shore line changes. These changes of the World Ocean lead to principle reorganization of the circulation system and changes of the ocean climate. Formation of circumzonal currents play the main role. Glaciation of the nearshore regions of the Antarctic coincide, for example, with the opening of the strait between the Australia and the Antarctic in the Oligocene Epoch. Subtropical gyres become separated from higher latitudes by circumpolar current. This results in lower meridional heat flux toward that latitudes and intensive cooling of the ocean in subpolar regions.

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ЧИСЛЕННОЕ МОДЕЛИРОВАНИЕ ПАЛЕОЦИРКУЛЯЦИИ МИРОВОГО ОКЕАНА

Численное моделирование глобальной океанской циркуляции позволяет реконструировать схемы течений и гидрологические поля в океанах геологического прошлого на основе решения уравнения гидротермодинамики океана и палеоклиматических данных.

Предложена математическая модель циркуляции океана для имитации гидрофизических полей в океанах с произвольной конфигурацией берегов. Поля температуры, солености и скоростей течений приспосабливаются в процессе решения к заданным стационарным полям температуры атмосферы (или поверхности океана), ветра и осадков.

Выполнены численные эксперименты по расчету современной циркуляции и реконструкции палеоциркуляции в мезозое-кайнозое (от юры до позднего миоцена). Показано, что решающим фактором формирования циркуляции в геологическом масштабе времени является распределение суши и моря, изменяющееся вследствие континентального дрейфа. Изменения конфигурации береговой линии Мирового океана приводят к принципиальным перестройкам циркуляции и климата океана. Особое значение имеют циркумширотные течения. Оледенение прибрежных районов Антарктиды совпадает, например, с раскрытием пролива между Австралией и Антарктидой и формированием Антарктического циркумполярного течения в олигоцене. Субтропические кольца циркуляции отсекаются от высоких широт циркумполярной струей, препятствующей меридиональному переносу тепла в субполярные регионы, что приводит к сильному выхолаживанию океана в высоких широтах.

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THE PLIO-PLEISTOCENE OCEANS

It is now becoming well known that the environmental changes that occurred during the Late Pliocene and Pleistocene had a major impact on the surface of the oceans. The change was particularly striking in the North Atlantic where druing the glacials the Gulf Stream flowed almost due east across the ocean towards Spain instead of warming the northerly coasts of Europe. From the point of view of the stratigrapher, the history of movements of this current are important because they provide the means by which oceanic climatic change may be correlated with events on the European continent: when the North Atlantic Ocean was in a glacial mode, the adjacent continent must also have been. DSDP Site 552A, drilled with the Hydraulic Piston Corer on Rockall Bank to the West of Ireland, shows a dramatic sequence of glacial-interglacial fluctuations which started abruptly at 2.37 million years ago and continued up to the present. It may never be possible to recover such a detailed record on the adjacent continent, but this deep sea record will enormously aid our understanding of those fragments of the record that are available in Europe.
The alterations to the deep water circulation may have been as important for our understanding of climatic variation as were the changes at the surface. During the glacials much less deep water formed in the North Atlantic than does today. The contrast in dissolved oxygen content between the depths of the Atlantic and of the Pacific scarcely existed at the glacial maximum. Changes in the chemistry of the ocean caused the atmospheric carbon dioxide content to be lower during the glacial than it is now, whereas during the last interglacial it was higher than it was during most of the Holocene (although it was not as high as it will become as a result of man's combustion of fossil fuels).

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KINEMATICS AND PALEOMAGNETICS OF THE TETHYS CONVERGENCE ZONE FROM TRIASSIC TO PRESENT

We used published data from magnetic anomalies in the Arctic, Atlantic and Indian oceans to discuss critically the kinematics of the Eurasian, African, Iberian, North American, Arabian and Indian plates. Nine key geologic periods have been chosen to establish base maps at 10, 20, 35, 65, 80, 110, 130, 155 and 190 MY. In addition we discuss a new Lower Triassic fit which takes into account the paleomagnetic data of stable plates which produces a sizeable amount of extension in the Tethys from Lower Triassic to Lower Jurassic. We have critically compiled all available paleomagnetic data on stable plates and Tethyan mobil belt. Data from the stable plates are first used to establish a common polar wander curve using the above kinematics. These give us the paleolatitudes of the 9 base maps. We then exsamine evidence for the paleomagnetically identifiable blocks in the Tethyan mobil belt, in particular Iberia, Apulia, Ionian zone, Pontides, Taurides, Caucasus, Alborz and Lut. Based on these data, we discuss whether the motions of the blocks were primarily controlled by Africa or Eurasia or were completely independent.

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КИНЕМАТИКА И ПАЛЕОМАГНЕТИЗМ ЛИТОСФЕРНЫХ ПЛИТ, ОБРАМЛЯЮЩИХ ТЕТИС, С ТРИАСА ДО НАСТОЯЩЕГО ВРЕМЕНИ

На основании опубликованных данных о линейных магнитных аномалиях в Арктике, Атлантике и Индийском океане обсуждаются относительные перемещения Евразиатской, Африканской, Иберийской, Северо-Американской, Аравийской и Индийской плит. Составлено девять карт-реконструкций положения этих плит для следующих временных интервалов: I0, 20, 35, 65, 80, II0, I30, I55 и I90 млн.л. Кроме того, составлена и обсуждается новая реконструкция относительного расположения всех перечисленных выше литосферных плит в раннем триасе. При ее составлении учтены палеомагнитные данные, позволяющие наиболее достоверно оценить величину растяжения, происходившего в бассейнах Тетиса на начальном этапе его существования (ранний триас - ранняя юра). Палеомагнитные данные для крупных плит, обрамляющих Тетис, в сочетании с кинематикой были использованы для расчета единой кривой кажущейся миграции полюса. Палеомагнитные данные для таких малых плит, либо блоков литосферы, как Иберия, Апулия, Ионийский блок, Понтиды, Тавриды, Кавказ, Эльбурс и Лут наряду с геологическими данными служили обоснованием того, в какие периоды малые блоки принадлежали либо Евразиатской, либо Африканской плитам, либо перемещались независимо.

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ANOXIC OCEAN ENVIRONMENTS

Organic C-rich pelagic and hemipelagic sediments of Cretaceous age were deposited in various paleotectonic settings of the North Atlantic-Tethys Ocean, the South Atlantic Ocean and the Indian Ocean, while black shales of the same age in the Pacific Ocean are less widespread. In the North Atlantic-Tethys Ocean the oldest black shales of Valanginian-Hauterivian age are restricted to deep basinal settings. During the Barremian and in the Aptian the organic rich facies became more extensive, as documented in the continental margin environments of the southwestern Tethys.
The degree of disturbance of the oceanic C-cycle during times of excessive burial of organic matter is reflected in the Early Cretaceous C-isotope stratigraphy. The C-isotope record suggests that the oldest black shale deposits were of only regional extent and had no impact on the C-cycle. Periodically more sluggish circulation in restricted deep water basins of the central Tethys and Atlantic Oceans lead to the formation of poorly oxygenated deep water with enhanced dissolution of carbonate and preservation of organic matter. Eluctuations in the C-isotope record of 1‰ in the Barremian and up to 3‰ in the middle Aptian reflect excessive burial of organic matter caused by periodic increase in global surface water productivity and specific paleotectonic conditions. Organic matter preferentially was buried in the deepest parts of the still young Atlantic and Indian Oceans and in the basinal settings of the newly formed and morphologically complex passive continental margins, where bottom water circulation was restricted. The severe but natural perturbations of the carbon budget have led to significant consequences of ocean-atmosphere equilibrium and of global climate.

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SECULAR VARIATIONS OF REE, TH, AND U IN MARINE FOSSIL APATITE AS A MEASURE OF REDOX IN PHANEROZOIC OCEANS

Biogenic apatite of conodonts, ichthyoliths, and inarticulate brachiopods from Upper Cambrian through Recent marine sediments was analy-

zed for trace elements by modifying standard instrumental neutron activation analysis. Apatite of modern fish debris apparently concentrates rare-earth elements (REE) during early diagenesis in the same proportions as seawater, and retains a signature of the oceanic REE pattern, suggesting the same relationship between fossil biogenic apatite and ancient seas. Patterns of eight REE from over 150 samples, normalized to North American Shale Composite Standard, show significant secular variations, notably in variations of the cerium anomaly. Cerium is defined by its relationship to neighboring elements as: $Ce_{anom} = \text{Log}\ (3Ce_n/2La_n + Nd_n)$.
REE also vary among depositional settings and are consistent among contemporaneous fauna from the same depositional framework, providing a REE fingerprint of oceanic chemistry and erosional provenance.
In the modern oceanic environment cerium is preferentially scavenged by iron oxides, resulting in a negative cerium anomaly in seawater REE patterns. This Ce-Fe affinity leads to a model of changing oxidation-reduction conditions in ancient seas that explains the variations in Ce_{anom} of fossil biogenic apatite. During times of widespread anoxia in the water column, dissolution of iron oxides would release cerium and effectively remove the negative Ce anomaly. Such anoxic events are recorded by the non-depleted Ce contents of fossil apatite at several time intervals during the Phanerozoic, which correlate with previously postulated oceanic anoxic events. Variations in Ce_{anom} appear to be related to Th/U variations, another potential indicator of seawater redox changes. The Ce_{anom} and Th/U age curves are generally compatible with previous redox interpretations of $\delta^{34}S$ and $\delta^{13}C$, for which major shifts occur at approximately the same times.

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PALEOZOIC OCEANS: AN ATTEMPT OF ABSOLUTE RECONSTRUCTIONS

Orientation of three intraplate magmatic belts, which can be considered as hot spot tracks, the Mongolian (from 130 to 280 m.y.), South Siberian (from 320 to 400 m.y.) and Baltic (from 280 to 365 m.y.) belts was used together with apparent paleomagnetic pole wander paths for reconstruction of a true motion of continents during Paleozoic. The reconstructions obtained show the old, Late Precambrian Pangea continued to exist in the Early Paleozoic having an inner arrangement of constituent continents strongly different from that in the Late Paleozoic Pangea. The continents were constantly located within the eastern hemisphere only. The western hemisphere was occupied by the

Paleo-Pacific ocean. Four oceans existed in Paleozoic between continents in the eastern hemisphere: (1) the Paleo-Atlantic inherited from the Late Precambrian time and closed before Devonian (400 m.y.), (2) the Asiatic paleoocean also inherited from Late Precambrian and closed 450 m.y. ago, (3) the Uralian paleoocean opened 500 m.y. and closed in the latest Permian (240-230 m.y.), (4) the Paleo-Tethys opened in Ordovician (480-450 m.y.) and inherited by the Mesozoic Tethys. Life duration of the oceans was 200-400 m.y. The main trend in the Earth's evolution during Paleozoic was a break up of the old, Precambrian Pangea and construction of the new, Late Paleozoic Pangea.

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ПАЛЕОЗОЙСКИЕ ОКЕАНЫ: ПОПЫТКА АБСОЛЮТНЫХ РЕКОНСТРУКЦИЙ

Для восстановления истинных движений континентов в палеозое были использованы ориентировки трех поясов внутриплитового магматизма (Монгольского с возрастом со 130 до 280 млн.лет, Южно-Сибирского - с 320 до 400 млн.лет, Балтийского - с 280 до 365 млн.лет) как следов движения плит над горячими точками и траектории кажущейся миграции палеомагнитных полюсов. С помощью проведенного анализа выявлено, что к началу палеозоя существовала позднедокембрийская (древняя) Пангея с существенно иной компоновкой континентов, чем в позднепалеозойской Пангее. Континенты постоянно располагались только в восточном полушарии. Западное полушарие было занято Палео-Тихим океаном. В палеозое в восточном полушарии между континентами существовали четыре океана: I) Палео-Атлантический, возникший в позднем докембрии и закрывшийся перед девоном (400 млн.лет назад); 2) Азиатский палеоокеан, также возникший в позднем докембрии и закрывшийся 450 млн.лет назад; 3) Уральский палеоокеан, открывшийся 500 млн.лет назад и закрывшийся в конце перми (240-230 млн.лет назад); 4) Палео-Тетис, открывшийся в ордовике (480-450 млн.лет назад) и унаследованный мезозойским Тетисом. Продолжительность существования океанов составляла 200-400 млн. лет. Главная тенденция эволюции Земли в течение палеозоя заключалась в распаде древней, докембрийской Пангеи и создании новой, позднепалеозойской Пангеи.

КОЛЛОКВИУМ/COLLOQUIUM 04

ГЕОЛОГИЯ АРКТИКИ
ARCTIC GEOLOGY

Conveners: I.S.Gramberg, J.Tiede

Co-Conveners: T.Gielsvik, G.I.Gorbunov, W.B.Harland, McMillan, M.Pitcher

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STRUCTURAL PECULIARITIES AHD HISTORY OF THE FORMATION OF THE POLAR-URALIAN REGION OF THE SOVIET ARCTICA

There are three structural stages Proterozoic, Paleozoic-Triassic and Iurassic-Anthropogen within the considered region of Polar Ural and Pie-Hoy. The first two stages are called Pre-uralides and Uralides accordingly. The Uralides are presented by four structure-formational complexes (SFC). The Lower-Proterozoic stage (Karelides) is consisted of metamorphic formations. Three structural stages are distinguished above.The lower stage (R_{2-3}) made of sedimentary-vulcanogenic formations corresponds to the regimen of the underdevelo - ped Baikalian geosyncline.The upper one (R_4-V) corresponds to the orogenic stage.The intrusive rocks belong to granite,gabbrogranodioritic and gabbro-diabasic formations mostly formed at orogenic pe - riod.

Two sectors can be distinguished at the paleozoic history of the formation of region, they are paleooceanic and paleocontinental sector.The shelf one of carbonate complex mainly; the bathyal of shale ahd Pie-Hoy one of shale-carbonate complexes are zones of dip submerge of the platform.The melanocratic basement and the row of SPC,corresponding to the various stage of the development of the Uralian geosyncline,are distinguished in the structure of paleooceanic sector.The orogeny stage is presented by the molasses of the foredeep and the intermountain deeps. The stage of the platform development has begun at the middle Iurassic. The allochtonous plates pushed on the shelf and orogeny formations are made of the bathyal and Pie-Hoy SFC. The formations of the paleooceanic sector are in allochtonous bedding also. The movement of paleooceanic sector has begun at the early carboniferous and has been continuing untill the early Iurassic. The movement of the Pie-Hoy allochton has taken place at the same time. The paleozoic intrusive magmatism is defined by intrusions of gabbro-diabases during the two stages of pressingtension of the Earth crust by subintrussions of the islandarc gabbro-tonalite-granodiorites and by the wide display of granitization and the metasomatose.

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ОСОБЕННОСТИ СТРОЕНИЯ И ИСТОРИЯ ФОРМИРОВАНИЯ ПОЛЯРНО-УРАЛЬСКОГО РЕГИОНА СОВЕТСКОЙ АРКТИКИ

В пределах рассматриваемого региона, охватывающего север Полярного Урала и Пай-Хой, выделяются три структурных этажа: протерозойский, палеозойско-триасовый и юрско-антропогеновый. Первые два этажа именуются соответственно доуралидами и уралидами. Доуралиды представлены четырьмя структурно-формационными комплексами (СФК). Нижнепротерозойский (карелиды) сложен метаморфическими формациями. Выше выделяются три СФК. Нижний (R_{2-3}), сложенный осадочными формациями, отвечает режиму активизированной платформы. Средний (R_{3-4}), сложенный осадочно-вулканогенными формациями, характеризует этап развития недоразвитой байкальской геосинклинали. Верхний (R_4-V) отвечает орогенному этапу. Интрузивные образования принадлежат к гранитной, габбро-гранодиоритовой и габбро-диабазовой формациям, сформированным в основном в орогенный этап.

В палеозойской истории развития региона выделяются два сектора: палеоконтинентальный и палеоокеанический. В составе палеоконтинентального сектора выделяются три одновозрастных СФК: шельфовый, преимущественно карбонатный; батиальный сланцевый и Пайхойский сланцево-карбонатный,- зоны глубокого погружения платформы. В составе палеоокеанического сектора выделяются меланократовое основание и ряд СФК, отвечающих различным стадиям развития Уральской геосинклинали. Орогенная стадия представлена молассами краевого и межгорных прогибов. Со средней юры начался этап платформенного развития. Батиальный и Пайхойский СФК слагают аллохтонные пластины,надвинутые на шельфовые и орогенные формации. Формации палеоокеанического сектора также находятся в аллохтонном залегании. Надвигание палеоокеанического сектора началось в раннем карбоне и продолжалось до ранней юры. В это же время происходило передвижение Пайхойского аллохтона. Палеозойский интрузивный магматизм характеризуется внедрением габбро-диабазов на двух этапах растяжения-сжатия земной коры, внедрением субинтрузий липаритов, формированием островодужных габбро-тоналит-гранодиоритов, широким проявлением гранитизации и метасоматоза.

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PLATE TECTONIC HISTORY OF THE ARCTIC

The Arctic ocean represents the last great challenge in establishing the broad outlines of the histories of the present oceans of the earth. The rotation of the Lomonosov ridge away from the Barents shelf during the Tertiary is well-established and a presently unique relationship has been demonstrated between the Gakkel ridge and the Poloussnoye graben system. Earlier history of the Arctic is poorly known but a possible and testable scenario involves rifting of the North Slope Alaska and Chukotsk block (NSAC) from the Canadian Arctic islands in the Late Jurassic and rifting of the New Siberian Block (NSB) from along-strike on the same margin a little later. Both NSAC and NSB were involved, after rapid rotation, in the assembly of N.E.Siberia with such other blocks as "Greater Japan" (Much of Kyushu, Honshu, Hokkaido, Sakhalin, Sikhote Alin, Kamchatka and Koryak) and Omolon. During older Mesozoic, Permian and Carboniferous times NSB and NSAC occupied one Atlantic-type margin of the triangular Boreal Embayment of the Pacific and the Verkhoyansk Atlantic-type margin of Siberia (with the prominent Vilyuy rift embayment) occupied the other. These rifted-margins, which are now caught up in the Brooks Range, S. Anyui, Sviatoy Noss, Sette Daban and Chirskiy suture zones, had formed during the Late Devonian shortly after and close to the site of the Innuitian suturing event between Siberia and North America.

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THE NORTH AMERICAN-SIBERIAN CONNECTION, A MOSAIC OF ACCRETED TERRANES IN ALASKA AND CHUKOTKA

Alaska and North-East U S S R , the isthmus connecting the North American craton with the Siberian platform, is a mosaic of tectonostratigraphic terranes. These terranes consist of cratonic fragments in a matrix of exotic oceanic and continental margin terranes, including structurally complex sequences rich in submarine volcanic rocks, flysch, and mafic/ultramafic plutonic rocks.

Most of these terranes comprising Alaska and North-East U.S.S.R. are thought to consist of terranes suspected of being allochthonous with respect to the North American craton (NAC) and to the Siberian Platform (SP). Among these, the only major terranes made of Precambrian and Paleozoic rocks that may be craton fragments are: Tatonduk and Yukon crystalline terranes of east-central Alaska, the Nixon Fork terrane of southwestern Alaska, and the northern Alaska North Slope, Endicott and Seward terranes which continue into Chukotka and Wrangel Island to form the Arctic Alaska-Chukotka superterrane. Other craton fragments in North-East U.S.S.R. include the Omolon and Prikolymsk terranes.

Only the Tatonduk terrane can be traced with reasonable certainty back into a craton. The others are all suspect because they are separated by faults, exotic younger terranes, and large successor basins from NAC or SP. Comparison of the Precambrian and Paleozoic geological history of these suspect terranes and NAC or SP show important differences suggesting fragments of widely different parts of NAC or SP, or fragments of other cratons fronting on Panthalassa.

By reversing the process of northward terrane megadrift and reconstructing the paleogeography back to Cretaceous time, the Alaska-Chukotka part of the isthmus narrows and becomes a peninsula. Meanwhile, the land bridge joining the Siberian platform and Alaska-Chukotka breaks up into terranes that move southward. Early Mesozoic and Paleozoic paleogeographic reconstructions suggest that a wide Panthalassa oceanic basin separated North America from the eastern margin of the Siberian platform. Instead of an isolated ocean in the Arctic, circum-Arctic stratigraphic, tectonic, and paleomagnetic data support an extension of Panthalassa across the northern margin of Pangea which included NAC and SP.

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CENOZOIC SEDIMENTATION PATTERNS IN THE EVOLVING ARCTIC OCEAN: CANADA BASIN AND ALPHA-CHUKCHI REGION TO LOMONOSOV RIDGE

The very incompletely known Cenozoic history of the central Arctic Ocean includes dramatic changes in sedimentary processes. The Late Mesozoic-Early Cenozoic Arctic Basin was the site of extensive accumulation of biogenic silica. T-3 core 437 and CESAR core 6, taken 150 km apart, consist of more or less identical Late Cretaceous silicoflagellate-diatomaceous sediment. This Cretaceous evidence together with T-3 core 422 (Early Cenozoic), indicates that a broad belt of siliceous ooze, interpreted to represent upwelling conditions, accumulated over the present Alpha Ridge, 50-70 my ago. As the Arctic Ocean assumed its modern size and position during the Middle Cenozoic, silica deposition shifted to sub-polar latitudes and was replaced by glacial-marine sedimentation. Ice rafted debris blanketed the entire Amerasian Basin by at least late Miocene. In the Canada Basin, turbidites are extensive and have masked ice rafting during at least the last 700,000 years. From the Chukchi-Alpha Ridges to the Lomonosov Ridge pack ice and iceberg transported sediment has been deposited more or less continually since the late Miocene. Locally, currents have transported finer grained sediment from bathymetric highs such as the Lomonosov Ridge, into depositional sinks such as the Makarov Basin.

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STRUCTURE AND EVOLUTION OF THE MARGINS AROUND THE NORWEGIAN-GREENLAND SEA

Following Mesozoic phases of crustal extension, the region between Norway and Greenland became relatively quiet with regional subsidence dominating in a large basinal area which extended into the North Sea and the Barents Sea. At about Paleocene/Eocene time the mid-Atlantic rift progressed northward and sea floor spreading started along the newly formed plate boundary. The initiation of Cenozoic rifting and the subsequent drifting phase has fundamentally defined the structural and depositional framework of the present day margins. Particularly important observations are: the existence of marginal highs apparently related to subaerial volcanic activity, the different amounts of marginal subsidence both with respect to region and time, the effects of the middle Oligocene change in relative plate motion on the margin structures, and lastly, the two-stage evolution of the Greenland Sea with its associated shear movements.

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TERTIARY DEFORMATION IN SPITSBERGEN AND OPENING OF THE NORVEGIAN-GREENLAND SEA

Four fracturation phases have been determined, by means of microtectonic analysis, in the different Paleogene basins of Spitsbergen (European plate) : Main central basin, Ny Alesund basin, Forlandsundet graben. The same events are recognized in the Upper Paleozoic formation. The corresponding paleostress fields are about : NS compression, EW extension, EW compression and NS extension in succession.

This structural evolution of the western part of Spitsbergen during the Early to Mid Tertiary can be related with the different episodes of the Greenland-Norvegian sea development. The first compressive phase corresponds with the dextral transcurrent movement between Greenland and Spitsbergen, since C.24 (51 Ma). The EW extension corresponds to the rifting process which took place between the new separated blocks since C.13 (35 Ma). This extension can explain the continental overlap between north-east Greenland and Spitsbergen in the kinematic reconstructions prior to A.13 (G.WINK, 1982).

The last two tectonic events do not seem to be related to any known kinematic evolution of the north-atlantic ocean; they are probably only related to the structural evolution of the new European continental margin.

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GEOLOGICAL STRUCTURE OF THE ARCTIC CONTINENTAL MARGIN OF THE USSR

The Barents-Kara, Laptev, East Siberian-Chukchi marginal plates and offshore continuation of the continental West Siberian plate can be recognized on the Arctic shelf of the USSR considered as a passive continental margin on the basis of the basement crustal structure, sedimentary cover and relation to structures of the deep Arctic basin.

Along with other sedimentary basins of the Arctic they form a part of the Arctic sedimentary superbasin. In general, marginal plates are marked by heterogenous basement, persistent subsidence and, hence, by a great thickness of a sedimentary cover, and degeneration of continental fold structures by the transition to the shelf. On the Barents-Kara plate the sedimentary cover rests on the folded basement which has undergone destruction had has blocky structure. The Laptev plate was emplaced on the platform basement reworked in the course of oceanic rifting. Peculiar feature of the East Siberian-Chukchi plate is that its sedimentary cover was formed on the folded basement involved into subsidence earlier than it acquired a platform state. The paper deals with the crustal structure under the shelf and ocean, geophysical characteristic, areas of the reworked crust apparently due to continental rifting are outlined. The history of sedimentary basement, and peculiar types of geologic structures are discussed as well.

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ГЕОЛОГИЧЕСКОЕ СТРОЕНИЕ АРКТИЧЕСКОЙ КОНТИНЕНТАЛЬНОЙ ОКРАИНЫ

На арктическом шельфе СССР, относящемся к пассивным континентальным окраинам, по особенностям строения коры фундамента, осадочного чехла и взаимоотношения со структурами глубоководного Арктического бассейна обособляются Баренцево-Карская, Лаптевская, Восточно-Сибирско-Чукотская окраинно-материковые плиты и подводное продолжение материковой Западно-Сибирской плиты.

В совокупности с другими осадочными бассейнами Арктики они **входят в состав Арктического осадочного супербассейна. Окраинно-материковые плиты в общем характеризуются гетерогенностью фундамента, устойчивым погружением и соответственно большой мощностью осадочного чехла, вырождением складчатых структур континента при переходе на шельф и**

другими особенностями. На Баренцево-Карской плите осадочный покров залегает на складчатом основании, претерпевшем деструкцию и характеризующемся блоковым строением. Лаптевская плита сформировалась на платформенном основании, переработанном процессами океанского рифтогенеза. Для Восточно-Сибирско-Чукотской плиты характерно, что ее осадочный чехол сформирован на складчатом основании, вовлеченном в погружение до достижения им платформенного состояния. В работе приведены данные о строении земной коры шельфа и океана, дана ее геофизическая характеристика и намечены участки переработки коры, очевидно, связанные с проявлениями континентального рифтогенеза. Изложена также история развития осадочных бассейнов и охарактеризовано своеобразие типов геологических структур.

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THE STRUCTURE AND THE HISTORY OF THE FORMATION OF THE BARENTS SEA SOUTH FRAMING

Peculiar features of the structure and geologic history of the Jurassic margin of the Barents Sea are discussed. Tectonics and history of the Jurassic part of the Barents Sea are shown to be related to those of the Baltic shield and the eastern European platform. The above is supported by the continuation of structures of the Timan-Pechora aulocogen and Pechora syneclise in the southern Barents Sea shelf. The similarity between structures of the North Barents Sea plate and those of Norwegian and North Sea is inferred.

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СТРУКТУРА И ИСТОРИЯ ФОРМИРОВАНИЯ ЮЖНОГО ОБРАМЛЕНИЯ БАРЕНЦЕВА МОРЯ

Рассмотрены особенности строения и геологической истории южного обрамления Баренцева моря. Показано, что тектоника и история развития южной части Баренцева моря закономерно связаны с тектоникой и историей развития Балтийского щита и Восточно-Европейской платформы. Это находит выражение в продолжении структур Тимано-Печорского авлакогена и Печорской синеклизы в южной части Баренцевоморского шельфа. Обращается внимание на сходство структур Северо-Баренцевоморской плиты со структурами Норвежского и Северного морей.

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SEDIMENTARY BASINS AND GEOLOGIC STRUCTURE OF THE CONTINENTAL MARGIN NORTH OF ALASKA

Multichannel seismic-reflection profiles suggest that three pulses of rifting created the first-order geologic structures and localized the sedimentary basins of the present continental margin north of Alaska. An Early Jurassic pulse isolated shelf deposits of the Mississippian to Triassic Arctic Alaska Basin from their sourceland to the north and created an east-west trending Jurassic basin beneath the eastern Beaufort shelf. The basin contains more than 2 km of clastic rock, probably mainly lutite.
Late Neocomian to Albian rifting formed the Canada Basin of the Arctic Ocean by sea-floor spreading. From 4 to 10 km of submarine-fan and abyssal-plain deposits incompletely fill this ocean basin. Clastic sediment from southern sourcelands overstepped the newly rifted margin by Albian time and prograded the present continental-terrace sedimentary prism of the Beaufort and Chukchi Seas. This prism, more than 13 km thick, is dominated structurally by growth faults and rotational megaslumps; off northeastern Alaska it contains large syndepositional diapiric-shale ridges and Quaternary detachment folds. Both late Neocomian(?) and latest Cretaceous or early Paleogene pulses of rifting between Wrangell Island and the Chukchi Continental Borderland appear to have thinned the continental crust into which the North Chukchi Basin subsided. The earlier pulse is recorded by marked basinward thickening of Cretaceous strata, and the later one by basinward thickening of Tertiary strata and by locally numerous antithetic faults and foundered fault blocks in the Cretaceous strata. Sediment in the basin is more than 12 km thick. Because the basin appears to underlie the shelf only adjacent to the Chukchi Borderland, these contiguous features may be tectonically related.

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ARCTIC PALEOOCEANOGRAPHY IN THE LATE CENOZOIC TIME AND ITS RELATIONSHIP TO GLOBAL CLIMATES

Sediment cores from the Arctic Ocean yield significant faunal and lithologic evidence of three major oceanic-climatic regimes (represented by stratigraphic units) during the last 5 m.y. The record commences near the time of a major global cooling phase which culminated with the marked expansion of the Antarctic ice sheet synchronously with the onset of high latitude Northern Hemisphere glaciation. The emergence of the Panamanian Isthus ~3.5 m.y. ago caused

reorganization of oceanic circulation and the inception of a vigorous Gulf Stream. Increased transport of moist air to polar highlands nourished local ice sheets. The oldest, unit (III), comprises sediments deposited between ~5 and 3 m.y. ago when the Arctic Ocean was cold but free of perennial ice.
A global warming commenced ~3 m.y. B.P. Unit II records the inception of density-salinity stratification in the Arctic as a consequence of the sudden dilution of surface water by the influx of meltwater during a deglaciation. Water temperatures indicated by the planktonic foraminifera are incompatible with the presence of perennial ice cover. Following the culmination of Northern Hemisphere high latitude continental uplift, ~1 m.y. ago, ice sheets attained maximum extent and perennial ice covered the Arctic Ocean. Ice then spread southward over the N. Atlantic and N. Pacific. Eventually the moisture source to the pole was greatly diminished and the Arctic and circum Arctic ice decayed. Melting progressed southward and when complete deglaciation was attained, a new glacial cycle commenced in Arctic latitudes. Nine 100 K.y. cycles are recorded in unit I sediments.

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STRUCTURE AND HISTORY OF THE AMERASIAN BASIN

The Arctic Ocean is composed of two major basins: the Amerasian and Eurasian ones separated by the Lomonosov Ridge. The Eurasian Basin is a typical oceanic feature formed by axial accretion along the Arctic segment of the Mid-Ocean Ridge system. Magnetic anomalies indicate that the Nansen Ridge became active at about anomaly 24 (55 m.y. B.P.). The boundary between the two basins, Lomonosov Ridge is generally accepted to be a continental sliver split off from the Barents continental margin by the Mid-Ocean Ridge. The Amerasian Basin is an older feature than the Eurasian Basin and is much more complex. It is characterized by a major marginal plateau (Chukchi) and a large enigmatic ridge (Alpha-Mendeleyev). The southern Canada Basin is commonly accepted to have been formed by rotation of northern Alaska away from the Canadian Islands, however, the northern basin apparently was the result of a complex tripple junction. The difficulties in determining the structure and origin of these features are exacerbated by a confusing magnetic pattern and lack of data.

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HISTORY OF THE ARCTIC OCEAN FORMATION

The difference in the geological structure of the Eurasian and Amerasian basins of the Arctic Ocean is shown to be due to their different geological history. The Eurasian basin was formed in the Cenozoic when a continental block of the Lomonosov Ridge split off and drifted away from the Eurasian lithosphere plate. The Amerasian basin is a part of an ancient (Early Mesozoic?) oceanic plate cut off the Pacific at the close of the Early Cretaceous by the suturing of continental blocks of Asia and North America.

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ИСТОРИЯ ФОРМИРОВАНИЯ СЕВЕРНОГО ЛЕДОВИТОГО ОКЕАНА

Показано, что различие в геологическом строении Евразийского и Амеразийского бассейнов Северного Ледовитого океана обусловлено их различной геологической историей. Евразийский бассейн сформировался в кайнозое в результате раздвижения Евразийской литосферной плиты и отколовшегося от него континентального блока хребта Ломоносова. Амеразийский бассейн представляет часть древней (раннемезозойской?) океанической плиты, отчленившейся от Тихого океана в конце раннего мела при смыкании континентальных блоков Азии и Северной Америки.

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SEDIMENTATION AND TECTONICS OF A DIFFUSE, OBLIQUE-SLIP PLATE BOUNDARY: THE CANADIAN ARCTIC ISLANDS FROM 80 Ma B.P. TO THE PRESENT

Use of a revised magnetic anomaly time scale provides a more accurate chronology of sea-floor spreading events in Labrador Sea-Baffin Bay. New stratigraphic data from Meighen and Remus Basins in the eastern Arctic Islands shows that sedimentary and tectonic events there can be correlated with relative movements of Greenland between 80 and 36 Ma B.P. caused by Labrador Sea-Baffin Bay spreading. Within the eastern Arctic Islands these movements generated the Eurekan Orogeny across the diffuse Greenland-Canada plate boundary. Subsequently the Arctic Islands were affected by uplift and erosion, and then by extensional faulting and renewed clastic sedimentation between 15 Ma B.P. and the present.

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PALEOMETEOROLOGY/CLIMATOLOGY OF THE POLAR REGIONS

In the Late Cretaceous and Early Tertiary, the Arctic region was characterized by generally much higher temperature than today. Boreal and sub-tropical forests existed, for example, on Greenland and Svalbard. This has often been explained in terms of a lower latitudinal position than today. This is not tenable, however. The explanation seems instead to be that there was a quite different atmospheric circulation at that time.
The paleomagnetic pole was in the Arctic basin (close to the Bering Strait). Plant elements and insect faunas indicate that this region was surrounded by a thin boreal zone and then a very thick sub-tropic zone. No real arctic zone existed. The concentric pattern indicates that the rotation and magnetic poles were close and in the Arctic.
During the Late Cretaceous and Early Tertiary, there was a circum-equatorial oceanografic circulation. At the same time, the temperature and biological zonation of the Arctic indicate that much more heat reached the Arctic than today, i.e. that the polar regions were not separated (meteorologically) in the way they are today.
This seems to indicate that the rising heat from the equatorial regions was transported all the way up to the polar regions, and was not deflected down at around Lat. 45° as it is today. This would explain both the high temperatures in the Arctic and the absence of a strict latitudinal zonation.
By the closing of the circum-equatorial circulation (eastern Tethys, western Tethys and finally Panama), the present circulation was established, which was the base for the subsequent formation of polar and high to mid-latitude ice caps. It also concurs with the suddenly increased seasonality in Mid-Miocene time (i.e. the establishment of a latitudinal climatic zonation like today). This means that the atmospheric circulation cells were quite different in the Late Cretaceous to Early Tertiary from those of today and the Late Cenozoic.

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THE GEOLOGY AND OIL-GAS-BEARING POTENTIAL OF THE YAMAL-GYDAN SYNECLISE (THE WESTERN SIBERIA)

During Mesozoic the Yamal-Gydan syneclise was a region of maximum

downwarping within the West Siberian plate. In structure and oil- and gas potential it differs from the remainder of the plate. The sedimentary cover of the syneclise is composed of Baikalian and older paraplatform formations and a plate complex represented by terrigenous polyfacial Triassic-Cenozoic sediments. Within the syneclise, including Messoyakh sill 28 deposits were discovered; among them 11 gas, 4 gas condensate and 6 oil- and gas condensate deposits. Within the discovered fields 143 pools were found. Major discoveries were made on Yamal Peninsula. The commercial oil-gas capacity of the Lower Jurassic, Upper Jurassic, Berriassian-Valanginian, Valanginian-Hauterivian and Hauterivian-Cenomanian Complexes was proved for this area.
It should be emphasized that only Cretaceous deposits were studied. Most of Jurassic deposits has not been drilled in as yet. Triassic and Paleozoic deposits seem to be perspective, from the latter in the Novovartovsk deposit gas condensate influx was registered.

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ГЕОЛОГИЯ И НЕФТЕГАЗОНОСНОСТЬ ЯМАЛО-ГЫДАНСКОЙ СИНЕКЛИЗЫ (ЗАПАДНАЯ СИБИРЬ)

Ямало-Гыданская синеклиза являлась в мезозое областью максимального прогибания в пределах Западно-Сибирской плиты. По своему строению и нефтегазоносности она отличается от остальной части плиты. В состав чехла здесь входят прибайкальские и более древние параплатформенные комплексы и плитный комплекс, представленный терригенными полифациальными отложениями триаса-кайнозоя. В ее пределах, включая пограничный Мессояхский порог, открыто 28 месторождений, в том числе газовых II, газоконденсатных 4, нефтегазоконденсатных 6. В месторождениях выявлены I43 залежи. Основные открытия сделаны на п-ове Ямал. Установлена промышленная нефтегазоносность нижне-среднеюрского, верхнеюрского, берриас-валанжинского, валанжин-готеривского, готерив-сеноманского комплексов.
При этом следует учитывать, что изучены в основном меловые отложения. Юрские на значительной части площадей еще не вскрыты. Интерес на перспективу представляют триасовые и палеозойские отложения. Из последних получены притоки газа с конденсатом на Нововартовском месторождении.

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ENDOGENIC DIFFERENTIATION OF MATTER IN THE GEODYNAMIC SYSTEM OF THE ARCTIC OCEAN

The distribution of endogenic (magmatogenic and ore) formations with respect to major dynamic zones and evolution of typical structure of the Arctic Ocean geodynamic system is discussed against the background of six-stage structural evolution of the system existing on the Earth during the last 260 Ma and embracing the Cenozoic ocean and adjacent areas of Eurasia and North America to divide ridges inclusive.

The recognized regularities of the endogenic matter differentiation allow to suggest a bipolar trend of structural-mineral changes which controls an interelated development of new mafic (oceanic) and salic (continental) massifs of lithosphere and to outline a principal metallogeny pattern for any portion within the geodynamic system of the Arctic Ocean for the period from the Permian to Antropogene.

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ЭНДОГЕННАЯ ДИФФЕРЕНЦИАЦИЯ ВЕЩЕСТВА В ГЕОДИНАМИЧЕСКОЙ СИСТЕМЕ СЕВЕРНОГО ЛЕДОВИТОГО ОКЕАНА

На фоне шестиэтапной структурной эволюции геодинамической системы Северного Ледовитого океана, существующей в теле Земли последние 260 млн.лет и охватывающей сам кайнозойский океан и сопредельные пространства древней Евразии и Северной Америки вплоть до водораздельных хребтов, охарактеризовано распределение эндогенных (магматогенных и рудных) формаций относительно главных динамических зон и истории развития типовых структур данной системы. По выявленным закономерностям эндогенной дифференциации вещества установлена биполярная направленность структурно-вещественных преобразований, обеспечивающая взаимосвязанное развитие новых мафических (океанических) и салических (континентальных) массивов литосферы, и намечена принципиальная схема металлогении для любого участка в пределах геодинамической системы Северного Ледовитого океана за период от перми по антропоген.

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TECTONIC EVOLUTION OF THE EAST ARCTIC SYSTEM

Tectonic structures of islands, a shelf and coast of the Laptev, East Siberian, Chukchi and Beaufort Seas belong to the East Arctic System.

The Pre-Riphean continental crust, periodically affected by rifting processes, occurs at its base. Up to the end of the Mesozoic the carbonaceous, terrigenous, tuff-terrigenous and molasse formations accumulated in shallow depressions of the System. These formations are platform ones in its northern part, while in the southern part these are miogeosynclinal ones, being similar to Mesozoic complexes of the Verkhoyansk-Chukotsk area. The faulting and granitoid magmatism gave weak evidence in the System.

The Riphean-Paleozoic and Mesozoic complexes are typically shelf deposits that are characteristic of the former passive continental margins of the Atlantic type. In the east the System is complicated by a paleorift. At its place the Innuitian folded belt arose. On the Wrangel Island and in its vicinity a zone of the belt fading begin to show.

In the Cenozoic all the System and the adjoining Kara and Hyperboreal Platforms were subjected to tectonic destruction. The spreading resulted in deep basins with an oceanic crust and in Arctic seas with a thinned continental crust. The Recent Arctic shelf is a repeated passive margin with a tendency of inherited evolution.

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ТЕКТОНИЧЕСКАЯ ЭВОЛЮЦИЯ ВОСТОЧНО-АРКТИЧЕСКОЙ СИСТЕМЫ

Тектонические структуры островов, шельфа и побережья морей Лаптевых, Восточно-Сибирского, Чукотского и Бофорта принадлежат к Восточно-Арктической системе.

В ее основании находится дорифейская континентальная кора, которая лишь периодически нарушалась процессами рифтогенеза. До конца мезозоя в неглубоких прогибах системы накапливались карбонатные, терригенные, туфотерригенные и молассовые формации. В северной ее части они платформенные, в южной - миогеосинклинальные, идентичные комплексам Верхояно-Чукотской области мезозоид. Разломная тектоника и гранитоидный магматизм в рассматриваемой системе проявились чрезвычайно слабо.

Рифейско-палеозойские и мезозойские комплексы представляют собой типично шельфовые образования, свойственные былым пассивным континентальным окраинам Атлантического типа. На востоке эта система осложнена палеорифтом, на месте которого возник Иннуитский складчатый пояс. На о-ве Врангеля и в его окрестностях намечается зона затухания пояса.

В кайнозое вся система и прилегающие к ней Карская и Гиперборейская платформы подверглись тектонической деструкции. В результате спрединга образовались глубоководные впадины с корой океанического типа и арктические моря с утоненной континентальной корой. Современный Арктический шельф - это повторная пассивная окраина с тенденцией унаследованного развития.

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NORWEGIAN-GREENLAND BASIN - RIFTING AND OCEANIZATION

Tectonics of the Norwegian-Greenland basin is highly variated. Three principal tectonic processes considerably affect the evolution of this region: rifting, oceanization and trappogenesis. In the course of time, rifting developed from scattered rifting, which covered considerable spaces of the ancient continent as a branched system of intracontinental graben-rifts, to localized oceanic rifting, which took place in the axial parts of the recent mid-oceanic Mohn and Kolbeinsei ridges, to decay of the peri-oceanic Viking, Faeroes-Shetland, North Shetland graben-rifts, and the inner parts of the Voring and More plateaux. The processes of oceanization developed by breaking of continental margins into a number of blocks separated from the main massif by graben-rifts; the blocks experienced different phases of oceanization in the course of their submerging to the depths of the newly formed oceanic depressions, such as the Norway, Lofoten and Greenland basins. During the first stages in the evolution of the basin, the oceanic trappogenesis created continental and shelf basaltic covers and further localized on the floor of the newly created basins in the form of oceanic trappes. Evidence of space-time inhomogenity is observed within all the structures of the region; it reflects the dynamics of tectonic development and the transition of continental crust into oceanic and back again. The effect of vertical movements on the evolution of the basin is dominant, whereas that of horizontal movements is much lower.

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НОРВЕЖСКО-ГРЕНЛАНДСКИЙ БАССЕЙН : РИФТОГЕНЕЗ И ОКЕАНИЗАЦИЯ

Область Норвежско-Гренландского бассейна тектонически весьма неоднородна. В ее развитии существенную роль играли три важнейших процесса:

рифтогенез, океанизация и траппогенез. Рифтогенез проходил с развитием во времени от рассеянного на значительном пространстве древнего континента в виде ветвящейся системы интраконтинентальных рифтов к локализованному в осевых частях современных рифтогенальных океанических хребтов Мона и Кольбейнсей и отмиранием ставших периокеаническими рифтов-грабенов Викинг, Фареро-Шетландского, Северо-Шетландского, внутренней части плато Воринг и Мёре. Дробление континента, а затем континентальных окраин сопровождалось погружением и переработкой отделяемых периокеаническими рифтовыми желобами блоков с их последовательно прогрессировавшей океанизацией. Завершенная океанизация сопровождалась формированием во впадинах океанических траппов. Траппогенез начинался на первых стадиях развития бассейна формированием континентальных и шельфовых базальтовых покровов, а завершился локализацией траппов на дне новообразованных океанических котловин. В развитии бассейна преобладающую роль играли вертикальные движения и меньшую - горизонтальные.

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AMERASIA BASIN, ARCTIC OCEAN: MAGNETIC ANOMALIES AND THEIR DICIPHERMENT

Despite intensive aeromagnetic surveying, the age, origin, and tectonic evolution of the Amerasia Basin still remain largely unknown. The magnetic anomaly pattern is complex, with high amplitudes over the northern Canada Basin, the Alpha-Mendeleev Ridge (AMR), and the Makarov Basin. Low amplitudes, more characteristic for sea-floor spreading, occur in the southern Canada Basin; the existence there of an extinct buried spreading axis is probable. Magnetic anomalies over the AMR and adjacent basins tend to parallel both the regional ridge structure and the smaller-scale ridge/valley topography. Over at least part of the Alpha R. the magnetic anomalies are partly caused by basement topography of high magnetization and normal polarity. The southern Canada Basin most resembles a normal ocean basin and may have been formed between 110 and 155 Ma. If the northern Canada Basin and AMR are oceanic, the crust must be atypical, perhaps like the back-arc ridge complexes or hotspot - generated oceanic plateaus. At satellite heights (MAGSAT) the Alpha Section of the AMR is associated with a strong positive magnetic anomaly (locally over +16 nT). Such high amplitudes normally occur only over continents, although oceanic plateaus are associated with positive anomalies of lower amplitude.

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CRUSTAL STRUCTURE OF THE ARCTIC INFERRED FROM GEOPHYSICAL DATA

Results of geophysical studies of the crust under the North Polar region of the Earth are presented.
Apart from conventional geophysical methods a deep-sea magnitometry technique proposed by geophysists of PGA "Sevmorgeologia" is developed. Comprehensive magnetic and other geophysical studies within the Arctic basin allow to recognize peculiar features of magnetically active crust deep structure up to the Moho inclusive. The Arctic shelf is shown to have crust changing from continental (35-40 km) to transitional (25-30 km) type. Areas underlain by "anomalous crust" in central parts of the Barents, Kara, and Laptev seas are confined to zones of intracontinental rifting.
In general, the western and eastern parts of the Arctic shelf of the USSR differ in thickness, magnetic activity, and complex crustal structure probably resulted from different geologic history. A schematic diagram of crustal geoblocks of the shelf is presented. Two quite different megablocks - Eurasian (underlain by oceanic crust) and Amerasian (having mainly transitional crust) - are recognized in the Arctic basin. A two-layered structure of the magnetically active oceanic crust is inferred for the area of probable spreading. The antipodal symmetry suggested previously by the Soviet geophysists for the deep structure of the North and South polar areas of the Earth was confirmed; it may be due to peculiar regime of rotation forces acting there.

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СТРОЕНИЕ ЗЕМНОЙ КОРЫ АРКТИКИ ПО ГЕОФИЗИЧЕСКИМ ДАННЫМ

Приводятся результаты геофизического изучения земной коры Северной Полярной области Земли.
Наряду с использованием традиционных геофизических методов развивается разработанный геофизиками ПГО "Севморгеология" метод глубинной магнитометрии. Комплексный анализ магнитных и других геофизических данных в пределах Арктического бассейна позволил выявить особенности глубинного строения магнитоактивной коры вплоть до поверхности Мохо-

ровичича. Устанавливается, что в пределах Арктического шельфа СССР тип земной коры изменяется от континентального (35-40 км) до переходного (25-30 км). Участки "аномальной коры" в центральных частях морей Баренцева, Карского и Лаптевых связываются с зонами проявления внутриматерикового рифтогенеза.

В целом западная и восточная части Арктического шельфа СССР отличаются по мощности, магнитоактивности и сложности строения земной коры, что, очевидно, отражает различие их геологического развития. Дается схема геоблоков земной коры шельфа. В глубоководной части Арктического бассейна выделяются два существенно различных мегаблока: Евразийский (с океанической корой) и Амеразийский (преимущественно с корой переходного типа). Намечается двуслойная структура магнитоактивной океанической коры в области возможного спрединга. Подтверждается установленный ранее советскими геофизиками факт антиподальной симметрии в глубинном строении северной и южной полярных областей Земли, что может быть связано с особенностью режима действующих здесь ротационных сил.

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STRUCTURE OF THE ALPHA-MENDELEEV RIDGE

In the spring of 1983 the Department of Energy, Mines and Resources, Canada, carried out a multidisciplinary geophysical and oceanographic expedition to study the Alpha Ridge, Arctic Ocean. It was code-named CESAR for Canadian Expedition to Study the Alpha Ridge. The studies included bathymetry, gravity, sub-bottom and intermediate reflection seismic, crustal refraction seismic, heat flow, magneto-variational measurements, coring and dredging, sea floor photography and sediment dynamics. The CESAR results are compared with other studies having been carried out over the Alpha-Mendeleev Ridge. Based on these studies the nature and origin of the ridge is discussed.

ТЕКТОНИКА АЗИИ
TECTONICS OF ASIA

Conveners: T.K.Huang, A.L.Yanshin
Co-Conveners: K.V.Bogolepov, P.N.Kropotkin, Nguyen Ngiem Minh, J.Stöklin, V.C.Thakur, S.Uyeda, K.S.Valdiya, Zhan Wenyou

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PALEOTETHYS - TETHYS: CONTINUOUS DEVELOPMENT

In the Caucasian segment of the Alpine-Himalayan foldbelt long-living marine basins are known, where the Variscan and Oldcimmerian folding stages did not result in termination of geosynclinal regime. They evolve continuously during the Paleozoic and Alpine time. Among those the Southern Slope geosyncline of the Great Caucasus seems to be unique as far as it comprises continuous Devonian-Eocene sequence of monotonous deep-marine sediments. The sequence consists mainly of continental slope and basinal deposits (semi-pelagic terrigenous muds, silicites, turbidites, flysch). Comparatively small volumes of volcanics, localised at different stratigraphic levels are represented by undifferentiated tholeiite-basalts and bypolar basalt- keratophyric series. The pre-Alpine folding stages vere accompanied here only by formation of islands (cordillieras) their denudation and local breaks in sedimentation. Neocimmerian folding was more intense. The western continuation of the Southern Slope geosyncline, seems to be Mountinous Crimea (Tauric series) and Kotel zone (Bulgaria). Eastwards it apparently extends into the Transcaspian region (Balkhan) up to the Kopet Dag. Another structure continuously evolving from the Variscan-Eocimmerian into Alpine time seems to be the ophiolitic belt of Northern Anatolia-Lesser Caucasus (Sevan). This belt marking the Paleozoic-Mesozoic ocean, was separated from the Great Caucasian geosynclinal basin by the Pontian-Transcaucasian volcanic arc. By paleomagnetic data the latter two structures vere situated at the southern margin of the Eurasiatic continent. They represented a couple island arc-back arc basin i.e. an active margin of West Pacific type. Continuous development of the Variscan-Oldcimmerian geosynclinal basins into the Alpine time indicates that the collision of Eurasiatic and Africa-Arabian continents and closing of the tethyan basins occured only in the Late Alpine time.

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ПАЛЕОТЕТИС -ТЕТИС: УНАСЛЕДОВАННОЕ РАЗВИТИЕ

В Кавказском отрезке Альпийско-Гималайского складчатого пояса известны длительно развивающиеся бассейны, в которых варисские и древнекиммерийские фазы складчатости не привели к завершению геосинклинального режима, благодаря чему наблюдается их унаследованное (сквозное) развитие в альпийские геосинклинали. Среди них уникальным представляется геосинклиналь Южного склона Большого Кавказа, где установлено наличие практически непрерывного разреза однотипных отложений от девона по эоцен включительно. Разрез сложен в основном фациями континентального склона и его подножья (турбидиты, флиш, силициты). Относительно небольшие массы вулканитов, развитые на разных стратиграфических уровнях, представлены в основном недифференцированными толеит-базальтами либо контрастно-дифференцированными базальт-кератофировыми сериями. Доальпийские фазы складчатости сопровождались здесь лишь образованием островов - кордильер, их размывом и локальными несогласиями. Более интенсивно проявилась новокиммерийская складчатость. Продолжением геосинклинали Южного склона на западе принято считать Горный Крым (таврическая формация) и зону Котел (Болгария). На востоке она, по-видимому, тянется в Закаспий (Балханы) до Копетдага.

Другой структурой с унаследованным варисско-древнекиммерийско-альпийским развитием нам представляется офиолитовый пояс Северной Анатолии - Малого Кавказа (Севан). Этот пояс, маркирующий палеозойско-мезозойский океанический бассейн был отделен от геосинклинального бассейна Большого Кавказа Понтийско-Закавказской вулканической дугой. Последние, по палеомагнитным и биогеографическим данным.располагались у южного края Евразиатского континента, составляя пару островная дуга - окраинное море, т.е. активную континентальную окраину типа запада Тихого океана.

Непрерывное (сквозное) развитие варисско-древнекиммерийских геосинклинальных бассейнов Кавказского региона в альпийские свидетельствует о том, что коллизия Евразиатского и Африка-Аравийского материков и закрытие бассейнов Тетиса произошло лишь в позднеальпийское время.

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DEEPLY-SEATING FAULTS OF CENTRAL ASIA

In the USSR the theory of deeply-seating faults in the Earth crust has been developed by A.Peive. Such faults under geologi-

cal development for hundreds of millions of years, often separates different formations, controls mineral deposits.
The author studied the deeply-seating faults in Tien-Shan, Altai, Caucasus, Himalayas. Up to this point the Main Central Thrust, Main Boundary Fault and suture line of Indus have been distinguished in Himalayas (Gansser & others). The continuation of the Indus suture line has been investigated by the Chinese geologists (Teng & others, 1983). We have obtained new data. The report shows the significance of the Himalayan Main Axial Deeply-seating Fault zone, in which the Main Central Thrust forms the boundary between the lowmetamorphised formations of the Southern Himalayas and the polymetamorphic crystalline schists and anatectic gneissic granitoides, also formed at the Southern Himalayan rock complexes. A Panjab University expedition along the cross-section Kulu, Rotang-Pass, Zinskar and Indus (Pande, V.J.Gupta, Surender Kumar & others,1969); investigations by McPawell and Konaghan (1973) showed beyond doubt that the Central Thrust is the southern boundary of the Main Axial Deeply-seating Fault, a body which was known since long as the crystalline axis of the Himalayas. On the northward a totally different formations, Tetis Himalayas is developed. Its contact with the rocks of the crystalline axis all over is tectonic (A.Sinha, 1982).
The Main Axial Deeply-seating Fault is a zone composed of echalonic ultrametamorphic roots of the larger over-thrust covers of the Southern Himalayas - plates of Chail (up to 4000 m) and Jutog (more than 2000 m). In the rocks of Chail A.Ashgirei, N.Umnova & A.Sinha detected the spore of early Carboniferous age and also graywacks of spilite-albitofir composition. The that the Southern Himalayas was a geosyncline zone broadens the possibility of exploration of mineral deposits.

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ГЛУБИННЫЕ РАЗЛОМЫ ЦЕНТРАЛЬНОЙ АЗИИ

В СССР учение о глубинных разломах в земной коре разработано А.В.Пейве. Они развиваются сотни миллионов лет и часто разделяют различные формации пород, контролируют месторождения.
Автор изучал глубинные разломы Тянь-Шаня, Алтая, Кавказа, Гималаев. До сих пор в Гималаях выделялись Главный пограничный сброс, Главный центральный взброс и сутура Инда (Гансер и др.); продолжение последней исследовано китайскими геологами (Тенг и др., 1983).
Мы получили новые данные. В работе показано значение и дан обзор геологии зоны Главного осевого глубинного разлома Гималаев. Главный

центральный взброс соответствует границе между малометаморфизованными формациями Южных Гималаев и полиметаморфическими кристаллическими сланцами и анатектическими гнейсированными гранитоидами. Все эти кристаллические тела возникли преимущественно в фанерозое также за счет южногималайских комплексов пород.

Экспедиция Пенджабского университета по пересечению Кулу, Рутанг-Пасс, Зинскар, Инда (Панде, В.Дж.Гупта, Сурендар Кумар и др., 1969) и исследования МакПауэла, Конагхана (1973) показали, что Главный центральный взброс является всего лишь южным ограничением зоны Главного осевого глубинного разлома, тело которого издавна именуется кристаллической осью Гималаев. Севернее распространены совершенно иные формации Тетис Гималаев. Контакт последних с кристаллическими породами всюду тектонический (Аншу Синха, 1982).

Главный осевой глубинный разлом составлен зоной эшелонированных ультраметаморфизованных тел, корней наиболее крупных шарьяжей Южных Гималаев - пластин Чейла (до 4 000 м), Джутога (более 2 000 м) и лежащих выше кристаллических пород (5 000 м). В сланцах Чейла Г.Ажгирей, Н.Умнова и А.Синха (1981) обнаружили споры раннекарбонового возраста и граувакки спилито-альбитофирового состава - факты, доказывающие существование геосинклинали в Южных Гималаях и открывающие перспективы поиска соответствующих месторождений.

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DEEP STRUCTURE OF CENTRAL ASIA ALONG THE TIEN SHAN-PAMIR-HIMALAYAS GEOTRAVERSE

The orogen-folded structures of Tien Shan, Pamir, Karakorum and Himalayas are characterised by the anomalous structure of the deep interior, extremum parameters of geophysical fields, and high seismicity. An important feature in the structure of the lithosphere is the much thicker crust (65-75) as compared to the thickness on stable plates (35-37). Moreover, the crust has lower values of average velocities (6.2-6.2 km/s) which grow towards the south, from Tien Shan to Pamir and Karakorum. The upper mantle has higher velocities of seismic waves propagation, from 8.24 km/s at the depth of 55 km to 8.6 km/s at the depth of 300 km. The top of the asthenospheric layer is fixed at the depths of 120-150 km, its bottom in the north and south of the region lying at the depth of 200 km and in the central part at 300 km. This means that the band of the thickest crust stretches in the zone of the likewise thickest asthenospheric layer. This zone coincides with the deep Bouguer anomaly minimum (-500 m gal) and with the depression in the geoid surface. Therefore, the recent active stage of development of orogen-folded structures is caused by processes not only in the Earth's crust and upper mantle, but in the asthenosphere at the depth of about 150-200 km as well. Seismicity of the lithosphere of the region is the result of geodynamic processes manifested for its higher layers by block displacements of the crust and by shifts of steeply tilted mantle blocks in the lower layers (Pamir-Hindukush seismofocal zone).

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ГЛУБИННОЕ СТРОЕНИЕ ЦЕНТРАЛЬНОЙ АЗИИ ПО ГЕОТРАВЕРСУ ТЯНЬ-ШАНЬ-ПАМИР-ГИМАЛАИ

Горно-складчатые сооружения Тянь-Шаня, Памира, Каракорума и Гималаев характеризуются аномальным строением глубинных недр, экстремальными параметрами геофизических полей и высокой сейсмичностью. Важной особенностью строения литосферы является резко повышенная (65-75 км) мощность земной коры по сравнению с ее мощностью на стабильных плитах (35-37 км). При этом она характеризуется невысокими значениями средней скорости (6,2-6,4 км/с), которая повышается в южном направлении - от Тянь-Шаня к Памиру и Каракоруму. Верхняя мантия характеризуется повышенными скоростями распространения сейсмических волн - от 8,24 км/с на глубине 55 км до 8,6 км/с на глубине 300 км. Кровля астеносферного слоя фиксируется на глубинах I20-I50 км. Его подошва отмечена на севере и юге региона на глубинах 200 км, в центральной части - на глубине 300 км, т.е. полоса наибольших мощностей земной коры простирается в зоне также наибольших мощностей астеносферного слоя. Этой зоне соответствуют глубокий минимум аномалий Буге (-500 мГл) и депрессия по поверхности геоида. Таким образом, современный активный этап развития горно-складчатых структур обусловлен процессами, происходящими не только в земной коре и в верхней мантии, но и в астеносфере на глубинах около I50-200 км. Сейсмичность литосферы региона обусловлена геодинамическими процессами, выраженными для ее высоких слоев блоковыми перемещениями земной коры и смещением круто-падающих мантийных блоков для нижних этажей (Памиро-Гиндукушская сейсмофокальная зона).

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SOUTH-EAST ASIA AS A PART OF GONDWANALAND - RIFTING, DRIFTING AND COLLISION

Several authors have suggested that all or parts of South East Asia were continguous with Gondwanaland but until recently there was little evidence to support this idea. Our work on the Lower Palaeozoic of the Shan-Thai Block (western Thailand, Malaysia) strongly suggests that at least this part of S.E. Asia was adjacent to Gondwanaland and probably adjacent to Australia. The Cambrian trilobites and sandstones are very similar to those in N.W. Australia. The Ordovician carbonates contain evidence of tropical conditions, a north-south (present-day) trending shoreline, and contain a molluscan fauna of Gondwana affinities. Many of the species and most of the genera of nautiloids, polyplacophorons and gastropods are in common between Shan-Thai and Australia making juxtaposition a probability. An Early Palaeozoic position just north of Timor is the most likely. The dominantly Carboniferous Singa Formation (in Malaysia) and Phuket Group (in Thailand) probably represent the distal effects of the Upper Carboniferous glaciation. It is possible that rifting occurred during the Lower Carboniferous and by the Upper Carboniferous Shan Thai was already distant from Australia. Middle Permian and Triassic sediments record tropical conditions prior to Triassic collisions with the Indo-China Block and with Southern China.

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SYSTEMS OF THE EURASIAN ACTIVE LINEAMENTS ACCORDING TO SPACE IMAGERY

The majority of Eurasia's large lineaments show evidence of Neogene-Quaternary tectonic shifts of variable intensity, which determined their morphology. Lineaments are elements of the recent regmatic net, partly inherited from earlier epochs, and form orthogonal and diagonal systems relative to the rotation figure of the Earth. At the same time some segments of the megalineaments coincided with the boundaries of the lithospheric plates and large blocks and became either "tracks" for significant lateral motion or "barriers" for blocks with different strikes of motion. Correspondingly, lineamants classified into interplate, active in-plate and passive in-plate lineaments. Interplate and active in-plate lineaments often continue oceanic transform faults or can be identified with the continental rifts or flank wrench faults and frontal zones of folding and thrusting in the areas of plate convergence. Modern rift zones, dextral and sisnistral wrench faults, thrusted and folded zones of the subductive or obductive types can be interpreted in space images by thepeculiar structural patterns. Records of neotectonic shifts have established the convergence of the Gondwana plates (i.e., the African, Arabian, and Indian plates) and the Eurasian plate, and rocks being squeezed out of the northern frontal parts of the Gondwana plates. Besides movements on the large faults, plastic flow of rocks took place here, which deformed marginal parts of the interacting plates. Active zones of abrupt, creep and variable styles of the recent movements can be subdivided. The first is characterised by rare (once a several hundred years) impulses of activity, separated in time by "dead" periods; the second is characterised by the continuous, though of variable velocity, movements; the third style combines the features of the first and the second. The regime depends on physical properties of the rocks. The considered approach to the lineament tectonics explains their global distribution as well as their connection with other structures resulting from interaction of plates and blocks of the lithosphere.

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СИСТЕМА АКТИВНЫХ ЛИНЕАМЕНТОВ ЕВРАЗИИ ПО ДАННЫМ ДЕШИФРИРОВАНИЯ КОСМИЧЕСКИХ СНИМКОВ

Вдоль большинства крупных линеаментов Евразии, отдешифрированных на мелкомасштабных космических изображениях, происходили более или менее значительные неоген-четвертичные перемещения, определившие морфологические особенности линеаментов. Они представляют собой элементы современной регматической сети мегатрещин, частично унаследованной от более древних эпох, и образуют относительно фигуры вращения Земли ортогональную и диагональную системы. Вместе с тем отдельные участки мегалинеаментов совпали с границами плит и крупных блоков литосферы и послужили "рельсами", вдоль которых происходили значительные латеральные перемещения, или "шлагбаумами", разграничившими блоки с разным направлением движений. Соответственно линеаменты разделяются на межплитные, активные внутриплитные и пассивные внутриплитные. Межплитные и активные внутриплитные линеаменты нередко продолжают трансформные разломы океанов, могут совпадать с внутриконтинентальными рифтами, а также фланговыми сдвигами и фронтальными складчато-покровными структурами, возникающими при сближении плит. Новейшие раздвиговые зоны, правые и левые сдвиги, области скучивания поддвигового и складчато-надвигового типов различаются рисунками структур, дешифрируемых на космических снимках. По характеру новей-

ших перемещений устанавливаются сближение плит гондванской группы - Африканской, Аравийской и Индостанской - с Евразийской плитой и отжимание горных масс в стороны от северных выступов гондванских плит. Наряду с перемещениями по крупным линеаментам-разломам здесь имело место пластическое течение горных масс, изменившее форму краевых частей взаимодействующих плит. Различаются активные зоны с импульсным, криповым и переменным режимами современных движений. Для первых характерны редкие (через сотни лет) вспышки движений, разделенные эпохами покоя, для вторых - непрерывные, хотя и изменяющиеся по скорости перемещения, а третьи сочетают черты двух первых типов. Режим движений зависит от физических свойств горных пород.
Изложенный подход к проблеме линеаментов объясняет как их планетарное распространение, так и соотношения с другими структурами, возникающими при взаимодействии плит и блоков литосферы.

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A PRELIMINARY SYNTHESIS OF THE GEOLOGICAL FEATURES OF QINGHAI-XIZANG (TIBET) PLATEAU

The Qinghai-Xizang plateau can tectonically subdivided into several blocks presumably separated by sutures. There are four sutures decreasing in age from north to south have been recognized. The two southern sutures separated three blocks of Gondwanian origin (the Indian plate, Lhasa block and the Qantang block). The third one corresponds to the southern margin of Laurasia. All blocks south of it once were part of the northern margin of Gondwana and are made of old basement materials. They are characterized by a neritic environment in which Paleozoic carbonates and subordinate clastics accumulated. It is also characterized by the deposits with Glossopteris flora in Jolmo Lungma area and marine glacial deposits yielding Stepanoviella and Eurydesma faunas throughout the whole northern Xizang and by the Tethyan affinities of rich, predominantly neritic faunas, the insignificance of Paleozoic deformation and volcanism. From the dawn of late Early Permian following the world's great rifting periods the northern margin of the Gondwana was broken off by rifting from the mother land and subsequent northerly drift caused the opening of Neo-Tethys in their rear and narrowing of Palaeo-Tethys in front. During the late Triassic the Litian-Jinsha River basin (Palaeo-Tethys) was closed and was responsible for the Jinsha suture. During the Jurassic the Bangong-Nu Jiang basin as a back-arc basin developed after the volcanic arc behind which it lies. It was closed at the latest Jurassic. The short time interval between the formation of the oceanic crust and their obduction shows that the parts of the ocean floor to be obducted were newly formed and still close to a spreading ridge. The evolution of the Himalayan orogeny can be divided into several stages. During the first spisode, the date of which not yet well constrained, an oceanic subduction zone produced an ocean-continent or cordillerian-type belt. After this, the oceanic domain between India and Asia vanished and a continent-continent collision occured. This episode is Eocene-Oligocene in age and is responsible for the formation of the Yarlung Zangbo suture. Thus, a migration of the main orogenic processes from north to south can be clearly discerned. The continental-continental interaction after total consumption of each oceanic plate led to the mountain building of the collision type.

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FAULT LINEAMENTS OF BHUTAN HIMALAYA

Some major fault lineaments roughly trending NW-SE, have been recognised during recent geological mapping in the Bhutan Himalaya, which cut across separate various tectono-lithostratigraphic belts and tectonic planes. These lineaments, in part, control drainage course and also come out as recognisable lineament fabric in satellite imagery. Another not-so-prominent set of ENE-WSW trending lineaments is also present.

The main lineaments in Bhutan from west to east are (i) Jaianti-Phontsholing-Torsa lineament, (ii) Raidak lineament, (iii) Geylegphug-Chirang-Chekha lineament, (iv) Mangde-Chu lineament, and (v) Bumthang lineament. Some more lineaments are also recognisable in satellite imagery. Along these lineaments, the Tethyan sequences of Black Mountain and Lingshi are abruptly truncated against the Central Crystallines (No.iii); tectono-lithostratigraphic belts are displaced by 35 kms.(No.i); and major lithological units appear/disappear. Major faults like Torsa Faule and Mangde-Chu Fault match perfactly with Nos.i and iv respectively. Parts of lineaments also coincide with Main Boundary Fault and Main Central Thrust where the former displace the latter tectonic planes.

These lineaments, at least in parts, form regional faults which have developed and subsequently reactivated during different geological periods, the last movement being in Neogene Period during which Siwaliks and the Main Boundary Fault are displaced.

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KINEMATICS AND EVOLUTION OF THE MONGOL-OKHOTSK GEOSUTURE

The Mongol-Okhotsk geosuture (MOG) is the largest lineament in East Asia separating on the territories of Priamuria, Transbaikalia and North Mongolia, the Siberian platform and the Central Asia fold belt. On the territory of Mongolia it is traced through series of Hangai, headstreams of Selenga Bayangol faults. Its length is about 3500 km and the width exceeds 20 km. MOG is governing the accumulation of Riphean - Lower Paleozoic, Middle - Upper Paleozoic and Mesozoic sedimentary-volcanogenic and sedimentary formations. Bodies of Riphean-- Lower Paleozoic ultrabasites and gabbrides, Paleozoic and Mesozoic granitoids and dyke belts of different age are confined to it. The analyses of different age strike-slip faults, overthrusts, upthrusts, gaping faults, sigmoidal folds, fault like folds has been carried out along MOG and faults conjugated with it and horizontal displacements of Earth crust blocks in some geological epochs of Riphean and Phanerozoic are established. It is shown on sections that on MOG the right normal shift (about 20 km) has been developed in Late Riphean; in Early Paleozoic - the right (more than 10 km); in Late Paleozoic - Early Mesozoic - the right (more than 70 km) on the West and the left (more than 3 km) on the East with fading out toward Chita; in Late Mesozoic - the right (the first hundreds meters); in Cenozoic - the left (the first meters). MOG is manifested itself as the transform fault in Riphean, Paleozoic and Mesozoic. In Riphean and Paleozoic active horizontal displacements were on the West flange and in Mesozoic - on the East that was probably related to gaping faults of the paleo-Asian, paleo-Pacific and Pacific oceans. Thus the specificity of its endogenic metallization was defined: on the West flange - copper-molibdenum, on the East - molibdenum and in central part - rare metal-polymetallic and fluorspathic.

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КИНЕМАТИКА И ЭВОЛЮЦИЯ МОНГОЛО-ОХОТСКОГО ШВА

Монголо-Охотский шов (МОШ) - крупнейший линеамент Восточной Азии, разграничивающий на территории Приамурья, Забайкалья и Северной Монголии Сибирскую платформу и Центрально-Азиатский складчатый пояс. На территории Монголии он проводится через серию разломов Хангая, верховьев Селенги, Баянгол. Длина его до 3500 км, ширина более 20 км. МОШ контролирует накопление рифейско-нижнепалеозойских, средне-верхнепалеозойских и мезозойских осадочно-вулканогенных и осадочных образований. К нему приурочены тела рифейско-нижнепалеозойских гипербазитов и габброидов, палеозойских и мезозойских гранитоидов и пояса даек различного возраста. По МОШ и сопряженным с ним разломам проведен анализ разновозрастных сдвигов, надвигов, взбросов, раздвигов, сигмоид, приразломных складок и установлены горизонтальные перемещения блоков земной коры в некоторые геологические эпохи рифея и фанерозоя. По срезам показано, что по МОШ в позднем рифее проявилась правая (до 20 км) сдвиговая составляющая; в раннем палеозое - правая (более 10 км); в позднем палеозое-раннем мезозое - правая (более 70 км) на западе и левая (более 3 км) на востоке с затуханием по направлению к г. Чита; в позднем мезозое - правая (первые сотни метров); в кайнозое - левая (первые метры). МОШ проявил себя как трансформный разлом в рифее, палеозое и мезозое. В рифее и палеозое активные горизонтальные перемещения были на западном фланге, а в мезозое - на восточном, что, вероятно, связано с раздвигами палео-Азиатского, палео-Тихого и Тихого океанов. Это и определило специфику его эндогенного оруденения: на западном фланге медно-молибденового, на восточном - молибденового, а в центральной части редкометально-полиметаллического и плавикошпатового.

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THE TECTONICS OF THE AFGHANO-TADZHIK SEKTOR OF THE ASIAN TETHYS

The territory of Afghanistan is contiguous to South Tadzhikistan. A number of adjacent tectonic regions on these territories represent parts of the greatest structures of the Asian Tethys. The data accumulated up to the present allow to distinguish the following main tectonic regions within Afghanistan and South Tadzhikistan: I) Early Kimmerian folded areas - Afghano-North Pamirian and Firuzkokh-Banditurkestanian, II) Late Early Kimmerian platform - North Afghanistan, III) Middle Kimmerian folded area - Afghano-South Pamirian, IV) Late Kimmerian folded areas - South Afghanistan and Khinduradzh-Khinduradzh-Khazarian, V) Early alpine folded area - Afghano-East Iranian, VI) Middle alpine folded areas - Suleiman-Kirtarian and Turkmeno-Khorosanian, VII) Late Alpine superimposed basins - Afghano-South Tadzhikistan, Afghano-South Turkmenian, Seistanian and others.
Definition of heterochronous folded areas has been made in accordance with traditional principles, the age of the last geosynclinal cycle and the time of the final folding movement being taken into

account. Synchronous pairs of folded areas (1.Afghano-North Pamirian and Firuzkokh-Banditurkestanian, 2. South Afghanian and Khinduradzh-Khazarian, 3. Suleiman-Kirtarian and Turkmeno-Khorosanian) differ between themselves in geographical location and developmental regime.

The arrangement of regions confirms the tendency to the regular successive rejuvenation to the folded structures from the north toward the south, noticed earlier by the investigators of the geology of Middle Asia. Other tendency characterizes Late Alpine superimposed basins. The plan of their disposition is conditioned by the pattern of mountain structures of the most recent stage of the development of Mediterraneous foldbelt. Great extensive faults, or systems of closely situated faults, serve as boundaries for the folded areas. The plan of their disposition is Neogene-Quaternary, and by kinematic nature most of them are shifts.

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ТЕКТОНИКА АФГАНО-ЮЖНОТАДЖИКСКОГО СЕКТОРА АЗИАТСКОЙ ЧАСТИ ТЕТИСА

Территория Афганистана и Южного Таджикистана являются соседними. Ряд смежных составляющих их тектонических регионов представляет части единых крупнейших структур азиатской части Тетиса. Накопленный материал позволяет различать в пределах Афганистана и Южного Таджикистана следующие тектонические регионы: 1) раннекиммерийские складчатые области - Афгано-Северопамирскую и Фирузкох-Бандитуркестанскую; 2) эпираннекиммерийскую платформу - Североафганскую ; 3) среднекиммерийскую складчатую область - Афгано-Южнопамирскую ; 4) позднекиммерийские складчатые области - Южноафганскую и Хиндурадж-Хазарскую; 5) раннеальпийскую складчатую область - Афгано-Восточноиранскую; 6) среднеальпийские складчатые области - Сулейман-Киртарскую и Туркмено-Хоросанскую ; 7) позднеальпийские наложенные впадины - Афгано-Южнотаджикскую, Афгано-Южнотуркменскую, Сейстанскую и др.

Выделение разновозрастных складчатых областей произведено в соответствии с традиционными принципами тектонического районирования, с учетом возраста последнего геосинклинального цикла и времени завершающих складчатых движений. Одновозрастные пары складчатых областей (Афгано-Северопамирская и Фирузкох-Бандитуркестанская , Южноафганская и Хиндурадж-Хазарская, Сулейман-Киртарская и Туркмено-Хоросанская) различаются между собой географическим положением и режимом развития.

Расположение регионов в плане подтверждает подмеченную ранее исследователями геологии Средней Азии тенденцию к закономерному последо-

вательному омоложению с севера на юг возраста складчатых сооружений. Иная тенденция свойственна позднеальпийским наложенным впадинам. План их расположения обусловлен рисунком горных сооружений на новейшем этапе развития Средиземноморского складчатого пояса.
Границами складчатых областей служат крупные протяженные разломы или системы сближенных разломов. План расположения их неоген-четвертичный, а кинематическая природа большинства из них сдвиговая.

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STRUCTURAL AND SEDIMENTARY BASIN DEVELOPMENT IN IRAN

The first generalized tectonic map of Iran was published by J. Stocklin at al. (1968) in which all Iranian ranges were shown as fully developed Alpine orogenic belts. However, the very complex new structural picture obtained from different parts of Iran in recent years, not only strengthened the notion of even greater structural mobility on the basis of Plate Tectonic concepts but also emphasized the role of Paleozoic block faulting in the development of various sedimentary basins in Iran. Available evidence shows that the entire Iranian landmass, including Kopet Dagh, was a northern-continuation of the epi-Baikalian Afro-Arabian platform from the Infracambrian to the beginning of Mesozoic time. However, because of post-Cambrian block-faulting several areas were differentiated depending upon the sedimentary environment and/or development of gaps during the long Paleozoic interval. One of the manifestations of the Alpine orogeny was the rifting during the late Triassic to Early Cretaceous times, leading to Red-Sea type narrow oceanic basins, the relicts of which can be recognized as ophiolitic suites. Similarly various phases of the Alpine orogeny, which affected various Parts of Iran to varying degrees of intensity can be observed.
Based on a study of crustal character (oceanic or continental), orogenic history and structural style, a new zonation and structural sub-division is proposed as summarized below: (See attached map)
1. Zone of continental crust, epi-Baikalian basement with platform cover-consisting of the Zagros folded belt, Zagros crushed zone, Soltanieh-Misho zone, West Central Alborz, Hamadan-Urmieh zone, Central and Northeast Iran (including Eastern Alborz) and Kopet Dagh.
II. Zone of rifting (or relict ocean crust) made up of the Sistan-Baluchestan flysch zone, south Caspian depression, Ophiolite Melange of north-western part of Main Zagros thrust, Ophiolite Melange Ring in Central Iran and the Ophiolite Melange of Eesfandegeh-Hajiabad zone.

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TECTONIC EVOLUTION OF SOUTHEAST ASIA

The complete range of tectono-structural elements of compressive arc-trench systems, major wrench faults, and continental crustal attenuation and rifting can be recognized in Southeast Asia for different time intervals throughout the Phanerozoic. The framework of the region is dominated by Precambrian blocks complete with their Palaeozoic miogeoclinal shelves. Between these blocks are narrow intensively folded Phanerozoic mobile belts, which developed on oceanic crust, the remains of which now appear as fragmented ophiolite and melange zones. The Precambrian blocks have rifted from Northern Australia (Gondwanaland) and have approached each other as a result of sea-floor spreading and oceanic lithosphere subduction, resulting in various volcano-plutonic arcs at various times, eventually to collide and suture together along the mobile belts. The independent Mesozoic and Cenozoic movement of large lithosphere blocks along northwestern-southeastern transform faults appears to be the major cause of compression ahead of them and extension behind them. The main landmarks of the Southeast Asia Phanerozoic history were: collision in the Cathasian Caledonides zone at the end of the Silurian - beginning of the Devonian, rifting of Gondwanaland margins and the Tethys origin in the beginning of the Carboniferous, closing of the paleo-Tethys Basin as a result of the East Asiatic Continent and some Gondwanaland fragments collision at the end of the Triassic, formation of extended continental marginal volcano-plutonic belts as a result of the Tethys closing process beginning at the end of the Jurassic - first half of the Cretaceous, the complete closing of the Tethys east segment and the Himalayan orogeny manifestation in the middle of the Cenozoic, beginning of the Eurasia - Australia collision at the end of the Cenozoic. An elucidation of past geodynamic conditions and structural relations of different blocks is important for assessing the mineral potential of the Southeast Asia region.

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ТЕКТОНИЧЕСКАЯ ЭВОЛЮЦИЯ ЮГО-ВОСТОЧНОЙ АЗИИ

В Юго-Восточной Азии устанавливается закономерная латеральная последовательность тектонических структур, формировавшихся в различные временные интервалы на протяжении фанерозоя и включающих системы дуга-желоб с преобладающим сжатием, главные сдвиги, структуры, связанные с утонением континентальной коры и рифтогенезом. Жесткую раму региона составляют блоки докембрийского фундамента вместе с прилегающими к ним палеозойскими миогеосинклинальными (шельфовыми) зонами. Между этими блоками расположены узкие интенсивно складчатые фанерозойские подвижные пояса, развивавшиеся на океанической коре, остатки которой в настоящее время сохранились в фрагментах среди офиолитовых поясов и зон меланжа. Докембрийские блоки дрейфовали от Северной Австралии, входившей в состав Гондваны, и сближались друг с другом в результате спрединга океанического дна и процессов литосферной субдукции, приводивших к возникновению разновозрастных вулкано-плутонических дуг, в конечном счете сталкивавшихся и спаявшихся вместе в составе подвижных поясов. В мезозое и кайнозое независимые перемещения крупных литосферных блоков вдоль трансформных разломов северо-западного простирания были главной причиной проявления процессов сжатия во фронте и процессов растяжения в тылу таких блоков. Основными вехами фанерозойской истории Юго-Восточной Азии были столкновение в зоне катазиатских каледонид на юго-востоке Китая на рубеже силура и девона, рифтогенез гондванских окраин и заложение бассейна Тетис в начале карбона, закрытие бассейна Палеотетис в результате столкновения Восточно-Азиатского континента и гондванских микроконтинентов в конце триаса, образование протяженных окраинно-континентальных вулкано-плутонических поясов в результате начала закрытия бассейна Тетис в конце юры - первой половине мела, полное закрытие восточного сегмента бассейна Тетис и гималайская орогения в середине кайнозоя, начало столкновения Евразии и Австралии в конце кайнозоя. Выяснение геодинамических обстановок прошлого и структурных связей различных блоков имеет важное значение для установления закономерностей распределения полезных ископаемых в регионе.

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VOLCANISM AND TECTONICS OF THE PALEOZOIC OF THE NORTH PART OF THE CENTRAL - ASIATIC FOLDED ZONE

Some tectonic-magmatic stages which reflect the evolutionary direction of the rise of the continental crust are distinguished in the history of the geological development of the Paleozoic formations of the studied region. The toleiite and calc-alkali bazaltic and andesite-bazaltic formations, composing the upper of the ophiolite complexes in common jointly with the dikes of the diabase and gabbro and gabbro-diabases were being formed in Vend - Early Paleozoic along the northern periphery of the Paleoasiatic ocean in the conditions of the marginal seas. The presence of the fragments of the island arc volcanic complexes in its different parts, especially along the margin a continent - ocean is the typical peculiarity of Vend - Early Paleozoic stage of the development of the region. They are presented by the differentiated series of the basalt-andesite-dacite composition. The acid volcanites which occur seldom are timed usually to the highs of the sections and are always later in the age relation. The volcanic island arc is reconstructed in the Middle Paleozoic along the northern margin of the formed Paleothetys. In this time in the active continental margin the lengthy volcano-plutonic belt was formed, it is separated by the marginal seas from the island arc. The alkalinity of the rocks, especially in the plutonic series increases in the cross-section of the belt from margins deep into the continent. The geodynamic conditions of the active continental margin of the Andian type existed in the Late Paleozoic within the limits of the studied region. The volcanic and plutonic processes were intensively proceeding here. Their processes lead to the formation of the calc-alkali and alkali-basaltic differentiated and contrasting volcanic series, united into the large volcano-plutonic belts and areals.

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ВУЛКАНИЗМ И ТЕКТОНИКА ПАЛЕОЗОЯ СЕВЕРНОЙ ЧАСТИ ЦЕНТРАЛЬНО-АЗИАТСКОГО СКЛАДЧАТОГО ПОЯСА

В истории геологического развития палеозоид исследованного региона выделяется несколько тектоно-магматических этапов, которые отражают эволюционную направленность становления континентальной коры. В венде - раннем палеозое по северной периферии Палеоазиатского океана в обстановке окраинных морей формировались толеитовые и известково-щелочные базальтовые и андезит-базальтовые формации, составляющие совместно с дайками диабазов и габбро-диабазов верхнюю часть офиолитовых комплексов. Характерной особенностью венд-раннепалеозойского этапа развития региона является присутствие в разных его частях, особенно вдоль границы континент-океан.фрагментов островодужных вулканических комплексов. Они представлены дифференцированными сериями базальт-андезит-дацитового состава. Редко встречающиеся кислые вулканиты приурочены обычно к верхам разрезов и в возрастном отношении являются всегда более поздними. В среднем палеозое по северному краю образовавшегося Палеотетиса реконструируется вулканическая островная дуга, где развиты преимущественно андезит-базальтовые известково-щелочные вулканиты. В это время на активной континентальной окраине сформировался протяженный вулкано-плутонический пояс, отделенный от островной дуги окраинными морями. В поперечном сечении пояса от окраин вглубь континента отчетливо нарастает щелочность пород, особенно в плутонических сериях. В позднем палеозое в пределах исследованного региона существовала геодинамическая обстановка активной континентальной окраины андийского типа, где интенсивно протекали вулканические и плутонические процессы, приведшие к формированию известково-щелочных и щелочно-базальтовых дифференцированных и контрастных вулканических серий, объединяемых в крупные вулкано-плутонические пояса и ареалы.

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THE EARTH CRUST EVOLUTION IN NORHEASTERN SIBERIA (YAKUTIA)

In the Archean and Early Proterozoic, in the territory of the Siberian Platform and Verkhoyano-Kolymsk mesozoids, the East-Siberian continent was formed, in which Early Archean granite-gneiss folded belts and Late Archean-Early Proterozoic greenstone belts of both trough and areal types are recognired. Superimposed on them are Early Proterozoic basins filled with weakly deformed continental terrigenous deposits and volcano-plutonic belts with bimodal alkaline magmatism.
In the Riphean and Middle Paleozoic, the territory of the East-Siberian continent underwent intracontinental rifbing. Within the Siberian Platform in the site of rift zones major sedimentation basins, i.e. syneclises, were formed during the Vendian-Early Paleozoic and Late Paleozoic-Mesozoic. In the mesozoides, the rift zones were inherited by narrow and deep terrigenous-carbonaceous depressions (Sette-Daban and Momo-Taskhayakhtakh) in the Vendian-Early Paleozoic and by large suboceanic extension depressions (Verkhoyansr and Yano-

Indigirka) in the Late Paleozoic-Early Mesozoic. Large blocks of the Eastern-Siberian continent survived in the form of median masses. In the Late Mesozoic, under the conditions of horizontal twofold and threefold compression of NE and SE trend (probably caused by the opening of oceanic basins in the Arctic Ocean) in the Verkhoyano-Kolymsk area intracontinental absorption (thin-skinned thrusting) zones (West-Verkhoyansk, Kular-Sartang, Inyali-Debin, Polousny, Anyni) were developed. Belts of crustal granite batholiths were formed in the back parts of the intracontinental absorption zones. Similarity of structural and geodynamic conditions of the formation of Mesozoic structures in the Verkhoyano-Kolymsk area and those of Pre-Riphean folded belts in the East-Siberian continent is supposed.

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ЭВОЛЮЦИЯ ЗЕМНОЙ КОРЫ СЕВЕРО-ВОСТОЧНОЙ СИБИРИ (ЯКУТИЯ)

В архее и раннем протерозое на территории Сибирской платформы и Верхояно-Колымских мезозоид был сформирован Восточно-Сибирский континент. В его составе устанавливаются раннеархейские гранито-гнейсовые складчатые пояса, позднеархейско-раннепротерозойские зеленокаменные пояса трогового и ареального типов. На них наложены раннепротерозойские впадины, выполненные слабодеформированными континентальными терригенными отложениями.и вулкано-плутонические пояса с бимодальным магматизмом.

В рифее и среднем палеозое на территории Восточно-Сибирского континента проявились процессы внутриконтинентального рифтогенеза. На Сибирской платформе на месте рифтовых зон в венде-раннем палеозое и позднем палеозое-мезозое сформировались крупные седиментационные бассейны - синеклизы. На территории мезозоид рифтовые зоны в венде-раннем палеозое были унаследованы узкими и глубокими терригенно-карбонатными прогибами (Сетте-Дабанским и Момо-Тасхаяхтахским), а в позднем палеозое - раннем мезозое - крупными субокеанического типа раздвиговыми прогибами (Верхоянским и Яно-Индигирским). Крупные глыбы Восточно-Сибирского континента сохранились от разрушения в виде срединных массивов.

В позднем мезозое в условиях горизонтального двух- и трехкратного сжатия северо-восточного и юго-восточного направлений, по-видимому, связанного с раскрытием океанических котловин в Северном Ледовитом океане, в Верхояно-Колымской области образовались сквозькоровые надвиги или внутриконтинентальные зоны поглощения (Западно-Верхоянская, Куларо-Сартангская, Иньяли-Дебинская, Полуосненская, Анюйская). Пояса коровых гранитных батолитов формировались в тыловых частях внутриконтинентальных зон поглощения.

Намечается сходство структурных и геодинамических условий формирования мезозойских структур Верхояно-Колымской области и дорифейских складчатых поясов Восточно-Сибирского континента.

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MID-CRETACEOUS EVENTS IN EAST AND CENTRAL ASIA

In consequence of the further proved Jurassic age of the nonmarine Jehol or Witim fauna and the resultant international biostratigraphical correlation, the following Mid-Cretaceous Events in East and Central Asia would be shown out. In the Sino-Korean platform and the areas northwards to the Baikal regions, the Lower Cretaceous uplift in these regions; in the east of the two Mts., the basins of Sungari-Liaohe, North China, etc. resulted during the Early Cretaceous time together with formation of the Suchan basin in the east of the Ussuri river and the gap between the Itoshiro and Akaiwa subgroups in Japan. In Central and South China, beside the uplift of northwestern Zhejiang, the southeastern Zhejiang basins were formed contemporaneously with the formation of the Jianghan, Hengyang basins and the inherited Cretaceous basins of western Sichuan and central Yunnan, and also the Late Yanshanian igneous activities even in the western Himalayas, there was a considerable sedimentary break in the marine Cretaceous.
These crustal movements are apparently respondent to the cosmopolitan Mid-Cretaceous Events and Plate Tectonics.

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NEW RESEARCHES ON THE TECTONIC CHARACTERISTICS OF CHINA

Three Precambrian paraplatforms occur in China: Sino-Korean Paraplatform, Yangtze Paraplatform and Tarim Paraplatform. They are interspersed with and surrounded by Paleozoic geosynclines to form a mosaic structure in E.Asia. This was the result of the successive development of orogenic cycles: the Fuping Cycle, the Wutai Cycle, the Zhongtiao Cycle, the Yangtze Cycle, the Caledonian Cycle, the Variscan Cycle and the Alpine Cycle (which is subdivided into the Indosinian, the Yanshanian and the Himalayan subcycles), while three periods of rifting systems during the Phanerozoic were present: the Xingkai rifting, the Permian rifting in S.W.China and the Cenozoic rifting in E.China.

Plate tectonics dominated the Uralo-Mongolian-Okhotsk foldbelts to the north of the Sino-Korean and Tarim Paraplatforms, forming suture zones. The Karamaili-Pingdingshan-Hogenshan suture zone of Late Variscan age was the central zone, on both sides of which Early Variscan and Caledonian sutures were formed by subduction and collision, giving rise to a partially closed plate system. South of the Sino-Korean and Tarim Paraplatforms run the Qilian and Qinling Geosynclines; both appeared to be characterized by a closed system of plate motions.

The Tethys-Himalayan Region was divided near the northern margin by the Longmuco-Yushu and Jingshajiang-Changning-Shuangjiang suture zone, which separated Gondwana from Eurasia in Paleozoic times but became a suture zone by the collision of the northward drifting Gondwana in Late Permian. In Indosinian time this region was rifted widely apart along the Indus-Zangbo line, which reclosed in Eocene time. The presence of the complicated Late Paleozoic and Meso-Cenozoic suture zones in Tibet, W.Yunnan and S.Asia indicated the closing, opening, reopening and reclosing of the seas separating the several tectonic regions, showing a characteristic "accordion movement" of plate tectonics.

The Precambrian craton and Paleozoic foldbelts were activized during the Indosinian, the Yanshanian and the Himalayan Cycles. The Indosinian Cycle was the turning point in the formation of Gondwanaland and Eurasia. Yanshanian activization was most pronounced in E.China, while Himalayan activization dominated W.China, thus giving rise to the three tectonic domains.

The polycyclic evolution of the foldbelts and other crustal structures was pronounced in China as shown by the Tianshan, Qinling, S.E.China, etc. The polycyclic plate motions in Mongolia and Tibet were particularly striking.

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TECTONIC EVENTS AND THE RIVER COURSES OF NORTH-WESTERN BANGLADESH

The north-western region of Bangladesh is composed of depressed Indian platform represented by the Rangpur Saddle situated in the Garo-Rajmahal gap. Drilling, seismic and gravity data revealed that the block subsidence of the basement rock is responsible for the formation of the gap and that the previous assumption of strikeslip movements along the Dauki fault is inaccurate. The courses of the mighty rivers (the Ganges and the Brahmaputra) flowing through this gap are directly related to the structure and tectonics of the region. Interpretation of the aeromagnetic data made it possible to identify sub-surface faults along which some major rivers are flowing and it is observed that an unusual straight course of the Brahmaputra in the region is due to the presence of sub-surface north-south fault. The courses of the major rivers have changed in response to tectonic movements which is evidenced by the upliftment and subsidence of the earth crust in the region. The study shows that any man-made diversion of the major rivers through proposed link canal in such a tectonically active zone will creat serious ecological problem and can be disastrous.

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STRUCTURES AND TECTONIC EVOLUTION OF THE JAPANESE ISLANDS

The Japanese Islands have developed since Silurian through six stages: Silurian—Mid.Carboniferous, Late Carboniferous—Mid. Permian, Late Permian—Mid.Jurassic, Late Jurassic—Cretaceous, Paleogene and Neogene—Recent stages. Ancient Islands arc, fore-arc basin and/or continental slope area in each stage are recognized well by the study on paleogeography, but not ancient accretion belts of oceanic sediments and ophiolites on the earth surface, except for possible ones of the Kamuikotan-Sorachi and Nikoro belts in Hokkaido. Each stage is characterized by its own plate system or subduction system and by its own high temperature condition, granite or andesite activity and high pressure condition.

The Japanese Islands area was originally nearly straight, and was bent stage by stage. Subduction zones also changed the position against to the area stage by stage. Thus, younger tectonic belt superposed upon the older belt. The Cretaceous granite in Southwest Japan intruded into the Triassic-Jurassic high pressure belt of the Sangun, and the Neogene andesitic volcanic belt was formed diagonally upon the Cretaceous granite belt in Northeast Japan. Tectonic zones at present in Japan, in this way, are conglomerates of superposed old and young tectonic belts. None of the tectonic zones is accreted micro-continents.

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THE PARTICULARITY OF THE DEVELOPMENT OF THE EARTH CRUST IN THE PALEOZOIDS OF THE TIEN SHAN

The large blocks of the Precambrian is revealed now in the Paleozoids of the Tien Shan. They allow to characterize the history of the development of the structures from the Archean - the Early Proterozoic. The formational composition of the structural stories, formed during Late-Archean, Early-Proterozoic (Carelian ?), Grenvillian (Issedonian), Baicalian, Caledonian and Hercynian stages, is the testimony of the variety of the conditions, across which the tectonic blocks forming the Earth crust of the region have passed. The composition of the Pre-Riphean formations testifies synonymously, that the mature continental earth crust, has already existed by the beginning of the Riphean. The Grenvillian structural story is composed of the formations, which characterize the specific conditions of the combinations of the miogeosynclinalical and mobil-platformical peculiarities. The Phanerozoic structural plan is established in the Late Riphean in the Northern and Middle Tien Shan, when the intracratonic geosynclinals, the orogenic belts, the midland massifs arise and develop as a result of sialic earth crust's destruction, formed during the Carelian stage. The Southern Tien Shan enters the geosynclinalical development at the end of the Early Paleozoic. Accordingly the formation of the second continental earth crust in the Northern Tien Shan completes in the Caledonian epoch, and the Southern Tien Shan - in the Hercynian stage. In the development of the tectonic regimes of the Riphean-Paleozoic time is discovered this succession of the change of the states generally is such as: subplatformic-riftogenic-geosynclinalic-orogenic-platformic. The change of the regimes in time is reflected in the lateral ranges of the structural elements. The principal periods of the stabilisation fixed by "through" asonalic coverly formations are: the end of the Early- the beginning of the Late Proterozoic, in between the Middle and Late Riphean, the beginning of the Vendian, the end of the Early and Late Paleozoic. The principal levels of the activisation are: the beginning of the Late Riphean, the end of the Early- the beginning of the Middle Paleozoic, the development of the earth crust in the Tien Shan flows cyclicly. The each cycle is distinguished by the peculiarity, the unique.

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ОСОБЕННОСТИ РАЗВИТИЯ ЗЕМНОЙ КОРЫ ПАЛЕОЗОИД ТЯНЬ-ШАНЯ

В пределах палеозоид Тянь-Шаня выявлены многочисленные блоки докембрия, позволяющие характеризовать историю развития структуры начиная с архея-раннего протерозоя.

Формационный состав структурных этажей, сформированных на обосабливающихся позднеархейском, раннепротерозойском (карельском(?)),ренвильском (исседонском), байкальском, каледонском и герцинском этапах, свидетельствует о разнообразии состояний, через которые прошли составляющие кору региона тектонические блоки. Состав дорифейских образований однозначно свидетельствует о том, что к началу рифея в Тянь-Шане уже существовала зрелая кора континентального типа. Гренвильский структурный этаж сложен формациями, характеризующими специфические условия сочетания особенностей миогеосинклинали и подвижной платформы. В позднем рифее в Северном и Срединном Тянь-Шане устанавливается фанерозойский структурный план, когда возникают и развиваются интракратонные геосинклинали, орогенные пояса, срединные массивы за счет деструкции сиалической коры, оформившейся в карельскую эпоху. Южный Тянь-Шань охватывается геосинклинальным развитием с конца раннего палеозоя. Соответственно формирование вторичной континентальной коры в Северном Тянь-Шане завершается в каледонскую, а в Южном - в герцинскую эпохи.

В развитии тектонических режимов рифейско-палеозойского времени выявляется ряд закономерностей. Последовательность смены состояний в общем виде такова: субплатформенное - рифтогенное - геосинклинальное - орогенное - платформенное . Смена режимов во времени находит отражение и в латеральных рядах структурных элементов.

Главные периоды стабилизации и рифтогенно-орогенной активизации субсинхронны. Рубежи стабилизации, фиксирующиеся "сквозными" азональными формациями чехольного типа: конец раннего - начало позднего протерозоя, между средним и поздним рифеем, рифей - начало венда, конец раннего и позднего палеозоя. Основные рубежи активизации: начало позднего рифея, конец раннего - начало среднего палеозоя.

В целом развитие земной коры Тянь-Шаня протекало циклично, каждый цикл отличался своеобразием, неповторимостью.

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POST-PALAEOZOIC GEOTECTONIC EVOLUTION NORTH OF THE LUT BLOCK (NE IRAN)

Between the Kopet Dagh and the central Iranian Lut block the following tectonic units are distinguished from N to S: the Sabzewar zone with ophiolites and Cretaceous to Palaeogene sediments; to the south, it continues to the Oryan basin with Palaeogene sediments and an andesitic suite; the Tankar block which consists of a Precambrian to Palaeozoic basement with a cover of Mesozoic to Cenozoic shallow marine sediments. The Tankar block has probably been splitt off the Central Iranian microplate. Nevertheless, its sedimentary and structural history cannot be linked directly with the adjacent Lut block. This may be due to pre-Tertiary rotations of the Central Iranian microplate. The Oryan basin was folded and overridden from N to S by gravitational nappes which developed between Upper Cretaceous and Oligocene times. Ophiolitic melanges observed in the Oryan basin and in the southermost Sabzewar zone are interpreted as the base of the eldest nappes. Nappe formation was connected with the closure of an oceanic belt between the Turan plate and the Central Iranian microplate in the Upper Cretaceous.

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СОВРЕМЕННЫЕ ПРЕДСТАВЛЕНИЯ О ГЕОЛОГИЧЕСКОМ СТРОЕНИИ ТЕРРИТОРИИ МНР

Анализ фактического материала по геологии МНР показывает, что формирование континентальной коры на всей ее территории происходило в длительное время, начиная с глубокого докембрия вплоть до раннего мезозоя. Докембрийские комплексы, в составе которых выделяются дорифейские (включая архейские), рифейские образования,слагают срединные массивы (Тувино-Монгольский, Центрально-Монгольский) и отдельные выступы, сильно переработанные последующими тектоно-магматическими процессами. В пределах этих древнейших структур гранитно-метаморфический слой сформировался в дорифейское время.

Вендско-кембрийские комплексы Монголии представлены формационно различными отложениями, сформировавшиеся на коре различного типа - океанического, переходного и континентального, слагавшими соответственно самостоятельные раннекаледонские структурно-фациальные зоны. Последние характеризуются специфическим набором формаций геосинклинального и орогенного этапов развития. В ранних каледонидах в конце кембрия в результате тектонического скучивания и становления гранитоидных массивов сформировался достаточно мощный гранитно-метаморфический слой.

В позднекембрийско-раннеордовикское время геосинклинальное условие осадконакопления продолжалось в каледонидах Монгольского Алтая, где отлагались мощные флишоидные песчаниково-сланцевые толщи. Вследствие деструкции раннесформированных структур и заложения новообразованных геосинклинальных прогибов в верхнем ордовике и девоне формирование континентальной коры на территории Монгольского Алтая завершилось лишь к нижнему карбону.

Средне- и верхнепалеозойские комплексы слагают в Монголии целый ряд крупных структур различной тектонической природы. Среди них наиболее значительными являются следующие.

1. Южно-Монгольские герциниды, в строении которых главенствующую роль играют среднепалеозойские геосинклинальные образования, представленные всем набором характерных эвгеосинклинальных формаций.
2. Солонкерская структурно-фациальная зона крайнего юга Монголии, представленная верхнепалеозойскими и раннемезозойскими геосинклинальными отложениями.
3. Новообразованные наложенные геосинклинальные и орогенные прогибы, локализованные в пределах докембрийских и каледонских структур севера Монголии и выполненные существенно терригенными и аэральными вулканогенными отложениями.

Мезозойские структуры Монголии представлены резко наложенными на более древний фундамент межгорными впадинами, выполненными континентальными молассоидными и наземными вулканогенными отложениями большой мощности. Палеогеновые отложения совместно с верхнемеловыми слагают платформенный чехол. Неогеновые и антропогеновые отложения отражают этап новейшей тектонической активизации.

Таким образом, современные представления о геологическом строении территории МНР предполагают длительное протекание в этом обширном регионе Центральной Азии геосинклинального процесса - процесса созидания континентальной коры, неоднократное проявление в регионе рифтогенеза как явления деструкции земной коры и широкое проявление здесь в геологическом прошлом горизонтальных тектонических движений, а на мезозойском и каинозойских этапах геологического развития региона еще и длительное развитие процессов тектонической ревивации и активизации.

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MAIN VERTICAL CRUSTAL MOVES IN ASIA SINCE THE BEGINNING OF CAMBRIAN

By using a new type of maps, which can be called "relative stability maps", the vertical component of the crustal moves has been studied since the early Cambrian. Maps have been drawn in combining sets of five successive paleosedimentologic original maps along a square grid, each square receiving a number from 0 to 5, according to the number of occasions it appears under sedimentation. Then, from the numbers, it is easy to draw relative stability curves showing the tendancy to go up or down for the crust., Combining the effects of epirogeny and orogeny. It is possible so to distinguish more or less stable blocks and to see appear border zones with a narrow disposition of the curves. Several maps presented along the time scale both under the to-day and past geographic and paleogeographic structure of Asia.

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THE OMOLON MASSIF: A TECTONOTYPE OF MEDIAN MASSIFS

The Omolon Massif (130 sq.km) is one of the most fascinating structural elements of the Verkhoyansk-Chukchi Mesozoic fold region. It is often used to exemplify median massifs in textbooks, as well as theoretical and regional treatises. This fact and also a rather good knowledge and exposure of the Omolon Massif on the surface enable us to envisage it as a tectonotype of such structures. In terms of the composition and structure of its Pre-Riphean basement and cover (Riphean-Cretaceous) it resembles ancient platforms. However, the massif differs from the latter primarily by a more complicated fold-block structure and a wide distribution of various magmatites. The latter are arranged in a series of colcanic and intrusive complexes ranging from Proterozoic through Anthropogene and belong to the calc-alkalic or alkalic series, with tholeitic series being less significant. This set and quantitative rations of igneous rock series are characteristic of orogenic or rift structures. Many peculiarities of the Massif's structure can be explained in terms of concepts implying a prolonged destruction of the Pre-Riphean crust. The Omolon Massif is precisely a crustal block uplifted in the marginal part of the Yana-Kolyma miogeosynclinal system. On the northeast and southeast it is bounded by the Oloy and Koni-Taigonos eugeosynclinal zones. Within the latter, the latteral analogs for the magmatic complexes distributed in the Massif become sodic in character. The principal metallogenic feature of the Omolon Massif which enables to distinguish it among other mesozoides structures of the Northeastern USSR is co-occurence of different-age mineral deposits (ranging from Precambrian to Late Mesozoic) and different facies of mineralization (gold, silver, iron, copper, and molybdenum).

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ОМОЛОНСКИЙ МАССИВ - ТЕКТОНОТИП СРЕДИННЫХ МАССИВОВ

Омолонский массив (130 тыс.км^2) - один из наиболее интереснейших структурных элементов Верхояно-Чукотской мезозойской складчатой области. Он часто приводится в качестве примера срединных массивов в учебных руководствах, теоретических и региональных работах. Это обстоятельство, наряду со сравнительно высокой степенью изученности и неплохой обнаженностью, позволяет считать Омолонский массив тектонотипом структур подобного рода. По составу и строению дорифейского фундамента и чехла (рифей - мел) он сходен с древними платформами. Однако массив коренным образом отличается от них значительно более сложной складчато-глыбовой структурой и насыщенностью разнообразными магматитами. Последние группируются в ряд разновозрастных (от протерозоя до антропогена) вулканических и интрузивных комплексов, укладывающихся в рамки известково-щелочной и щелочной серий при подчиненной роли толеитовой. Такой набор и количественные соотношения серий изверженных пород характерны для орогенных и рифтовых структур. Многие особенности строения массива объясняются с позиции представлений о длительной деструкции дорифейской континентальной коры. Один из ее приподнятых блоков в краевой части Яно-Колымской миогеосинклинальной системы и представляет собой Омолонский массив. С северо-востока и юго-востока он обрамлен Олойской и Кони-Тайгоносской эвгеосинклинальными зонами. В пределах последних латеральные аналоги магматических комплексов, распространенных на массиве, приобретают натриевый характер. Главная черта металлогении Омолонского массива, выделящая его среди других структур мезозоид Северо-Востока СССР, - пространственная совмещенность разновозрастного (от докембрия до позднего мезозоя) и разноформационного оруденения (золото, серебро, железо, медь, молибден).

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TRANSBAIKALIAN AS THE LARGEST CENTRE OF THE MANTLE PULSATION

The earth of Transbaikalian is characterized by the many-stage mobility, the structure in blocks separated complexly, the massive development of magmatism of the different age, the wide development of the tectonic fractures which played the determining role in the formation of the regional geological structures and location of the

endogenic deposits. Each geological stage was accompanied by the active development of the tectonic magmatic processes.
Periodically showing abyssal geodynamic processes, connected with the pulsation character of the mantle evolution seem to be the basis of so stormy and many-stage style of the tectonic development of Transbaikalian. In the course of the geological history of the region the hot mantle masses went up over and over again providing the outflow of magma to the earth surface and causing the different -scale tectonic-magmatic show in connection with which were created the Pre-Cambrian-Paleozoic and Mesozoic-Cenozoic structures known in Transbaikalian. In this plan Transbaikalian is considered by us as the largest centre of the pulsation rise of the hot mantle masses.

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ЗАБАЙКАЛЬЕ - КРУПНЕЙШИЙ ЦЕНТР ПУЛЬСАЦИИ МАНТИИ

Земная кора Забайкалья характеризуется многоэтапной подвижностью, сложно расчлененным блоковым строением, массовым проявлением разновозрастного магматизма, широким развитием тектонических разломов, сыгравших определяющую роль в формировании региональных геологических структур и размещении эндогенных месторождений. Каждая геологическая эпоха сопровождалась активным проявлением тектономагматических процессов.
В основе столь бурного и многоэтапного стиля тектонического развития Забайкалья лежат, по-видимому, периодически проявляющиеся глубинные геодинамические процессы, связанные с пульсационным характером эволюции мантии. Горячие мантийные массы в ходе геологической истории региона неоднократно поднимались, обеспечивая выход магмы к поверхности земли и вызывая разномасштабные тектоно-магматические проявления, в связи с которыми создавались известные в Забайкалье докембрийско-палеозойские и мезозойско-кайнозойские структуры. В этом плане Забайкалье рассматривается нами как крупнейший центр пульсационного подъема горячих мантийных масс.

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NOTION EVOLUTION AND NEW INFORMATION OF THE SIBERIAN PLATFORM SOUTHERN BOUNDARY

1. The southern border of the Siberian platform was characterized on its first study stage by the sublatitudinal line in the issue of Archean crystalline foundation from the U.Sajans to the Aldan shield.

2. After the age determination of the multiple folding between the Baikal Lake and the Aldan this folding was considered to be an expression of the Upper Proterozoic (Baikal) geosynclinal tectogenesis (1933). We can see it on maps as a wide meridional "gulf" of the Ural-Mongolian belt. They moved the basement border to the North up to the Phanerozoic mantle boundary.

3. The tectonic and airspacegeologic study of the Baikal region in the last years has shown that on the ancient platform basement in deep faults a big avlacogen was formed filled with sedimentary, volcanogenous and different intrusive rocks. Those rocks formed the protoplatform Upper-Proterozoic cover.

4. This cover was crumpled to folds, more intensive in avlacogen borders, in deep submeridional shifts. In the northern parts of the avlacogen the fissures got an arched form. The formation of all fissures was caused by a grandiose latitudinal overlap of the block basement of the Ural-Mongolian belt onto the platform foundation. In the main overlap and its attended fissures the basement crush in blocks took place, also the squeezing out of basic rocks (ophiolites) the basement granitization and a wide intrusion of granitoidal magmas. On this way the fold block melange was formed; the border of the remained monolite basement part was shifted to the north and the foundation sank under the melange and mobile belt basement.

5. The earth crust movement in the Phanerozoic, especially the tectonic-magmatical Mesozoic activation shaded in the primary Precambrian plan of the platform foundation, but made no influence on its southern latitudinal border disposition.

6. The new information of the Baikal folding genesis and different disposition of the foundation southern border are of great importance for the prospecting for useful minerals under the mobilism aspect.

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ЭВОЛЮЦИЯ ПРЕДСТАВЛЕНИЙ И НОВЫЕ ДАННЫЕ О ЮЖНОЙ ГРАНИЦЕ СИБИРСКОЙ ПЛАТФОРМЫ

I. Южная граница Сибирской платформы на первой стадии ее изучения отмечалась субширотной линией по выходам архейского кристаллического фундамента от Восточного Саяна до Алданского щита.

2. После установления возраста сложной складчатости между оз.Байкал и Алданом складчатость, показанная на картах как широкий меридиональный "залив" Урало-Монгольского пояса, стала считаться проявлением верхнепротерозойского (байкальского) геосинклинального тектогенеза (I933 г.). Границу фундамента платформы переместили к северу, до края фанерозойского чехла.

3. Тектоническое и аэрокосмогеологическое изучение последних лет Вост.Забайкалья показало, что на древнейшем фундаменте платформы по глубинным разломам сформировался крупный ступенчатый авлакоген, заполнившийся осадочными, вулканогенными и разнообразными интрузивными породами ,образовавшими протоплатформенный верхнепротерозойский чехол.
4. Чехол был смят в складки, интенсивнее в краевых бортах авлакогена, глубинными субмеридиональными сдвигами. В северной части авлакогена разломы приобрели замыкающую дугообразную форму. Образование всех разломов было обусловлено грандиозным широтным надвигом глыбового основания Урало-Монгольского пояса на фундамент платформы. По главному надвигу и сопряженным с ним разломам произошли раздробление фундамента на блоки, выжимание основных пород (офиолитов), гранитизация фундамента и широкое внедрение гранитоидных магм; так образовалась зона складчато-блокового меланжа; граница оставшейся монолитной части фундамента сместилась к северу, а сам фундамент погрузился под меланж и основание подвижного пояса.
5. Движения земной коры в фанерозое, особенно тектоно-магматическая мезозойская активизация,затушевали первичный докембрийский план фундамента платформы, но не повлияли на расположение южной широтной его границы.
6. Новые данные о генезисе байкальской складчатости Вост.Забайкалья и ином расположении южной границы фундамента платформы имеют большое значение для направления поисков полезных ископаемых в свете идей мобилизма.

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A BLOCK-LIKE STRUCTURE OF THE HIMALAYA FROM GRAVITY AND LANDSAT IMAGERIES ANALYSIS

One degree mean Airy-Heiskanen isostatic anomaly map, prepared from the published material (Qureshy 1969, and Marussi 1979) of the Pamir Syntaxial region, when compared with surface geology, shows corelation with some known geologic features and in others shows significant departures.
A strong northwest trending gravity high with maximum contours of +70 mgals (30°N, 75°E - 36°N, 73°E) over the middle Himalaya extends northwestward up to the vicinity of Chitral (36°N, 72°W). It abuts against the northeast trending Chaman fault and gravity contours, and cuts across the Nanga Parbat diapir-like massif, suggesting a deeper source for the gravity anomaly. Its northwestward boundary, more or less, follows the northern Suture (NMS) of Bard

et al (1979). The southern boundary of the gravity feature correlates well with MMT (the southern Suture) of Bard et al. west of Nanga Parbat (35°N, 74°E) - a region characterized by outcrops of high *density Kohistan arc sequence comprising ultramaffic Klippes, green* schist belt with peridotite blocks, ultramafic complex, amphibolitic belts, pyroxene granulite belt, oceanic series, volcanic and volcano sedimentary equivalents and syn and post-kinematic dioritic and granodioritic intrusives. Such a correlation is obscured in the southeastern part, where the gravity high falls over crystallines and Precambrian rocks of Central and Middle Himalaya. The southeastern boundary demarcates the transition zone from the lesser to middle Himalaya bounded by the Main Central Thrust (MCT). The 'high' in this region seems to suggest probable existence of high density material, possibly along MCT, similar to those occurring west of Nanga Parbat.

The linearity of the gravity contours in Himalaya and Hindu Kush region, when seen in the context of tectonic lineaments reported from Landsat imageries analysis (Ebblin,1976) and the high angle deep faults, reported from Deep seismic sounding results (Beloussov et al.,1980), suggests that, though the sedimentary cover shows syntaxial bending, the controlling deeper structure may be blocklike. That is, the syntaxis is rather a junction of two, almost orthogonal trends, and probably belonging to different tectonic regimes. A somewhat similar situation is reported from Landsat imageries analysis from Alaska (Smith,1974) where the sedimentary cover shows syntaxial bending, but not the linears from Landsat imageries, which, in that region seem to control mineralization.

The question arises whether the Kohistan ultramafic complex represents the obducted island arc (as inferred by Bard et al.) or is the manifestation of the upward mobility of mantle material along deep faults causing, in turn, the uplift of the Himalaja as a result of basalt layer thickening (Qureshy, 1969).

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ALPINE FAULTS OF SOUTH-WESTERN ASIA AND CONDITIONS OF THEIR FORMATION

Among numerous and diverse Alpine faults of south-western Asia worth special attention are three groups of faults and zones of deformation concentration. The first group os represented by faults of viscous-plastic sliding; these are tectonic nappes accompanied usually by intense plastic deformation, metamorphism and desintegration of rocks associated with Alpine eugeosynclinal formation (flysh, volcanics and olistostromes) and with rocks of ophiolitic association. The origin of these disjunctives is attributed to the middle stage of the Alpine cycle (Cretaceous-Paleogene); all of them are located in the inner zone of the Alpine orogenic belt developed on the Mesotethys oceanic crust and exposed to the most intense tectonic deformations. The second group of faults is composed of faults of brittle shearing (wranch, upthrow faults and overthrusts) and zones of flattening developed in outer (epicratonic) zones of the Alpine orogenic belt, but affecting its inner part as well. Their formation becomes most intense since the end of Eocene, though in places early Alpine structures of this type are registered. The third group of Alpine faults consists of "through" zones of concentration of deformation cutting in transverse and diagonal directions all zones of the Alpine belt and passing far beyond its boundaries. These are peculiar structures of shearing and breaking, commonly dispersed over vast zones of a considerable extension with links of different morphology and time of origin; active formation of these structures as uniform morphologically and kinematically zones of deformation began from the late Miocene. These disjunctive systems form a regmatic net over the entire territory of south-western Asia and adjacent areas; together with the most important morphological and historic-geological structural lines, they determine the general Alpine structural pattern of the region. This pattern is characterized by quasisymmetrical arrangement of structures relative to a north-trending zone at 60-62°E.L., and regular arrangement of structures of compression, displacement and extension in accordance with the concept of north-trending compression and shortening of the continental lithosphere of this region. The development of the Alpine belt as a planetary fault system of shifting and flattening in the convergence zone of Laurasia and Gondwanaland is consistent, with this concept too, while the evolution of types of rupture deformation reflects the physical-mechanical aspect of the related process.

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АЛЬПИЙСКИЕ ДИЗЪЮНКТИВЫ ЮГО-ЗАПАДНОЙ АЗИИ И УСЛОВИЯ ИХ ФОРМИРОВАНИЯ

Среди огромного разнообразия альпийских дизъюнктивов Юго-Западной Азии особого внимания заслуживают три группы разрывов и зон концентрации деформаций. Первая группа- разрывы вязко-пластического скольжения; это тектонические покровы, обычно сопровождающиеся интенсивной пластической деформацией,метаморфизмом и дезинтеграцией пород,сочетающиеся с альпийскими эвгеосинклинальными образованиями (флиш,вулканиты и олистостромы) и породами офиолитовой ассоциации. Возникновение этих дизъюнктивов относится к средней стадии альпийского цикла (мел-палеоген); все они приурочены к внутренней зоне Альпийского орогенического пояса, развившейся на океанической коре Мезотетиса и претерпевшей наиболее интенсивные тектонические деформации. Вторая группа дизъюнктивов - сколовые разрывы (сдвиги, взбросы и надвиги) и врезы (зоны сплющивания), развитые во внешних (эпикратонных) зонах Альпийского орогенического пояса, но затрагивающие также и внутреннюю его часть. Это структуры хрупкого скалывания (сколы) и сплющивания (врезы); особенно активное их формирование происходит с конца эоцена, хотя местами фиксируются и раннеальпийские структуры этого типа. Третья группа альпийских дизъюнктивов-"сквозные" зоны концентрации деформаций, рассекающие в поперечном и диагональных направлениях все зоны Альпийского пояса и выходящие далеко за его пределы. Это своеобразные структуры скалывания и отрыва,обычно рассредоточенные в пределах обширных зон значительной протяженности,отдельные звенья которых имеют различные морфологию и время возникновения; активное становление этих структур как единых в морфолого-кинематическом отношении зон деформации началось с позднего миоцена. Эти дизъюнктивные системы образуют регматическую сеть на всей территории Юго-Западной Азии и смежных областей и наряду с важнейшими морфологическими и историко-геологическими структурными линиями определяют общий альпийский структурный рисунок региона. Существенные черты этого рисунка- квазисимметричное расположение структур относительно субмеридиональной зоны 60-62^{o}в.д. и закономерное размещение структур сжатия, сдвига и растяжения в соответствии с концепцией меридионального сжатия и укорочения континентальной литосферы этого региона. Развитие Альпийского пояса как планетарной дизъюнктивной системы содвижения и сплющивания в зоне конвергенции Лавразии и Гондваны также соответствует этой концепции, а отмеченная эволюция типов дизъюнктивной деформации отражает физико-механическую сторону связанных с этим процессов.

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HIMALAYAN OROGENIC PROCESSES IN TIME AND SPACE

A southward progradation of underthrusting, subduction processes has occured in the western Himalaya from the late Cretaceous-Eocene closing of Tethys along the Indus-Tsangpo suture zone to the Oligocene-Miocene Main Central thrust zone to the Pleistocene Main Boundary thrust. Obduction of the Spontang ophiolite in the uppermost Cretaceous from a fore-arc position South of the Dras-Kohistan hornblende-clinopyroxene andesite island arc was associated with Northward dipping subduction. Biotite-hornblende granodiorites of the Ladakh (Trans-Himalayan) batholith have Cretaceous-Eocene ages and $^{87}Sr/^{86}Sr$ ratios (0.707) indicative of derivation from subducted mantle material contaminated by a small amount of crustal material. Following closure of Tethys, continued compressive stress led to renewed thrusting, crustal thickening by basement-cover duplex formation and regional metamorphism. Garnet-tourmaline-muscovite leucogranites were generated by crustal anatectic processes. They are associated with kyanite-sillimanite gneisses and migmatites, and have extremely high $^{87}Sr/^{86}Sr$ ratios (0.74 - 0.79). Late stage thrusting has inverted metamorphic isograds and caused large-scale backthrusting along the Indus Suture Zone.

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TECTONICS OF TURKEY: A PROGRESS REPORT

In Eurasia, Turkey occupies a critical location holding the keys to the solution of a number of problems of late Proterozoic and Phanerozoic evolution of the Old World, such as the entry into Europe of the Pan-African sutures of NE Africa and Arabia; the question of the oriental termination of Gondwana-Land-bound Hercynides and thus the nature of the S European Hercynian orogen; mutual relationships of various branches of 'Asiatic' and 'Mediterranean' Palaeo- and Neo-Tethys and thus the evolution of the Alpine-Himalayan mountain ranges ('Tethysides'). In addition to these large-scale problems, a host of smaller ones, both regional (e.g. the number of intra Tethyan blocks in Turkey) and theoretical (e.g. the geometry and kinematics of deformation in continental collision zones) can be approached by a study of Turkish geology. During the last quadrennium, considerable progress has occurred in our understanding of the geology of Turkey. This report builds on a similar one by Şengör and Yılmaz communicated to the last Congress in Paris and deals mainly with the topics listed above. Isotopic dating of rocks of the Menderes and Kırşehir Massifs revealed the existence of 'Eburnean' (2067+75 Ma) and 'Pan African' (700-500 Ma) events. The latter is correlated with the 'Pan African orogen' of Egypt and Arabia. The 'main Menderes metamorphism' took place between 30 to 30 Ma, indicates burial depths of 15-18 km, and correlates with coeval extreme structural telescoping in the W. Taurides. The 'main Kırşehir metamorphism' is older, pre-Maastrichtian, possibly early or mid-Cretaceous. The Istanbul Nappe of the W and Central Pontides and also probably the Sakarya Continent contain the only documented pieces of the Hercynian orogen in Turkey; the existing record indicates Ordovician rifting, Siluro-Devonian ocean expansion, and mid-Carboniferous collision resulting in a NE-facing asymmetric orogen with the associated arc probably in the basement of the Sakarya Continent. The orogen was located entirely to the S of Palaeo-Tethys and probably formed the E continuation of the Hercynides of S. Europe. The closure of the Hercynian ocean probably triggered the S-dipping subduction of Palaeo-Tethys in the N. Palaeo-Tethyan subduction first opened the Karakaya marginal basin in the late Permian, whose latest Triassic demise generated a wide zone of deformation that covers most of W and S-central Turkey. Neo-Tethyan oceans mostly opened during the Lias (N branch: Sinemurian-Hettangian) with no Triassic prelude; only the Eastern Mediterranean/Bitlis/Zagros ocean opened during the mid-Triassic. Novelties in the Alpide evolution include the separation of a Kırşehir Block from the Anatolide/Tauride platform during the ?Lias and its 90° anticlockwise rotation in the Cretaceous-Eocene, and the possible W extension of the Maden mini-ocean as far as the Psidian Taurus. Discovery of blueschists and eclogites within the Alanya allochthon has shown that it actually consists of three nappes whose evolution was more complex than hitherto believed. Although the interpretation of its causal mechanism has not changed, the details of the neotectonics of Turkey are now better known than four years ago. Improvements include the definition and characterization of a North Turkish province exhibiting E-W compression, the discovery of major, NE-NNE striking, SE-concave strike-slip faults emanating from the N Anatolian Fault and reaching well into central Anatolia, and very large amounts of block rotations around horizontal axes in the Aegean Graben System. In the light of the above-listed advances, we present an improved set of palaeotectonic maps showing the evolution of Turkey since the late Proterozoic and discuss their implications for the tectonic development of the central part of the Old World.

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BLOCK TECTONICS OF ASIA IN THE CENOZOIC

Main features of tectonics and topography of Asia in the Cenozoic are determined by the largest block structures, the origin of which is related by a number of investigators, only to the collision of the Indian and Eurasian plates. In this process the capacity of the lithosphere for transmission of tremendous stresses over large distances is significantly exceeded.
Seismic belts are a criterion for establishment of block boundaries active in the Cenozoic. Hypocenter depths and orientation of stress fields enable to evaluate the size of block boundaries and movements along them.
The two types of boundaries between the largest blocks are singled out: translithospheric and transcrustal. They include Mediterranean -Himalayan and West-Pacific (I type), Mongolian-Okhotsky and Laptevsk-Kolymsky (II type) seismic belts.
Analysis of neotectonic processes at the territory north of the frontal Hymalayan thrust shows that areas of dynamic influence of the boundary of the India-Eurasia continental collision are not more than 500 km wide. Outside these areas rejuvenation and formation of new structures in the Cenozoic occur due to different tectonic processes. The Mongolian-Okhotsky and the Laptevsk-Kolymsky seismic belts are results of activity of the transcrustal boundaries in the Cenozoic. Their zones of dynamic influence do not exceed 200 km. Rejuvenation of boundaries is associated with crustal destruction under the influence of processes beneath the lithosphere. Territories situated outside the areas of dynamic influence of block boundaries, develop in the Cenozoic passively. Tectonics of Asia is defined by mobile zones of the plate boundaries of various kinds.

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БЛОКОВАЯ ТЕКТОНИКА АЗИИ В КАЙНОЗОЕ

Основные черты кайнозойской тектоники и рельефа Азии определяются крупнейшими блоковыми структурами, происхождение которых рядом исследователей рассматривается только с позиций коллизии Индостанской и Евразиатской плит. При этом существенно превышается способность литосферы передавать громадные напряжения на большие расстояния. Критерием установления границ активных в кайнозое блоков являются сейсмические пояса. По глубинам гипоцентров и ориентировке поля напряжений можно судить о масштабе межблоковых границ и движений вдоль них.

Выделено два типа границ между крупнейшими блоками: транслитосферные и транскоровые. Их образуют Средиземноморско-Гималайский и Западно-Тихоокеанский (I- й тип) и Монголо-Охотский и Лаптевско-Колымский (2- й тип) сейсмические пояса.

Анализ неотектонических процессов на площади севернее фронтального Гималайского надвига показывает, что ширина областей динамического влияния от границы столкновения Евразиатской и Индостанской плит не превышает 500 км. За их пределами активизация или формирование новых структур в кайнозое связаны с действием других тектонических сил. Монголо-Охотский, Лаптевско-Колымский сейсмические пояса отражают активные в кайнозое транскоровые границы. Зоны их динамического влияния не превышают 200 км. Активизация границ связана с деструкцией коры под действием подлитосферных процессов.

Территории, расположенные вне областей динамического влияния межплитных границ развиваются пассивно, а тектоника Азии в кайнозое определяется подвижными зонами, отражающими межплитные границы разного типа.

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OROGENY AND TETHYS EVOLUTION IN THE MIDDLE EAST: AN APPRAISAL OF CURRENT CONCEPTS

This review of Tethys evolution and orogenic history in the Middle East intends to test the validity of the plate-tectonic concept as applied to the Irano-Himalayan foldbelt. A summary is given of the most relevant sedimentary, magmatic and structural phenomena. Emphasis is placed on time and sequence of events. A particularly critical area is the Oman-Makran sector of the main ophiolitic belt, where deformation has been severe yet collision has not occurred. The study shows that the wide Permo-Triassic Tethys Ocean required in all plate-tectonic models is not recorded in the Tethyan rocks themselves, and that neither the time and sequence of the tectonic and magmatic events nor certain structural phenomena such as ophiolite nappes and melanges can be satisfactorily explained by a simple subduction/collision mechanism. If crustal expansion in the Indian Ocean occurred at the rates indicated by sea-floor spreading data, geology requires an expanding Earth because compensatory crustal shortening in the Irano-Himalayan orogenic belt appears to have been insufficient. Earth expansion, if conceived as excess of ocean-floor spreading over crustal compression in the orogenic belts, could solve several of the contradictions discussed.

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PATTERNS OF MIDDLE PALEOZOIC FAUNAL PROVINCIALITY IN RELATION TO POSITIONS AND MOTIONS OF CONSTITUENT BLOCKS OF THE ASIA-AUSTRALIA SEGMENT OF THE GLOBE

More than 40 discrete crustal blocks (mini/micro-continents and 'suspect terrains') delineated by ophiolite belts, major geosutures, flysch wedges and radiolarites can be delineated in the Asia-Australia region. For the Palaeozoic, analysis has suffered from inadequacy of longitudinal constraints; this has led to important differences in models previously proposed for the disposition and motions of island-arcs and continental fragments, especially for pre-Permian reconstructions. The age of suturing of successive blocks can be shown to decrease in a general way from the Siberian Block towards the east, south-east and south. Tethys and the northern margin of East Gondwanaland likewise changed markedly in configuration through Palaeozoic and Mesozoic times as block after block moved towards and then sutured with the enlarging Asian (from Bashkirian = Eurasian) Block. It is against this background that Middle Palaeozoic, initially Devonian, brachiopod and trilobite faunas of the Asia-Australia region are being analysed quantitatively. Not all blocks have adequate faunas for useful analysis, but many do for appreciable parts of the record.
In a progress report, the extent to which patterns of biogeography appear to have changed with global tectonic patterns is illustrated, notably in the waningof provincial contrast in shelf faunas with the disappearance of deep-ocean barriers prior to suturing. Quantitative study of provinciality can, with due caution, be helpful in determining relative juxtaposition or isolation of crustal blocks at any given time.

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THE MAIN FEATURES OF TECTONICS AND HISTORICAL EVOLUTION OF THE S. R. VIETNAM

This report expresses the new opinions of tectonics and geological historical evolution of Vietnam in accordance with the results of geological mapping and investigations, that have been achieved for over lasting 20 years. Lying in the intersecting place of two Pa-

cific and Mediterranean planetory mobile belts. Vietnam has a heterogenous geological structure and belong to well known regional tectonic Units of South East Asia, such as the South China paraplatform, Katasian Caledonian folded geosynclinal system, Laos Vietnam Early hercynian folded geosynclinal system, Indosinian Central massif, Yunan Malaysia Late hercynian folded geosynclinal system and transition belt from the Asian continent to the Pacific Ocean. They had been reworked and activated intensively during Phanerozoic, especially in the Indosinian and Anpian tectogenetic stages. As a result of which complicated and various superimposed structures were formed, among them, the West Bacbo marginal suture system is very peculiar. From Archean up to Quaternary, the geological history of Vietnam is characterized by a multistage evolution with alternation or complicated combination of active construction and destruction. After forming the continental crust of the South China and Indosinian cratons at the begining of simen, there had been the forming and developing stages of Palaeozoic geosynclines, which were closed in turn at the end of Silurian in North Eastern Bacbo, at the end of Devonian in Northen Trungbo, at Permian-Triassic in the Westmost of the country. Mesozoic and Cenozoic were represented by tense processes of riftogenesis, orogenesis and tectonomagmatic activation. In East Vietnam sea during the Cenozoic, the formation of marginal sea has been occured.

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SOME TYPES OF SUBDUCTION ZONES IN EAST ASIA

There are a number of subduction zones in East Asian margin of the Pacific and Indian Oceans. These present day subductin zones exhibit features that are quite variable from one to another. It will be demonstrated that comparative studies of these subduction zones reveal fundamental characteristics inherent to the process of subduction. The most typical simple interoceanic subduction zone is the Mariana system where old Pacific palte is subducting without much mechanical interaction with the overriding Philippine Sea plate, causing active spreading of a back arc basin, the Mariana Trough. Similar, but less pronounced, features are observed along the Bonin system, where back arc spreading appears to be in its very initial stage.
Ryukyu and Andaman systems are other examples where a type of back arc spreading is in progress. Both systems appear to be under a strong, influence of tectonic framework of the East Asian continent, probably dictated by the collision and indentation of India into Asia. Contrasting features characterised by compressional stress regime and high seismicity are found in the Kurile and Jaspan subductin zones. These systems may be classified as Chilean type subductin zones. Nankai Trough is also considered to be Chilean type but subducting Shikoku Basin is quite young so that some peculiar features are

observed, such as high heat flow in the trench and lack of definite volcanic front and intermediate and deep earthquakes.
Less typical features are observed along Philippine and Indonesian systems. The tectonic situations in these systems are probably complicated by collision processes. Collision process is in progress in Taiwan and Izu region also.
Another interesting aspect is the subduction of marginal basins beneath island arcs: subductions of the South China Sea plate under Luzon and the Japan Sea plate under northeast Japan.
In this paper, anciant subduction and collision in East Asia will also be briefly reviewed in relation to the development of Asian continent.

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TECTONICS OF THE FOLDED FRINGE OF THE INDIAN PLATFORM

The folded belts encompassing the ranges of Kirthar-Suleiman, Himalaya and Patkai-Arakan represent the continental margin of the cratonic Indian Peninsula. Physically linked with and genetically related to the development of the Andaman-Indonesis island arc-trench system in the southeast and the Baluchistan-Oman subduction complex in the southwest, the Himalayan orogen evolved as a consequence of collision of the Indian and Asian continental plates. The junction of the two plates, known as the Indus-Tsangpo Suture Zone (ITSZ), is delineated by a severely compressed, sheared, narrow and largely vertical zone of obduction and tectonically implanted ocean-floor material including ultrabasics (locally metamorphosed to blueschists) within Upper Cretaceous flysch and radiolarites deposited in oceanic trench in front of the Asian continent. Intimately associated with this fossil subduction complex is the island arc embracing the Upper Cretaceous to Paleogene calc-alkaline volcanics of Kohistan (Pakistan), Ladakh and Shigatse (Tibet). The hornblende-bearing granodiorite-tonalite-diorite suites of Swat, Ladakh, Kailas-Mansarovar, Namcha Barwa and Lohit constitute the genetically connected Andean-type magmatic arc. In the intra-arc to back-arc bssin that developed, following collision, in the belt now occupied by the Indus, Tsangpo and Irrawady rivers, very thick deposits of conglomeratic molasse were laid in the Eocene to early Pliocene times. The Irrawady basin in central Burma, with its axial line of volcanoes, joins up southward with the still spreading marginal basin of the Andaman Sea, characterized by rift-and-graben structure, high heat flow and historical volcanism.
Both to the west and east of the obduction zone, the Himalayan orogen ends up in complexly deformed belts of strike-slip faults - Chaman Fault and Shan Border Fault - which have juxtaposed this Tertiary orogenic province against the Hercynian province embracing Hindukush, North Pamir, Kunkun and Shan States-Thailand and the Tenasserim Peninsula.

Between the parabolic suture zone, the continental-margin sediments resting on high-grade metamorphic basement of Precambrian heritage was (i) folded in the northern part into a synclinorium giving rise to the Tethys Basin now obliguely truncated by the ITSZ against the Asian plate, (ii) split in the middle by the intracrustal Main Central Thrust (MCT) which lifted the basement metamorphics (by about 20 km) to lofty Grat Himalaya and squeezed southwards parts of basement crystallines with their 1800 m.y. old granites, now covering as thrust-sheets large parts of the Riphean and Paleozoic sediments of the Lesser Himalaya, and (iii) dismembered in the southern part by the Main Boundary Thrust (MBT) which brought the Lesser Himalayan rocks over the underthrusting Tertiary foreland - basin - sediments including the Siwalik. The Siwalik has also been split by the Himalayan Frontal Fault (HFF) from the molasse deposits of the latest foreland basin of the Brahmaputra, Ganga and Sindhu. The underthrusting attending convergence of the Indian and Asian plates shifted from the ITSZ to MCT in the later Tertiary times and now to the MBT, as obvious from neotectonic movements and seismicity pattern. If this trend of movements is maintained, the HFF would be the next plane of underthrusting of the Indian plate under the Himalaya. Crustal accomodation consequent on covergence is also taking place by strike-slip movements along the many transverse faulta that cut the Himalayan arc into segments and blocks and along the E-W trending transcurrent faults in the Tibetan plateau and adjoining southwestern China.

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ТЕКТОНИЧЕСКИЕ РЕЖИМЫ ТЕРРИТОРИИ ВЬЕТНАМА И СОПРЕДЕЛЬНЫХ ОБЛАСТЕЙ

В истории тектонического развития изученной территории выделяются три мегаэтапа: I) мегаэтап возникновения базальтовой земной коры; 2) мегаэтап образования протоконтинентальной коры; 3) фанерозойский геосинклинально-орогенно-платформенный мегаэтап, как более полно изученный и включающий 8 этапов.

Первый из них, ранне-среднерифейский геосинклинально-платформенный этап, характеризовался двумя тектоническими режимами: миогеосинклинальным и платформенным. Граница между областями их проявления - глубинный регион Шонгма. В течение второго, позднерифейского рифтово-орогенного,этапа на севере существовал платформенный режим, а на юге - рифтово-орогенный. Граница между областями передвинулась на северо-восток и была представлена рифтовой зоной Камдьонг. Третий, раннепалеозойский рифтово-платформенный,этап характеризовался существованием рифтовых зон Шонгма и Авыонг, разделявших изученную территорию на три геоблока, характеризовавшихся платформенным режимом. Четвертый, среднепалеозойский рифтово-миогеосинклинально-орогенно-платформенный,этап характеризовался развитием платформенного режима в северной, миогеосинклинального-в центральной и орогенного-в южной частях. На пятом, позднепалеозойском платформенном,этапе платформенный режим распространился на всю территорию. Шестой, раннемезозойский рифтово-орогенно-платформенный,этап характеризовался развитием рифтовой зоны Шонгда и орогенного режима в центре северной части территории и платформенного в южной части. Седьмой, позднемезозойский,этап был типично орогенным, а восьмой, кайнозойский, - рифтово-орогенным. На фоне общего горообразования наметились две рифтоподобные зоны: Шонгхонг и Шонгба.

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THE GENERAL PATTERN OF SHEAR TECTONICS OF THE ASIAN CONTINENT AND ITS GEODYNAMIC CHARACTER

Among the Asian continent's shear faults there can be seen some order of orientation and direction of the movement of their wings that is represented by the two global shear zone systems singled out earlier by the author. The first of these systems consists of two subparallel shear zones, one of which situated along the Asian Pacific Ocean coast is characterized by left large-amplitude shears and the other one, stretching from the Iranian Plateau through the Minor Asia towards the North Sea is distinguished by the predominance of right large-amplitude shears. The location and direction of shear movements within the limits of these global shear zones reflects the general trend of displacement of the whole Eurasian lithosphere plate southwards. The second system is characterized by the complex of large-amplitude shears situated in the wide band in the middle of the Asian continent. In this band the large amplitude shears to the east of the Irkutsk amplitheatre - Birman Peninsula line have a predominant north-east strike and the left direction of the movement of its wings, and the analogous shears situated to the west of the mentioned line have a north-west orientation and right direction. The unloading of these tangent stresses takes place in the tectonic scale region of the Banda island are of the Indonesian Archipelago. The reality of the above-mentioned examples of tangent movement of the Asian lithosphere matter is corroborated by a series of other geostructural and geophysical data and presents a vivid geostructural proof of geodynamic influence of pole-fleeing forces on the structure of Asian Continent. The North America is characterized by similar regularities of shear tectonics.

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ОБЩИЙ ПЛАН СДВИГОВОЙ ТЕКТОНИКИ АЗИАТСКОГО КОНТИНЕНТА И ЕГО ГЕОДИНАМИЧЕСКАЯ ПРИРОДА

Среди сдвиговых разрывов литосферы азиатского континента усматривается упорядоченность ориентировки и направленности движения их крыльев, представленная выделенными ранее докладчиком двумя системами глобальных сдвиговых зон. Первая из этих систем состоит из двух субпараллельных сдвиговых зон, одна из которых, расположенная вдоль тихоокеанского побережья Азии, характеризуется ЛЕВЫМИ крупноамплитудными сдвигами, а другая, простирающаяся от Иранского плоскогорья через Малую Азию в сторону Северного моря, выделяется преобладанием ПРАВЫХ крупноамплитудных сдвигов. Местоположение и направленность сдвиговых движений в пределах этих глобальных сдвиговых зон отражают общую тенденцию смещения всей литосферной плиты Евразии в южном направлении. Вторая система характеризуется комплексом крупноамплитудных сдвигов, расположенных в широкой полосе в середине азиатского континента. В этой полосе крупноамплитудные сдвиги восточнее линии Иркутский амфитеатр - Бирманский полуостров имеют преимущественно северо-восточное простирание и ЛЕВУЮ направленность движения своих крыльев, а аналогичные сдвиги, расположенные к западу от указанной линии,- северо-западную ориентировку и ПРАВУЮ направленность. Эта вторая система крупноамплитудных сдвигов выражает тангенциальное тектоническое течение всего вещества литосферы Азии в сторону экватора. Разрядка этих тангенциальных напряжений происходит в области тектонической чешуи островной дуги Банда Индонезийского архипелага. Реальность приведенных примеров тенгенциального движения вещества литосферы Азии подтверждается рядом других геоструктурных и геофизических данных, являясь ярким геоструктурным доказательством геодинамического воздействия полюсобежных сил на структуру азиатского континента. Сходные закономерности сдвиговой тектоники характерны и для Северной Америки.

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TECTONIC EVOLUTION OF THE TETHYS-HIMALAYAS OF CHINA

This paper will discuss the following problems, using the information obtained in recent years:
1. Some new observations on the Yarlung Zangbo (Tsangpo River) suture zone and its adjacent areas;
2. Further discussion on the northern boundary of Gondwanaland;
3. The tectonic evolution of eastern Tethys.
The Yarlung Zangbo suture zone and its adjacent areas are characterized by a complicated structural framework forming an ancient "arc-trench" system.
The new finds concerning the Yarlung Zangbo ophiolite representing the ancient deep trench, the high-pressure and low-temperature metamorphic belt and the melange zone are presented in this paper.
In the light of new discoveries of Gondwanian sedimentary facies and of the cold-water fossils and their distribution features, the boundary between Gondwanaland and Eurasian plate is discussed.
The authors stress again that in the Mesozoic, the tectonic evolution of Tethys-Himalayas (eastern Tethys) is actually the history of the split of the northern margin of the Gondwanaland and its consequent collision with Eurasian plate, i.e., in that time there exhibited such a structural framework consisting of small oceanic basins or gulfs consequently converted into suture zone alternating with microplates.

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THE HISTORY OF FORMATION OF MIDDLE ASIA STRUCTURES, THEIR PLACE IN TECTONIC PLAN OF THE SOUTH-WEST OF ASIAN CONTINENT

The basic line in South-West Asia tectonic development in Phanerozoic eon is the south migration of geosyncline regime. The geosyncline belt evolution was completing in the epoch of diastrophism and continental crust formation. The younger belts partially overlay the ancient ones and crushed them. The earlier stabilized crust fragments became middle massifs in the younger belts. The continental crust in the whole Phanerozoic was periodically activated. Such regime is called tergale. The quasiplatform states and tergale remobilizations were synchronous with geosyncline periods and epochs of diastrophism in younger belts. Such is a general scheme of the increase of Asian continent. The younger belts partially overlying the ancient ones made the scheme of mobile belts ensemble development more complicated. Inside the tergales they appeared the younger belts of second order. The structure formation in some cases was highly complicated, as in South Thian Shan Hercynides, for example. Geosyncline PZ_2 complexes are collected there in nappe packets. Simultaneously and later than (C_2-P_1) sublatitudinal packet folds have been forming as a whole, and still later they were subjected to horizontal flexures. longitudinal steep uplifts and diagonal shifts (P_2-MZ). Subsequent submeridional compression makes the Thian Shan structures still more tangled. South-West of Asia, expect Hindustan and Arabian peninsular was formed by tergale belt ensembles. This group of mobile belts being typical enough, allowed to suggest a hypothesis of zonal tectogenesis, which interpretes the Phanerozoic continental crust evolution as a result of periodic influence of zonal melting in deep mantle belts onto the lithosphere independently moving to the North. The hypothesis permits to avoid many contradictions scecific to the fixism paradigma as well as to the hypothesis of new global tectonics.

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ИСТОРИЯ СТАНОВЛЕНИЯ СТРУКТУР СРЕДНЕЙ АЗИИ И ИХ ПОЛОЖЕНИЕ В ТЕКТОНИЧЕСКОМ ПЛАНЕ ЮГО-ЗАПАДА АЗИАТСКОГО КОНТИНЕНТА

Основной закономерностью тектонического развития юго-западной Азии в фанерозое является миграция к югу геосинклинального режима. Эволюция геосинклинальных поясов завершилась эпохой диастрофизма и становления континентальной коры. Молодые геосинклинальные пояса частично накладывались на более древние и раздробляли их. Фрагменты ранее стабилизированной коры становились срединными массивами в молодых поясах. Континентальная кора в течение всего фанерозоя периодически активизировалась. Такой режим назван тергальным. Периоды квазиплатформенного состояния и эпохи ремобилизации тергалей были синхронны соответственно периодам геосинклинального развития и эпохам диастрофизма молодых поясов. Такова генеральная схема наращивания Азиатского континента. Частичное наложение молодых поясов на древние усложняло общую схему развития ансамбля подвижных поясов. Внутри тергальной области возникали молодые пояса второго порядка (системы), в которых формирование структур нередко начиналось от срединных массивов и заканчивалось в осевых зонах систем. Структурообразование в отдельных поясах и системах являлось чрезвычайно сложным. Примером могут служить герциниды Южного Тянь-Шаня. Геосинклинальные комплексы PZ_2

собраны здесь в пакеты тектонических покровов. Одновременно и позднее (C_2-P_I) формировались субширотные складки пакетов в целом. Далее они подвергаются горизонтальным изгибам, продольным крутым взбросовым и диагональным сдвиговым смещениям (P_2-MZ). Последующее субмеридиональное сжатие еще более осложняет структуры Тянь-Шаня. Юго-запад Азии, кроме Индостана и Аравийского полуострова, сложен единым ансамблем тергальных поясов. Этот комплекс подвижных поясов, достаточно представительный, позволил предложить гипотезу зонного тектогенеза, трактующую эволюцию фанерозойской континентальной коры как результат периодического воздействия процессов зонной плавки в глубинных мантийных поясах на независимо перемещающуюся к северу литосферу. Гипотеза позволяет избежать многих противоречий, свойственных как парадигме фиксизма, так и гипотезе новой глобальной тектоники.

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MECHANISM OF FAULT-BLOCK TECTONICS IN CHINA AND ITS ENVIRONS

China and its Environs are situated right in crustal alternante position with complex crustal structures of continental, transitional and oceanic types to be a key area to solve problems of glable tectonics.

According to the analysis of the contemporary structural features, Asian continent and its margins are composed of stable fault-blocks and mobile fault-folded belts of different ages, scales and characteristic. Most of fault-blocks, surrounded and bounded by lithospheric fractures, are of rhombohedral shape, with basement consolidated due to tectonic cycles: Jinningian (about 900 m.y. or older) and hercynian (about 230 m.y.) respectively. The reactivity of the Jinningian basement in continental areas is relative weak because of thicker and more stable crust. The Hercynian basement in the transitional areas is under tension reducing the crustal thickness, sometimes even leading to the appearence of oceanic crustal material. The fault-folded belts in the continent are compesed of older oceanic or transitional crusts and younger continental ones which are also difined by lithospheric fractures. They are usually more active these fault-blocks, but often contain small relics of relative stable blocks and depressions.

As a rule, continental crust is usually resulted from compression and oceanic one from tension, while transitional one partly due to compression and partly due to tension.

Such a complex tectonic framework of China and its environs is presumed due tthe opposite moving of Angara and Gondwana continents. The resultant compression makes the upwelling of the western of Asia, while the resultant tenssion produces the creep of the Eastern towards the Pacific Ocean.

ЗЕМЛЕТРЯСЕНИЯ И ПРЕДУПРЕЖДЕНИЕ СТИХИЙНЫХ БЕДСТВИЙ
EARTHQUAKES AND GEOLOGICAL HAZARD PREDICTION

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SEISMIC HAZARD AND GROUND MOTION ESTIMATION IN REGIONS OF MODERATE SEISMICITY DEMONSTRATED FOR WESTERN GERMANY

Even in regions of only moderate seismicity but dense population seismic risk reduction becomes an important issue with regard to installations of high secondary destruction potential such as nuclear- and hydro-power stations, and chemical plants. Safety measures based on current procedures and regulations obviously lead to unrealistic results. With the availability of sophisticated numerical techniques it is necessary to provide improved and more realistic seismic input data for dynamic stress and strain calculations of engineering structures.

An attempt toward this goal has recently been undertaken in the Federal Republic of Germany. The seismological basis is a newly compiled catalogue of historical and recent earthquakes. For the homogenization of the data a revised magnitude-intensity relation was established. The determination of exceedance probabilities of given seismic intensities is based on the parcelling of the region into seismotectonic units, application of extreme value statistics with upper limits (Gumbel III - distribution) and intensity-distance relations.

The corresponding seismic ground motion is estimated from intensity dependent near field standard response spectra derived from a new set of strong motion seismograms, mainly from the Friauli and El Assnam earthquake regions. In order to arrive at site specific spectra, spectra observed on hard rock are compiled to define "basement standard spectra" which are subsequently modified by the soil transfer function of the respective site. Peak acceleration as a scaling factor has been abondoned and replaced by quantities more closely related to the seismic energy. A set of "standard time functions" fulfilling certain spectral requirements is preferred for dynamic calculations of construction elements over standard response spectra.

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ON THE CONNECTION BETWEEN THE NEOTECTONIC STRESS FIELD AND CATASTROPHIC LANDSLIDES

The present landforms on the earth's surface result from the interaction of two forces: endogenetic and exogenetic ones. This is the principle of antagonism.

Investigations made earlier have shown that both, submarine and land surface slides are controlled by the neotectonic stress field. In this paper the effects of endogenetic and exogenetic forces on the pre-design of landslides is further discussed in the light of some catastrophic landslide examples in China.

On March 7, 1983 there occurred a catastrophic landslide at Sale Mt., Dongxiang County, Gansu Province; its volume has been estimated to be more than $40 \cdot 10^6 m^3$ and the largest velocity 40-50 m/s. The landslide moved along two shear planes with the directions near E-W (80°-90°) and near N-S (165°-175°). The shear was caused by the regional neotectonic stress field with a principal compression direction of N40°E which was calculated from the data of valley trends, joint orientations and others. Meanwhile the alternating sequence of depressions and elevations on the landslide surface is a result of the instability of the exogenetic forces.

Old landslides (411 landslides) identified from aerial photos, which were caused by two large earthquakes - one in Tianshui on July 21, 1654 (epicenter: 105°30'E and 34°18'N, M=8) and the other in Tongwei on June 19, 1718 (105°12'E,35°6'N, M=7.5) are also studied in the paper. The comparison of the directions of these landslides with the direction of the neotectonic stress field in the regions investigated proves the controlling effect of the latter on the former. In Fujian Province in Southeast China the principal compression direction is 111° (according to valley trends) or 103° (according to fault solutions). If a railway line takes a direction in NNE, i.e. perpendicular to the principal compression direction, more landslides are to be expected along the line.

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ON THE EVALUATION OF TSUNAMI DANGER OF UNDERWATER EARTHQUAKES

The problem of evaluation of tsunami danger of underwater earthquakes is one of the important practical tasks of seismological investigations of the Pacific region. The existent tsunami warning systems are based mainly on seismic magnitude criterion. However more than 20-years experience of tsunami forecasting shows that the probability of

tsunami generation and intensity of waves depend not only on magnitude but also on other parameters of an earthquake, such as depth and mechanism of a source.
For the quantitative evaluation of this dependence the mathematical problem of generation of gravity and elastic waves in a layer of the compressive gravitating liquid overlaying the elastic halfspace is examined. The model source, having some properties of a real focus of an earthquake, is within the elastic halfspace. Unlike the traditional approach to the tsunami generation problem (the solution of the linearized hydrodynamic equations for the potential movement of a heavy incompressible liquid on the rigid bottom) this elastic model allows one to link the tsunami waves directly with a seismic source and to study the dependence of tsunami intensity on different source parameters.
The numerical analysis of the exact mathematical solution of the problem shows that the most intensive tsunami is generated by a vertical dip-slip fault located within the Earth's crust. Under other equal conditions a strike-slip and thrust-type of fault produce the tsunami waves 8-10 times less intensive than a dip-slip fault. The study of the dependence of tsunami amplitude on the source depth shows that only the shallow-focus earthquakes with the depths of less than 60 km can represent real tsunami danger.
These results lead to the conclusion that the efficiency of tsunami forecasting may be higher if the focal depth and source mechanism would be taken into account as the additional criteria of tsunamigenity. The precise and operational determination of these parameters is possible only based on the special seismic telemetering and processing system. To conclude, the requirements to this system and its possible configuration are discussed.

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ОБ ОЦЕНКЕ ЦУНАМИОПАСНОСТИ ПОДВОДНЫХ ЗЕМЛЕТРЯСЕНИЙ

Одной из практических задач сейсмологии при изучении землетрясений Тихоокеанского региона является задача оценки их цунамиопасности. Практика работы службы предупреждения показывает, что вероятность возбуждения волн цунами и их интенсивность определяются не только магнитудой подводного землетрясения, но также зависят от глубины, механизма и других параметров очага.
С целью изучения этой зависимости в работе построено решение прямой динамической задачи о возбуждении длинных гравитационных волн в слое сжимаемой жидкости, лежащем на поверхности упругой среды с находящим-

ся внутри нее модельным источником, имеющим некоторые свойства реального очага землетрясения. В отличие от традиционного подхода к задаче о возбуждении цунами (решение линеаризованных уравнений гидродинамики для потенциального движения идеальной тяжелой жидкости, лежащей на жестком дне), такая модель позволяет непосредственно связать волну цунами с порождающим ее сейсмическим очагом и изучить ее связь с параметрами очага, принятыми в сейсмологии и определяющимися из наблюдений над сейсмическими волнами.

Анализ построенного решения показал, что наиболее опасным с точки зрения цунами типом механизма очага является взбросовая подвижка по крутопадающему разрыву. Сдвиговая подвижка по такому же разрыву и подвижка типа пологого надвига возбуждают цунами в 8-10 раз меньше по амплитуде. Такой же эффект дает увеличение глубины очага с 10 до 60 км, в связи с чем реальную цунамиопасность представляют только мелкофокусные землетрясения.

Полученные данные показывают, что повышение надежности прогноза цунами может быть достигнуто путем использования глубины и механизма очага в качестве дополнительных критериев цунамигенности. Оперативное получение таких критериев возможно только на базе создания специализированной сейсмической системы. В работе рассмотрены требования к такой системе и ее возможная структура.

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SEISMIC POTENTIALITY OF THE CENTRAL AND EASTERN MEDITERRANEAN REGION

A first systematic survey on the occurence of large ($M \geqslant 6,75$) earthquakes in the Mediterranean area was undertaken by the authors in 1979 with the final aim of identifying areas of high seismic potential for large earthquakes in the near future (long-to-medium term forecast). That study was mainly based on principles and criteria similar to those developed in other seismic regions of the world. Several "seismic gaps" were specified; one of them was closed by the Irpinia earthquake ($M = 6.8$) south-east of Napels on 23 November 1980.

In meantime case studies have been carried out in the central and eastern Mediterranean region in order to search for more specific seismic regularity patterns. Since seismicity in the Mediterranean area is the consequence of the very complex collision process of the European- and the African-Arabian plates involving the interaction of several subunits we are faced with very inhomogeneous stress fields and strain release as documented by the seismic fault plane solutions. The seismotectonic situation shows that we are dealing with inter-plate and intra-plate earthquakes as well. It is, therefore, not unexpected that the "randomness" in the occurence of earthquakes is much larger than under the more "simple" conditions of Pacific subduction zones. This requires some modifications of the "gap" concept as originally proposed by Fedotov and by Mogi, and the adoption of experiences from typical intra-plate earthquakes such as earthquake swarms as indicators of future main shocks. Also attempts have been made toward time dependent prediction models. Regions such as Western Anatolia-Marmara Sea, Greece, Dalmatia, Southern Italy are being discussed under this view.

It has to be concluded that up to now only in fortunate cases seismic data may lead to clear and unambignous statements with regard to potentially large earthquakes. Most of the observed regularity patterns related to major earthquakes are not generally valid, or poorly developed, or obscured by random features of seismicity. Possibly regions with different seismotectonic regimes follow their own regularities. This requires further detailed investigations but reliable data are limited. Even if only with some probability a region appears to have a high potential for a major earthquake in the near future this may be useful for safety provisions and for the concentration of scientific observations and the search for short term precursors.

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LAND LEVEL VARIATIONS AND MASS MOVEMENTS PRODUCED BY THE 23 NOVEMBER 1980 EARTHQUAKE IN SOUTHERN ITALY

Abstract the paper gives a brief outline of the geomorphological and geotechnical repercussions of the disastrous earthquake that hit Southern Italy on 23 November 1980. Neotectonic activity is certainly the cause of the remarcable variations in elevations that have been found following the remarkable earthquake and that reached maximum positive and negative values of 35 cm and 75 cm respectively. Remobilizations of old landslides sometimes affecting villages were very frequent also in areas very far from the epicentral zone. Finally geodetic modifications of rock masses and morphological evolution of some slopes due to the earthquake caused big variations in flows from huge springs located in the epicentre area.

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VOLCANIC HAZARDS OF NORTH ISLAND, NEW ZEALAND - AN OVERVIEW

In October 1980, a National Civil Defence Planning Committee on Volcanic Hazards was established in New Zealand which as part of its function is required to assess and report on the likely areas and types of future volcanic activity, the risk to public safety and to comment on those areas which warrant special precautions for public safety. Eight volcanic centres in the North Island have been assessed and unpublished reports presented to the Committee. This paper summarises the hazards and incidence of volcanic activity at the 6 main volcanic centre areas - Auckland, White Island, Okataina, Taupo, Tongariro and Egmont. Average eruption rates over the last 20,000 years range up to $7km^3$/1000 years, as at Taupo (rhyolitic pyroclastics), with individual eruptions occasionally exceeding $100km^3$, and the chances of disastrous eruptions range up to 20% per century. An estimate of the population and value of property at risk is made and mitigation procedures are discussed.

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METHODS TO CALCULATE TSUNAMI RISK OF A COASTAL AREA

Estimation of tsunami risk of various coastal areas should be based on the following tsunami wave characteristics: water elevation on the shore line, drainage depth of the basin, duration of wave run-up and sea-floor drainage, current velocities during the run-up and run-back, tsunami phase velocity, type of tsunami wave destruction, pressure epures determined with account of their probability for any time interval. The paper discusses methods to calculate tsunami wave characteristics at different depths based on analytical and numerical solutions to the non-linear shallow water theory, physical modeling results, actual data of previous tsunamis and sea level variations for many years. One-dimensional methods to calculate tsunami wave characteristics may be used for coastal areas with

relatively smooth coastlines (with a roughness scale of over 10 km), in which case the calculation formulas are developed to nomograms convenient for practical estimates. The numerical methods discussed in the paper have been used to plot a tsunami zone diagram for the Kuril-Kamchatka and Japan coastal areas.

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МЕТОДЫ РАСЧЕТА ЦУНАМИОПАСНОСТИ ПОБЕРЕЖЬЯ

Оценка цунамиопасности различных участков побережья должна опираться на следующие характеристики волн цунами: высоту подъема уровня воды на берегу; глубину осушения бассейна; продолжительность заливания берега и осушения дна; скорость потока при накате и откате; скорость перемещения цунами; тип разрушения волн цунами; эпюры давления, определенные с учетом их обеспеченности за любой промежуток времени. В докладе описаны методы расчета характеристик волн цунами на различных глубинах, основанные на аналитических и численных решениях нелинейной теории мелкой воды, результатах физического моделирования, фактических данных о прошедших цунами,и многолетних колебаний уровня океана. Для участков побережья со сравнительно гладкой береговой линией (с масштабом изрезанности, превышающим 10 км) возможно использование одномерных методов расчета характеристик волн цунами и в этом случае расчетные формулы доведены до номограмм, удобных для практических оценок. Приведенные в докладе методы расчета использованы для построения схем цунамирайонирования побережья Курило-Камчатской зоны и Японии.

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ELECTROMAGNETIC INTERACTION OF PROCESSES IN THE LITHOSPHERE AND IONOSPHERE IN THE PERIOD OF PREPARING OF STRONG EARTHQUAKES

In the recent years the works on studing the electromagnetic effects preceeding the earthquakes are being held. The effects, witness for the existence of seismiatmospheric, ionospheric and magnetospheric interactions are found.
The general model of the sources of electromagnetic effects which are aroused by the big-scale distructions of the earth crust is suggested.
The possibility of use of the electromagnetic effects as the operative precursors of the earthquakes are discussed.

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ЭЛЕКТРОМАГНИТНОЕ ВЗАИМОДЕЙСТВИЕ ПРОЦЕССОВ В ЛИТОСФЕРЕ И ИОНОСФЕРЕ В ПЕРИОД ПОДГОТОВКИ СИЛЬНЫХ ЗЕМЛЕТРЯСЕНИЙ

В последние годы в СССР ведутся работы по изучению электромагнитных эффектов, предшествующих землетрясениям. Обнаружены эффекты, свидетельствующие о существовании сейсмоатмосферных, -ионосферных и -магнитосферных взаимодействий.
Предложена обобщенная модель источников электромагнитных эффектов, возбуждаемых при крупномасштабных разрушениях земной коры.
Обсуждаются возможности использования электромагнитных эффектов в качестве оперативных предвестников землетрясений.

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A DYNAMICAL ANALYSIS OF VOLCANIC EXPLOSION

A TV camera and a video tape recorder were installed at the observatory in order to record atmospheric shock waves and volcanic clouds emmitted by explosive eruption at Sakurajima Volcano. Still cameras were also set to record the trajectories of volcanic bombs in night. The following results were obtained, analyzing the observed pictures. (1) The disappearence of cloud at the front of shock waves and the instant formation of dense cloud in the rarefaction phase were observed. The velocity of the shock wave front was Mach 1.3-1.5 at the height of 300-600 m above the vent. The time when the shock waves started at the vent was 1.2-1.5 sec. later than the origin time of the explosion-quake, the focal depth of which was 1.5-2 km beneath the active crater. (2) Emmission of volcanic cloud was later than that of shock wave by a few seconds. (3) The initial velocities of volcanic bombs depended on the ejection angle (θ). The initial velocity of a bomb does not exceed $V_{max} \times \sin^{1.5}\theta$. Vmax observed is in the range of 110-160 m/s. The ejection of volcanic bombs began within a second after the emmission of shock wave.
The results reveal that the explosion-quake is not excited by the blast at the crater but induces the destruction of the crater bottom. Two model were proposed concerning the mechanism on the generation of atmospheric shock wave. The first case is a "piston model"(that is, the pyroclastic flow acts as a piston) as proposed by Nairn(1976). The second one is "shock tube model"(that is, the plug of vent acts as a diaphragm). The velocities of shock wave calculated from the both model are compatible with those observed. The formation of lava dome

at the crater bottom has been often observed. Therefore, the latter model may be preferable. The former one could, however, give an explanation for the generation of "secondary shock wave", which were observed during the ejection of volcanic cloud in the case of violent explosions at the volcano.

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A SET OF PREMONITORY SEISMICITY PATTERNS FOR STRONGEST EARTHQUAKES OF THE WORLD

Variation of a set of premonitory seismicity patterns allows to decrease by factor about 10 the time-space domain, where strongest (M ⩾ 8) earthquakes may be expected.

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КОМПЛЕКС ДОЛГОСРОЧНЫХ ПРЕДВЕСТНИКОВ ДЛЯ СИЛЬНЕЙШИХ ЗЕМЛЕТРЯСЕНИЙ МИРА

Описаны вариации ряда характеристик сейсмичности, на основе которых можно примерно в IO раз сократить пространственно-временной объем,в котором ожидается сильнейшее (M ⩾ 8) землетрясение.

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GLOBAL SEISMIC RISK - THE RECENT DRASTIC INCREASE

Global seismic risk is rapidly growing, due to the explosion of urban population and the increase of seismic vulnerability of large cities (while seismic activity remains about the same). Before the end of this century 40± 26 mlns of people only in the largest, with population 1 mln, cities of the world will experience intensity ⩾ VIII MM; counted are only the events, when such intensity covers ⩾ 100 km^2, so that each event does spell disaster.
These estimations are obtained by synthesis of global tectonic, seismological and demographical data. The reliability of the estimations are confirmed by comparison with seismic history.
The results described show, that seismic risk rapidly becames a

major concern of humanity and requires new extraordinary measures of preparedness and prevention.

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СЕЙСМИЧЕСКИЙ РИСК ДЛЯ КРУПНЕЙШИХ ГОРОДОВ МИРА

Глобальный сейсмический риск резко вырос из-за концентрации населения в крупных городах и повышения их сейсмической уязвимости (при примерно прежней сейсмической активности). До 2000 года только в миллионных городах мира $40^{\pm}26$ миллионов жителей окажется в зоне сотрясений $\geqslant$ УШ баллов (это относится к случаям, когда такие сотрясения охватывают $\geqslant$ 100 $км^2$).
Указанные оценки получены путем синтеза глобальных тектонических, сейсмологических и демографических данных. Надежность оценок подтверждается сравнением с сейсмологической историей.
Полученные результаты указывают, что сейсмический риск вырастает в проблему, требующую принципиально новых мер предотвращения и защиты.

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ON STRONG INTERPLATE EARTHQUAKE PREDICTION BY THE 1976 TANGSHAN EARTHQUAKE

The Tangshan earthquake occurred in July, 1976. It was the greatest earthquake which had caused a catastrophe. Its epc. located in the area where we have the densest stations and the longest history of monitory work. Although we didn't predict this earthquake, its occurrence has provided us with plenty of information. It is a typical representative of interplate strong earthquakes. Deep research of the information may give us a great deal of enlightenment. This paper mainly discuss the problem of strong earthquake prediction.
First we list some important precursors of the earthquake and point out as well some regularities displayed in the precursory phenomena. The complexity of the earthquake is thoroughly notes from which we then search for the approach the predicting a strong earthquake.
As regarding the complexity we discuss the complicated precursors and phenomena in the process of the main earthquake; various characteristics of aftershocks; macroscopic and microscopic change after the main earthquake.

The causes of above-mentioned complexity may be connected to the properties of mechanics, fracture mechanism, tectonic condition of source region, the influences of some other earthquakes around Tangshan region, the effects of meteological and astronomical factors.
The difficulties of predicting a strong earthquakes are discussed but under certain conditions some clues to prediction are found among the complexity. These clues are also discussed in paper. It lays emphasis on the necessity of making comprehensive prediction. In this direction some possible methods of predicting place time and magnitude of a future earthquake in China are discussed. Meanwhile, it points out the conditions and limits of earthquake prediction at present stage.

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ACTIVIZATION OF SEISMIC PROCESSES IN REGIONAL VOLUMES OF LITHOSPHERE AND RECENT VIEW ON THE PROBLEM OF LONG-TERM EARTHQUAKE PREDICTION

Before the series of strong motions in the Middle Asia the coordination of continuous anomalies in lasting (up to 25 years) variations of complex of prognostic parameters has been observed.Vast massifs of lithosphere are supposed to be involved into the regime of raised deformation as a result of large-scale tectonic processes. It is shown that the induced activization of seismic process is generated in the upper mantle and only later the Earth crust is involved into the process.
At the process of strong motion generation the relation of seismic prognostic parameters and deformation velocity is of hysteresis nature. This regularity indicates to the inelastic media changes not only in the source but also in the region around. The last greatly exceeds the earthquakes sources dimentions. It explains the long-range interaction of forerunners. Hysteresis nature of interrelation testifies to a possible cyclicity of the process of the Earth crust deformation changes.
Energetic calm synchronizes with the most intensive change of prognostic parameters. And, also, their long-time anomalies enable us to predict the beginning of raised activization

period (on the level of strong motions) of remarkable volumes of the Earth crust and upper mantle. This process completion and new equipondrous medium condition is controlled by the change of correlating relation character between the parameters. Sequence of seismic energy release along the large tectonic structures has been observed. The predicting map of regions of strong earthquakes generation (with M $\geqslant$ 5.5) has been plotted.

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АКТИВИЗАЦИЯ СЕЙСМИЧЕСКИХ ПРОЦЕССОВ В РЕГИОНАЛЬНЫХ ОБЪЕМАХ ЛИТОСФЕРЫ И НОВЫЙ ПОДХОД К ПРОБЛЕМЕ ДОЛГОСРОЧНОГО ПРОГНОЗА ЗЕМЛЕТРЯСЕНИЙ

Перед серией сильных землетрясений Средней Азии наблюдается согласованность продолжительных аномалий в долговременных (до 25 лет) вариациях комплекса прогностических параметров. Предполагается, что в результате имевших место крупномасштабных тектонических процессов в режим повышенного деформирования были вовлечены огромные массивы литосферы. Показано, что вызванная активизация сейсмического процесса берет свое начало в верхней мантии и лишь впоследствии в него вовлекается земная кора.

В прцессе подготовки и возникновения серии сильных землетрясений зависимость сейсмических прогностических параметров от скорости деформации носит гистерезисный характер. Эта закономерность свидетельствует о развитии неупругих изменений среды не только в области очага, как считалось ранее, но и в значительном региональном объеме, намного превышающем размеры очагов землетрясений, чем и объясняется дальнодействие предвестников. Гистерезисный характер взаимосвязи указывает на возможную цикличность процесса изменения деформации земной коры.

Энергетическое затишье, совпадающее по времени с наиболее интенсивным изменением прогностических параметров, а также их долговременные аномалии позволяют предсказать наступление периода повышенной активизации (на уровне сильных землетрясений) значительных объемов земной коры и верхней мантии. Окончание этого процесса и наступление нового равновесного состояния среды контролируется изменением характера корреляционной связи между параметрами.

Рассмотрена последовательность высвобождения сейсмической энергии вдоль крупных тектонических структур и на этой основе построена прогнозная карта мест возникновения сильных (с M$\geqslant$5,5) землетрясений.

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INTERCONTINENTAL EARTHQUAKE PREDICTION

Methods of prediction works on the example of the Central Asia according to seismologic and geophysical measurements is being dealt with. Examples of separate earthquake prediction are given. The factors distorting the instruments' reading and complicating getting prediction data are described. The effectiveness of the used observation complexes and directions of further works in the field of earthquake prediction are evaluated.

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ПРОГНОЗ ВНУТРИКОНТИНЕНТАЛЬНЫХ ЗЕМЛЕТРЯСЕНИЙ

Рассматривается методика прогнозных работ на примере Средней Азии по сейсмологическим и геофизическим измерениям. Приводятся примеры прогноза отдельных землетрясений. Описываются факторы, искажающие показания приборов и осложняющие получение прогнозных данных. Оцениваются эффективность применяемых комплексов наблюдений и направления дальнейших работ по прогнозу землетрясений.

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EARTHQUAKE: SOURCE, HAZARD, DISASTER

1. The history of concepts on large earthquake sources is considered. In the past, large earthquakes were quite naturally understood as geological catastrophes with extended sources. These sources got a character of abstract models, zero-, two- or three-dimentional, owing to progress of physical seismology. The genesis of destructive short-period seismic radiation was explained only by most recent models being connected with small irregularities in the source fine inner structure. The study of geological setting is needed to understand processes of source origin, development and extinction.
2. The methodology of seismic hazard estimation vary at the moment from specific "seismological actualism" ("It will be where it has been; there will be none where none has been") to the author's supposition that, during the locally largest earthquake the source changes its whole setting so deeply and irreversibly that it cannot be repeated in the future. At the moment, among other techni-

ques, the so-called "Bulgarian Algorithm" seems to be most efficient. General trend in errors of seismic zoning is also discussed.
3. Factors transforming seismic hazard into seismic disaster are discussed. Analysis of casualities and damages shows that when magnitude decreases the relative number of disasters decreases unproportionally. This cannot be explained by obvious geographic factors such as earthquake location at the sea or within the unpopulated areas and needs some geophysical explanation. Such factors as focal depth , size of the source, type of focal mechanism should be considered in order to select from all expected sources those producting disasters and, thus, to minimize the false alarm errors of seismic zoning.

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ЗЕМЛЕТРЯСЕНИЯ: ОЧАГ, ОПАСНОСТЬ, КАТАСТРОФА

I. Рассмотрено развитие представлений об очаге сильного землетрясения. В прошлом сильные землетрясения вполне естественно рассматривались как геологичевкие катастрофы с большим очагом. Прогресс физической сейсмологии привел к замене таких представлений абстрактными моделями с размерностью ноль, два или три. Генерация разрушительных короткопериодных сейсмических колебаний, связанная с неоднородностями тонкой внутренней структуры очага, нашла свое объяснение лишь в новейших моделях. Изучение геологических условий этого процесса необходимо для понимания истории возникновения, развития и отмирания сейсмических очагов.
2. Методика оценок сейсмической опасности в настоящее время варьирует от глубокого "сейсмического актуализма" ("где было, там будет; где не было, там не будет") до представлений автора о том, что сильнейший для данного места очаг в момент землетрясения настолько глубоко и необратимо меняет здесь всю обстановку, что никогда не сможет повториться в будущем. Среди прочих методик т.н. болгарский алгоритм в настоящее время представляется наиболее эффективным. Рассмотрены также общие тенденции изменения ошибок сейсмического районирования.
3. Обсуждаются причины, превращающие сейсмическую опасность в сейсмическую катастрофу. Анализ разрушений и жертв показывает, что при уменьшении магнитуды относительное число катастроф убывает непропорционально. Это не может быть объяснено географическими факторами, например положением эпицентра в море или ненаселенной местности ,и нуждается в геофизическом истолковании. Для объяснения должны учитываться такие факторы,как глубина очага, его размеры, тип механизма. Их учет позволит в дальнейшем выявлять среди ожидаемых очагов именно очаги ожидаемых катастроф и минимизировать таким образом ошибки ложной тревоги в сейсмическом районировании.

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TSUNAMI AND MEASURES OF AFTEREFFECT DECREASING

The piston floor shift is the main cause of tsunami excitation. Also, it may be effected by the cross shift of continental slope coast and by strong elastic floor vibration. But,yet,the lasts have not been investigated sufficiently. Possibility of tsunami excitation at an earthquake of a given M is the highest in block shelfs and the lowest in deep-sea trenches. But in the lasts tsunamis occur more often and are of an extreme force. Yet, there are no completed diagrams explaining the origin of tsunamigenic earthquake on the basis of underthrust fault of oceanic lithosphere to a continental one. Weak, stronger, more stronger tsunami in an ocean, their propagation in a coastal zone are perfectly explained by a linear wave theory, long wave linear theory, non-linear theory of long waves and St.Venant equation correspondingly. Nonlinearity is considerable near a coast; so,the force of tsunami increases with the waves height. It is irresistibly difficult to give a complete tsunami description but lately there developed a method of numerical description of tsunami propagation in an ocean with an uneven floor. Numerical methods of modelling of tsunami run-up on a coast are being developed now. There suggested intensity scales for an energetic classification of tsunami. In the first approximation the inclination of frequency diagram is constant in zones and in time. Thanks to numerical modelling of tsunami and statistical analysis of observations the tsunami zonation is carried out. Technical requirements for construction in a flooding zone has been worked out. Short-term tsunami forecast is carried out both by usage of earthquake recording and by ocean observations. Works on arrangement of automatic warning system in the Far East are being produced in the USSR.

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ЦУНАМИ И ВОЗМОЖНЫЕ МЕРЫ СНИЖЕНИЯ ПОСЛЕДСТВИЙ

Наиболее эффективный механизм возбуждения цунами состоит в поршневой подвижке дна. Цунами могут вызываться также сдвигом в крест берега континентального склона и сильными упругими колебаниями дна, но эффективность этих механизмов изучена недостаточно. Вероятность возбуждения цунами при землетрясении заданной магнитуды наивысшая в шельфовых зонах блокового строения и наинизшая в глубоководных желобах. Но в последних цунами возникают чаще всего и достигают предельной силы. Законченных схем, объясняющих механизм цунамигенных землетрясений, исходя из модели поддвига океанической литосферы под континентальную или других тектонических гипотез нет. Поведение слабых цунами в океане хорошо описывается линейной волновой теорией, более сильных - линейной теорией длинных волн, еще более сильных - нелинейной теорией длинных волн, распространение цунами в прибрежной зоне - уравнениями Сен-Венана. Нелинейность существенна вблизи берега; так, доля обрушивающихся цунами растет с высотой волн. Полное аналитическое описание цунами наталкивается на пока непреодолимые трудности, но в последнее время развита методика численного описания распространения цунами в реальном океане с неровным дном. Сейчас бурно развиваются численные методы моделирования наката цунами на берег, в том числе двумерного. Для энергетической классификации цунами предложены шкалы интенсивности (магнитуды). Наклон графика повторяемости выдерживается от зоны к зоне и во времени. Численное моделирование цунами и статистический анализ наблюдений позволяют проводить цунамирайонирование побережий. Сформулированы правила строительства в затопляемой зоне. Краткосрочный прогноз цунами осуществляется как путем использования записей землетрясений, так и путем прямых наблюдений в океане. Ведется работа по созданию на Дальнем Востоке СССР автоматизированной системы оповещения о цунами.

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FORECASTS AND PREDICTIONS OF ERUPTIONS AT MOUNT ST. HELENS, USA

Three types of written public statements about volcanic activity at Mount St. Helens are issued by scientists of the Casacades Volcano Observatory (U.S.Geological Survey) and the Geophysics Program (University of Washington). A factual statement describes current conditions but does not anticipate future events; such statements are revised when warranted and keep the public and governmental agencies informed on a timely basis. A forecast is a comparatively imprecise statement about expected activity weeks to decades in advance that is based on projection of past geologic, geophysical or geochemical records. Forecasts aid in long range land-use planning and in the development of emergency response plans. A prediction is a comparatively precise statement stating place, time, nature, and--ideally--

size of an impending eruption. A prediction is issued a few hours to a few weeks before an eruption, when sufficient data are available to provide a relatively clear view of future activity, as judged from similarities with past precursory patterns and from interpretations of the active volcanic processes. Increasingly more specific predictions are issued as the eruption nears. Predictions affect short range land-use planning, reduce risk to life and property, and provide a public test of scientific hypothesis about volcanic processes. Stratigraphic studies led to a long range forecast in 1975 of renewed activity at Mount St. Helens, possibly before the end of the century. On the basis of seismic, geodetic, and geologic data, short range forecasts for a landslide and eruption were issued in April 1980, before the catastrophic eruption on May 18, 1980. Predictions were made of all eruption from June 1980 to the end of 1982, on the basis of integrated geophysical, geochemical and geologic monitoring.

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ORTHOGONAL SEISMIC BELTS AND SEISMIC CAPS

In Northern China it has been analysed that the epicenters of shallow earthquakes are arranged in seismic bands rather than on the large structural faults. Basing on these findings a rheological hypothesis on the orthogonality of curvilinear seismic belts is proposed and an explanation is given for the phenomenon that large earthquakes have occured in the nodal regions of this network. A preliminary analytical study on the formation and characteristics of seismic gaps is presented.

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VOLCANO HAZARDS PROGRAM IN THE UNITED STATES

Volcano monitoring and volcanic-hazards studies have received greatly increased attention in the United States in the past few years. Before 1980, the U.S.G.S. Volcano Hazards Program was primarily focused on the active volcanoes of Kilauea and Mauna Loa, which have been monitored continuously since 1912 by the Hawaiian Volcano Observatory. After the reawakening and catastrophic eruption of Mount St.Helens in 1980, the Volcano Hazards Program was substantially expanded as the government and general public became aware of the potential for eruptions and associated hazards within the conterminous United States. In 1980 the David A.Jhonston Cascades Volcano Observatory was established in Vancouver. Washington, to systematically monitor the continuing activity of Mount St. Helens, and to acquire baseline data for monitoring the other, presently quiescent, but potentially dangerous Cascade volcanoes in the Pacific Northwest. Since June 1980, all of the eruptions of Mount St.Helens have been predicted successfully on the basis of seismic and geodetic monitoring.

The largest volcanic eruptions, but the least probable statistically that pose a threat to western conterminous United States are those from the large Pleistocene-Holocene volcanic systems, such as Long Valley caldera (California) and Yellowstone caldera (Wyoming), which are underlain by large magma chambers still potentially capable of producing catastrophic caldera-forming eruptions. In order to become better prepared for possible future hazards associated with such historically unprecedented events, detailed studies of these gigantic volcanic systems should be intensified to gain better insight into calderaforming processes and to recognize, if possible,the precursors of caldera-forming eruptions.

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SHORT-TIME PREDICTION OF VOLCANIC ERUPTIONS ACCORDING TO SEISMOLOGIC DATA

Eventually the cause of volcanic eruptions is the pressure increasing in magmatic source and leading out canal.Continuous pressure increasing causes volcanic structure deformation, rocks failure and eqrthquakes. Mean and large eruptions also follow the volcanic earthquakes. The lasts uniquely show the volcano condition and may be used to predict the place,time and the eruptions energy.

The author has estimated the regularities of volcanic earthquakes and eruptions relation. This has permitted to predict the place and time of breaks of secondary craters, and, also, the place,time and energy of central eruptions of andesite volcanoes.

According to seismological data the great explosions like Bezymjanyi (March 30,1956) and St.Helens (May 18, 1980) can be predicted.The basis of short-time prediction of eruptions is an operative tracking of the volcanoes seismic regime. Continuous observations of the Kamchatka volcanoes have allowed to forsee the eruption of Sheveluch on March 12, 1964 , and to predict the place and time of the Tolbachic large eruption three days before the event. It has started on June 6, 1975 and lasted up to December 10, 1976.

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КРАТКОСРОЧНЫЙ ПРОГНОЗ ВУЛКАНИЧЕСКИХ ИЗВЕРЖЕНИЙ ПО СЕЙСМОЛОГИЧЕСКИМ ДАННЫМ

Причиной вулканических извержений в конечном счете является возрастание давления в магматическом очаге и выводном канале. Постепенное возрастание давления вызывает деформации вулканической постройки, разрушение пород и землетрясения. Умеренные и большие извержения всегда предваряются вулканическими землетрясениями. Вулканические землетрясения однозначно отражают состояние вулкана и могут быть использованы для прогноза места, времени и энергии извержений.
Установленные автором закономерности связи вулканических землетрясений с извержениями позволяют предсказывать место и время прорывов побочных кратеров, а также место, время и энергию центральных извержений андезитовых вулканов. По сейсмологическим данным могут быть предсказаны и большие взрывы типа взрывов вулкана Безымянного (30 марта 1956 г.) и Сент-Хеленс (18 мая 1980 г.).
Основой краткосрочного прогноза извержений является оперативное слежение за сейсмическим режимом вулканов.
Непрерывные наблюдения за сейсмическим режимом вулканов Камчатки позволили предвидеть извержение вулкана Шевелуч 12 ноября 1964 года и предсказать за трое суток место и время Большого Толбачинского извержения, которое началось 6 июля 1975 г. и продолжалось до 10 декабря 1976 года.

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MODERN LARGE LANDSLIDES, PREDICTION AND PROTECTION

In XXth century tens of largest landslides have been registered at different geological regions. This represents the Earth crust regular development sometimes enlarged by technogenic factors.
Landslides generate in different rocks under the influence of many factors and are subdivided by motion mechanism. Stress values and distribution, degree and conditions of irrigation,

seismics and human activity have played a significant role in these types of formation. Among the largest landslides there prevailed the complex types with passing from one motion mechanism to another.

Confidence degree of estimation of high slopes condition and of large landslides prediction depends on the completeness of initial data. The lasts are defined by the diagrams of calculations and experiments. Methods of analogs taking into consideration the geological structure and development history of the given region are necessary for predicting of complex large landslides.

Measures of landslide prosess control and prevention of dangerous results are defined by the expected characteristics of the landslides themselves and the territory value. If the strengthening of slopes is difficult or unsuitable then the engineering and organizational measures are the regulation of landslides descent,damage decreasing and people evacuation. There are examples of active protection measures from large landslides in the USSR. Single-minded engineering-geological and regime investigations are necessary for a successful determination of the problem.

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СОВРЕМЕННЫЕ КРУПНЫЕ ОПОЛЗНИ, ВОПРОСЫ ИХ ПРОГНОЗА И ЗАЩИТЫ

В XX столетии в разных геологических регионах планеты зарегистрированы десятки крупнейших оползней. Они отражают закономерное развитие земной коры, усиленное в ряде случаев техногенными факторами. Оползни возникают в различных комплексах пород под влиянием многих факторов. Оползни чаще всего подразделяются по механизму движения; в формировании их типа существенную роль играют величины и распределения напряжений, степень и режим обводнения, сейсмичность и деятельность человека. Среди наиболее крупных оползней преобладают сложные типы с переходом от одного механизма движения к другому. Степень достоверности оценки состояния высоких склонов и прогноза крупных оползней зависит от полноты исходных данных, которыми определяются схемы для расчетов и экспериментов. Для прогноза сложных оползней больших объемов необходимы методы аналогий, учитывающие геологическое строение и историю развития данного района. Система мероприятий по борьбе с оползневыми процессами и по предотвращению их опасных последствий определяется ожидаемыми характеристиками самих оползней и ценностью территории. В тех случаях, когда укрепление склонов трудноосуществимо или нецелесообразно, инженерные и организационные мероприятия сводятся к регулированию схода оползневых масс, минимизации ущерба и эвакуации людей. В СССР есть примеры активных мер защиты от крупных оползней. Для успешного решения проблемы защиты от оползней необходимы целенаправленные комплексные инженерно-геологические и режимные исследования.

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VOLCANIC PROCESSES REVEALED BY GEOPHYSICAL OBSERVATIONS OF THE 1977 - 1982 ACTIVITY OF USU VOLCANO, JAPAN

Volcanic processes of Usu volcano manifesting characteristic activity of dacitic one for about 5 years, are deduced from the results of long-and short-term observations of earthquakes and deformations. At the beginning stage of the activity, it would appear abruptly and develop hyperbolocally resulting in the first outburst while, at the terminating state, it would disappear also abruptly someday. A qualitative model of visco-plasto-elastic property is proposed to interpret the volcanic processes, especially of the beginning and terminating stages. From a standpoint of prediction of eruptions of such volcanoes, we should observe any non-mechanical forerunning phenomena for long-term prediction, and add mechanical ones such as earthquakes and deformations to the above observations for short-term prediction,

ПЛЕНАРНОЕ ЗАСЕДАНИЕ "ГЕОЛОГИЧЕСКИЕ ПРОБЛЕМЫ ОХРАНЫ ОКРУЖАЮЩЕЙ СРЕДЫ"
PLENARY MEETING "GEOLOGICAL ASPECTS OF ENVIRONMENTAL PROTECTION"

Chairmen: E.A.Kozlovsky, M.Tolba

KOZLOVSKY E.A., Ministry of Geology of the USSR, Moscow, USSR

GEOLOGICAL PROBLEMS OF ENVIRONMENTAL PROTECTION

Man-nature interaction is dual in nature: man cannot exist without natural resources, including mineral ones, and at the same time he is able to actively rebuild nature.

Man's economic activity has become a powerful factor of nature transformation. It affects the present-day geological, hydrogeological, and other natural processes, as well as the circulation of substance and energy in nature. It has become commensurable with and often surpassing natural geological processes in size and consequence. Man's activity is constructive (construction of dams and channels, fortification of river banks and sea shores, land improvement, etc.) and also destructive. The air and surface and ground waters are poluted. Regional and local changes occur in the conditions of ground water recharge, flow, and discharge. Intensive ground water withdrawal leads to water level drop and to ground surface sagging and collapse. Construction of water storages involves underflooding and swamping of extensive areas. In many regions soils are impoverished and their productivity is decreased. Exogenic geological activity is intensified resulting in landslides, mudflows, bank caving, shore abrasion, karst formation and other processes. Geocryologic environment is affected in permafrost areas. Various changes occur in the geological environment as a result of mining, underground coal gas production, sulfur smelting, and other activities.

Huge amounts of economic minerals are extracted from the Earth. The Earth's mineral resources are plentiful but not inexhaustible; they are not renewable (except ground water) in historic time. A rational use of mineral resources has become an urgent problem. Of great importance is the multisided study of mineral raw materials, elaboration of scientifically grounded recommendations for diminishing their waste in production and processing, development of the technology of wasteless concentration and ultimate utilization of the mined ore mass including dumps and benefication waste. There are two aspects of rational utilization of mineral materials: (1) complete use of all useful components, and (2) environmental control.

Ground water is an important source of domestic and industrial water supply. In the USSR about 70 per cent of cities are supplied with fresh ground water. A substantial reserve of water supply in many areas and a radical measure of environmental control is the utilization of ground water recovered as a by-product in oil fields and coal mines. Mineralized ground water is regarded as a valuable source of chemical materials (iodine, bromine, lithium, strontium, boron, etc.), thermal energy and balneotherapy. At the same time ground water is easily poluted and its resources can be rapidly exhausted as a result of economic activity.

It is vitally important to develop the scientific basis and methods of prognostication of changes in the environment caused by man's activity and to devise measures to reduce its negative concequences. This work is under way under the international project "Protection of the Lithosphere as the Component of the Environment". The long-term scientific and production programme "Lithomonitoring" is developed in the USSR as a universal system of control, evaluation, and prediction of changes in the geological, ground water, engineering-geological and other conditions caused by the economic activity.

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ГЕОЛОГИЧЕСКИЕ ПРОБЛЕМЫ ОХРАНЫ ОКРУЖАЮЩЕЙ СРЕДЫ

Двойственная природа взаимодействия человека и природы: человек не может существовать без использования богатств природы, в частности земных недр, и одновременно способен активно перестраивать ее. Хозяйственная деятельность человека стала мощным фактором преобразования природы. Она активно влияет на современные геологические, гидрогеологические, инженерно-геологические и другие процессы, на круговорот веществ и энергии в природе. По масштабам и последствиям воздействия она стала соизмеримой с естественными геологическими процессами и нередко их превосходит. Это воздействие носит как созидательный (сооружение искусственных водохранилищ, каналов, укрепление берегов морей и рек, повышение биологической продуктивности территорий и т.д.), так и негативный характер.

Загрязняются атмосфера, поверхностные и подземные воды. Происходят региональные и локальные изменения условий питания, движения и разгрузки подземных вод. Мощный отбор подземных вод приводит к снижению их уровня, оседанию, а иногда и провалам земной поверхности. При создании искусственных водохранилищ нередки подтопление и заболачивание обширных площадей. Во многих районах наблюдается истощение почв и уменьшение их продуктивности.

Ускоряется проявление экзогенных геологических процессов - образование оползней и селей, абразия берегов, карстообразование и т.п. Изменяется геокриологическая обстановка на участках развития многолетней мерзлоты. Специфические и многообразные изменения геологической среды происходят при разработке месторождений, подземной газификации углей, выплавке серы и т.п.

Из земных недр извлекаются огромные количества полезных ископаемых. Богатства недр велики, но не беспредельны и в масштабах времени существования человеческого общества практически невозобновляемы (кроме подземных вод). Поэтому их рациональное использование становится все более актуальным. Чрезвычайно важны вопросы всестороннего комплексного изучения минерального сырья, разработки научно-обоснованных рекомендаций по сокращению его потерь при добыче и переработке, созданию безотходной технологии обогащения и переработки, использования всей добытой горной массы, включая отвалы вмещающих пород и отходы обогащения. Вопросы комплексного рационального использования полезных ископаемых имеют два аспекта: I) сырьевой (полное использование всех компонентов) и 2) охраны окружающей среды.

Подземные воды являются важнейшим источником бытового и промышленного водоснабжения. В СССР за счет пресных подземных вод организовано водоснабжение 2/3 городов. Резервом для улучшения водоснабжения многих районов и важной мерой охраны окружающей среды является использование подземных вод, извлекаемых попутно при добыче других полезных ископаемых - на нефтепромыслах, угольных шахтах и т.п. Минерализованные подземные воды все больше рассматриваются как комплексное полезное ископаемое, содержащее ценные химические вещества (йод, бром, литий, стронций, бор и др.) и обладающее тепловой энергией и бальнеологическими свойствами.

Вместе с тем в результате хозяйственной деятельности подземные воды очень легко подвергаются загрязнению, а их запасы при неправильной эксплуатации месторождений - истощению.

В связи с этим представляются исключительно важными создание научных основ и методов прогноза изменений окружающей среды в результате антропогенного воздействия, а также разработка мер по снижению его отрицательных последствий. Эти работы осуществляются в рамках международного проекта ОЛЮС - охрана литосферы как компонента окружающей среды. Разрабатывается долгосрочная комплексная научно-производственная программа "Литомониторинг СССР" как единая система контроля, оценки состояния и прогнозов изменения геологических, гидрогеологических, инженерно-геологических и других условий под влиянием хозяйственной деятельности.

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IMPACTS OF WATER RESOURCES PROJECTS ON THE ENVIRONMENT

The environment is characterized by fragile equilibria resulting from permanent interactions taking place in the terrestrial space and in geological time. These equilibria are governed by energetic (*hydraulic and hydrothermal*), geomorphological, hydrological and biological cycles of substance and energy transfer.
The impacts of Man's activity on the hydrogeological cycle and water resources can be classified into six aspects:

- modification of hydrologic regimes in water basins,
- inflow of irrigation water,
- exploitation of ground water,
- drainage in land reclamation,
- disposal of waste water,
- utilization of geothermal energy of aquifers.

These aspects are discussed with regard to possible negative effects produced by Man's activity and examples are given.
All projects of water resources development should be preceded by and accompanied with special studies of their harmful effects on the environment.

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SCIENTIFIC AND TECHNOLOGICAL PROGRESS AND ENVIRONMENTAL CONTROL

Progress in science and technology has given birth to the term "environment" which implies the part of the natural environment where nature and man are actively interacting. The scope of man-nature interaction is demonstrated by examples. Man cannot help interfering with nature for he cannot exist without its animal and plant kingdom, its water, and its mineral resources. Yet, as K.Marx stated in his "Capital", if culture evolves sporadically and is not consciously directed it leaves desert behind. In this connection a rational use of the natural environment is emphasized, and the necessity of long-term prognostication is stated. This point is discussed with reference to the environmental protection measures employed in the USSR in various construction projects, in soil erosion control, and in West Siberian oil field development. Environmental control is of vital importance to the entire mankind.

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НАУЧНО-ТЕХНИЧЕСКИЙ ПРОГРЕСС
И ОХРАНА ОКРУЖАЮЩЕЙ СРЕДЫ

Научно-технический прогресс привел к возникновению термина "окружающая среда", под которым понимается та часть природной среды, где происходит активное взаимодействие природы и целенаправленной деятельности человека. На ряде примеров в докладе показаны масштабы этого взаимодействия. Человек не может не оказывать влияния на природу, не может не пользоваться растительным и животным миром, не может не употреблять воду, не может не изменять твердую оболочку Земли - литосферу. Но, как писал в первом томе "Капитала" К.Маркс: "...культура, - если она развивается стихийно, а не направляется сознательно - оставляет после себя пустыню". В связи с этим подчеркивается важность рационального использования окружающей среды и необходимость долгосрочных прогнозов.

В докладе также рассматриваются вопросы охраны и рационального использования окружающей среды в Советском Союзе в связи с различными видами строительства, борьбой с почвенной и овражной эрозией, селями, освоением нефтегазоносных месторождений Западной Сибири.

Охрана окружающей среды является задачей первостепенной важности для всего человечества.

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INFLUENCE OF MINING ACTIVITIES ON THE ENVIRONMENT

Man is part of nature. Living beings consume more of the lithosphere than their bodies weight in order to fill their energy needs; man holds the record in this respect. Ever since he began to extract flint for the first tools he has fallen back on the treasure of the lithosphere to a greater and greater extent.
Since then the consumption of geopotential, which is striding along with the rise in world population and with the increase in per capita consumption of mineral resources, in rising at a steep rate, which does not seem to be levelled off. Especially in the case of surficial resources, this results in influencing vegetation and ani-

mals, rechanging the landscape, and producing emissions, immissions, noise polution and waste products, the disposal and recycling of which is at present connected with unsolvable problems.
Geotechnology can contribute to solve these problems. The geologist who is required to look for new geopotential to meet the growing demands for mineral resources is at the same time called upon to contribute to the search for solutions that avoid or eliminate technical problems as to mining and processing.
There is no reason to claim that the influence of mining on the environment is an unsolvable side-effect. There are many possibilities of reducing these effects to a tolerable amount.

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THE MANAGEMENT OF THE ENVIRONMENT AND ITS BACKGROUND IN THE NATURAL HISTORY

The principles of the interaction of Man and environment are outlined and the diversity of the human settlements and their environments are discussed, both as space horizontal and time vertical phenomena. Cultural landscapes develop as a function of the output from the natural environment to Man to fill his needs, and the structure of this output is subject to qualitative and quantitative changes with time.
Today's settlement-environment relation depends on the accumulated effect of the historical development of an area, and the understanding of the contemporary dynamics in the landscape formation must include knowledge in its natural and cultural history.
The future management of the environment and the principles for the planning of this management are discussed with this background.

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INTEGRATED USE OF NATURAL RESOURCES AND GEOENVIRONMENT

Use of natural resources increases mass transfer in the lithosphere and biosphere and affects the hydrosphere. Negative effects on the geoenvironment are produced in mining mineral resources by different ways, e.g. underground and opencast mining, underground leaching, coal liquifaction, etc. To reduce these effects they should be studied, identified, monitored, controlled and minimized at all stages of exploration and mining. Evaluation of their ecological economical and social impacts should be the subject of particular consideration. The main task of geoscience is to develop the strategies and optimal methods of exploration and utilization of mineral resources with regard to geoenvironmental protection.

Control of the integrated use of natural resources should include development of national and international recommendations to regulate the production and consumption of mineral resources and to create a monitoring system. These recommendations should serve as the basis for developing special codes and rules obligatory for users of natural resources. The codes and rules should become the basis for governmental control of exploration and mining with due regard for protection of the geoenvironment.

СПЕЦИАЛЬНЫЙ СИМПОЗИУМ
"МЕТАЛЛОГЕНИЯ И МЕСТОРОЖДЕНИЯ УРАНА"
SPECIAL SYMPOSIUM
"METALLOGENESIS AND URANIUM DEPOSITS"

Chairmen: V.E.Boitsov, R.D.Nininger, S.D.Simov, V.Ziegler

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CARACTERES GEOLOGICOS,MINERALOGICOS Y METALOGENICOS DE LOS INDICIOS URANIFEROS DE MACUSANI,DEPTO. DE PUNO (PERU)

Las características mineralógicas y condiciones de yacimiento de los indicios uraníferos que el IPEN ha encontrado en Macusani,150 Kms. al NNW del lago Titicaca, hacen de estas mineralizaciones un caso único entre los yacimientos de U asociados con rocas piroclásticas. Así, los estudios llevados a cabo demuestran que: 1) los minerales de U se hallan principalmente en los niveles superiores de la pila volcánica; 2) las rocas encajantes corresponden a tobas riolíticas y riodacíticas plio-cuaternarias formadas por cuarzo, sanidina, oligoclasa y biotita, a veces moscovita y andalucita, con abundantes clastos de cuarcitas y lutitas; 3) la biotita y el cuarzo ahumado son muy abundantes en las rocas mineralizadas; 4) la paragénesis se compone casi exclusivamente de pechblenda masiva, más o menos transformada en gummitas y minerales hexavalentes, y escasos sulfuros de hierro; 5) los minerales primarios de uranio rellenan fracturas subhorizontales y subverticales que miden entre unos centímetros y varios metros de longitud, y 1 a 70 mms. de anchura. Las fracturas subverticales son paralelas a las diaclasas que dan lugar a la disyuncion columnar, y las subhorizontales a un sistema de cizallas dúctiles, conjugadas, que se desarrolló por la sucesiva compactación, distensión, y contracción de los materiales piroclásticos. De acuerdo de estos factores, se establece un modelo metalogénico que permite explicar el orígen de este nuevo tipo de yaci - mientos de uranio.

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SOBRE EL ORIGEN Y LOS MECANISMOS DE TRANSPORTE Y DEPOSICION DEL URANITO EN LOS YACIMIENTOS EN PIZARRAS DE PENINSULA IBERICA: EL CASO DE MINA FE, SALAMANCA (ESPANA)

Las numerosas mineralizaciones de uranio existentes en el complejo esquisto-grauváquico (CXG) de la Península Ibérica, caracterizados por la paragénesis carbonatos, adularia, pechblenda (coffinita), sulfuros de hierro, tienen, aparte de una considerable importancia económica, un gran interés metalogenico, ya que hasta ahora no se ha podido explicar su orígen de manera convincente. Así, desde 1959, estas mineralizaciones se han atribuído al transporte y deposición del U en zonas fracturadas del basamento hercínico como consecuencia de alguno de estos procesos:

1) magmáticos, con intervención de fluídos hidrotermales relacionados con el emplazamiento de los granitos hercínicos;

2) supergénicos, por lixiviación del U de los granitos y su concentración "per descensum" a causa de los procesos de meteorización;

3) de segregación, por movilización del U de las rocas plutónicas durante los procesos tectónicos tardihercínicos y/o alpinos;

4) de difusión, por liberación del U contenido en ciertos metasedimientos fértiles del CXG y su concentración, por difusión térmica o flujo hidrotermal, a través de corrientes de convección.

En base a los estudios realizados últimamente sobre la edad de la pechblenda, las inclusiones fluídas de los minerales de la ganga, textura de los minerales filonianos, y los procesos tectónicos que dieron lugar a las brechas y fallas donde se encuentra la mineralización, se discuten en este trabajo las hipótesis anteriores y se atribuye el orígen a un posible "bombeo sísmico" del U contenido en las abundantes lutitas negras existentes en el CXG.

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GEOLOGICAL ENVIRONMENT OF THE VEIN-TYPE DEPOSITS IN THE APHEBIAN BASEMENT OF THE CARSWELL STRUCTURE ON THE ATHABASCA PLATEAU (NORTHERN SASKATCHEWAN) COMPARISON WITH OTHER DEPOSITS OF THE SAME TYPE

The Athabasca Plateau, widely known for its unconformity related high grade and massive uranium deposits, contains vein-type deposits as well: although less striking, they are nevertheless of great scientific and economic interest.
The Cluff Lake area basement deposits of the Western Athabasca Plateau have been the subject of several scientific papers:Claude and N deposits are now supplemented by the Peter River discovery.
This paper deals mainly with the Cluff Lake deposits but refers to others basement deposits of the Eastern Athabasca Plateau when data

are available: Dawn Lake, Rabbit Lake, the deposits of the western shore of the Wollaston Lake and large parts of the Key Lake are basement deposits.

Cluff Lake basement deposits are characterized by their stratigraphic position in or close to a dominantly alumineous, graphitic and pyritic metasedimentary formation (Peter River Gneiss), most probably a former black shale. They are also close to an underlying unit consisting of quartzofeldspathic gneisses (Earl River Complex) which could be a former arkosic sandstone, metamorphosed and reactivated. This latter unit is mainly found in the heart of dome shaped anticlines (Mantlegneiss Domes). The reactivation process created favourable conditions for mobilization of uranium into small concentrations early (1 700 My) in the metamorphics.

The main structure control of the deposits appears to be Husonian mylonites an subsequent fracturation. However it is after deposition of the Athabasca sandstone that the mylonites and their associated fractures were rejuvenated and invaded by hydrothermal fluids. A widespread alteration pervaded through the surroundings rocks and uranium precipitated in the open fractures.

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CORRELATION OF THE URANIUM GEOLOGY BETWEEN THE AFRICAN AND SOUTH AMERICAN CONTINENTS

The subject is discussed under six headings, the cratonic areas, the mobile belts, the Precambrian plataform series, the Early Phanerozoic and Gondwana, the Post-Gondwana and the Alkaline complexes. For the Precambrian correlations the main framework was the use of geotectonic units in both continents, with aid of geochronological data. The pre-drift attachments of the S. Luis craton with the West African craton plus the S.Francisco with the Congo craton were confirmed. The Late Precambrian mobile belts were correlated by means of the existing geological data, including the major ligneaments and principal trends. This was accomplished for the northeast Brazil and the Benin-Nigeria-Cameroon terrains as well as for the Ribeira belt in eastern Brazil and the West Congo belt in Africa. For the southern part, a paleotectonic reconstruction for Late Precambrian times concluded the Don Feliciano magmatic arch as a transverse structure in relation to the Damara-Katanga belt in the African side. Most of the uranium resources are confined to mobile belts.

The stablished correlations for early Paleozoic and Gondwana time

(Parana and Main Karroo basins) were expanded to terrains in Argentina, Angola and Congo basins.
The alkaline and carbonatitic complexes were grouped in clusters. It was found strong petrographic litho-chemical and geochronologic similarities between some clusters and, in special, between those of central eastern/southeast Brazil and Angola, which constitutes a very large alkaline-carbonatitic uranium bearing province.
The uranium occurrences related to these geotectonic units are described with respect to their host rock (type and age) and mineralization (type, age, dimensions, mineralogy and paragenesis). Four maps of the fitted continents were prepared containing the geology, tectonic, correlation features, uranium deposits and areas of potential for further exploration.

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THE ZHELTORECHENSKOE URANIUM DEPOSIT

The deposit is situated in the Zheltorechenskaja syncline which is a part of Krivorozhsko-Kremenchugski margin trough. The fold is an isocline with almost a vertical hinge line. It consists of the rocks of Archean Konsko-Verkhovtsevskaja series (amphibolite) and lower Proterozoic Krivorozhskaja series. The latter is divided into 3 suites: lower (quartzite), middle (amphibole-magnetite and biotite schists, ferruginous quartzites) and upper (dolomites, quartzites, graphite-biotite and actinolite schists, metasomatic talc-carbonate rocks). The two lower suites form the limbs of the fold and the upper one forms the core of the fold. As the result of the early ferrum-magnesian metasomatism the bedded steep iron ore bodies were formed in the keel interlocking of the fold.

Lenses, shoots and bedded uranium ore bodies with dissementated or veined mineralization are localized within soda-carbonate metasomatites, which composition is effected by the initial rock. Out of biotite, graphite-biotite schists and vein granites, albitites with alkaline amphibole, egyrin, brannerite, uraninite, pitchblende were formed; magnetite-ribekite rocks, egyrinites, martite-carbonate metasomatites with uraninite were formed out of iron ores, amphibole-magnetite schists and ferruginous quartzites. Uranium-bearing malacone-apatite ores with thorium and rare earths are localized in talc-carbonate rocks, veined coffinite-pitchblende ores - in albitites. Ore bodies are controlled by the bends of the limbs and axial plane of the fold together with longitudinal dip and secant sloping fractures.

The vertical depth of the deposit is about 2 km. The metasomatites run along the west limb for 1500 m, along the east - 900 m, and into the keel interlocking for 700 m. The metasomatites are dozens of meters deep. At the depth lower than 1 km they decrease and uraniumoores are replaced by uranium-containing malacon-apatite

The deposit is hydrothermal metasomatic. The temperature of mineralisation is 200-300°C. The uranium mineralization in the ore zone took place 1770± 50 m.y. ago.

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ЖЕЛТОРЕЧЕНСКОЕ МЕСТОРОЖДЕНИЕ УРАНА

Месторождение локализовано в Желтореченской синклинали, являющейся частью Криворожско-Кременчугского краевого прогиба. Складка изоклинальная с почти вертикальным шарниром, сложена породами архейской конкско-верховцевской серии (амфиболиты) и нижнепротерозойской криворожской серии, состоящей из трех свит. Нижняя свита представлена кварцитами; средняя - амфибол-магнетитовыми, биотитовыми сланцами, железистыми кварцитами; верхняя - доломитами, кварцитами, актинолитовыми, графит-биотитовыми сланцами, метасоматическими тальк-карбонатными породами. Две нижние свиты слагают крылья складки, верхняя - ядро. В результате железомагнезиального метасоматоза в килевидном замыкании складки сформированы крутопадающие пластовые железорудные залежи.

Линзы, столбы, пластовые тела урановых руд с вкрапленным и реже прожилковым оруденением локализованы исключительно в пределах карбонатно-натриевых метасоматитов, состав которых зависит от состава исходных пород. По биотитовым, графит-биотитовым сланцам, жильным гранитам образовались альбититы с эгирином, щелочными амфиболами, браннеритом, уранинитом, настураном; по железным рудам, амфибол-магнетитовым сланцам, железистым кварцитам - магнетит-рибекитовые породы, эгириниты, мартит-карбонатные метасоматиты с уранинитом. В тальк-карбонатных породах развиты урансодержащие малакон-апатитовые руды с иттриевыми редкими землями и торием, а в альбититах - прожилковые коффинит-настурановые руды. Рудные тела контролируются изгибами крыльев и осевой плоскости складки в сочетании с продольными крутыми и секущими пологими разрывными нарушениями.

Вертикальный размах оруденения около 2 км. Вдоль западного крыла складки метасоматиты протягиваются на I500 м, вдоль восточного - на 900 м и в килевидном замыкании - на 700 м. Мощность метасоматитов -

десятки метров. На глубине более I км площади метасоматитов постепенно сокращаются и урановые руды сменяются урансодержащими малакон-апатитовыми.

Месторождение является гидротермально-метасоматическим. Температура минералообразования 200–300°С. Возраст уранового оруденения I770 ± 50 млн.лет.

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GENETIC PATTERN FOR THE DEPOSITS OF URANIUM-ALBITITE FORMATION

I.Albitites, characterized by heterogenous origin (sedimentary-diagenetic,metamorphic, magmatic and metasomatic) are of widespread occurrence in many Precambrian shields.

2.Uranium-bearing albitites from uranium-albitite formation occur in metasomatic albitites within zones of cataclasm and mylonitization.

3.The uranium-bearing metasomatic albitites differ from the ordinary ones by their increased permeability, presence of blastoclastic structures, impregnations of hematite, aegirine, alkaline amphibole, chlorite, epidote and carbonates.

4.Albite in the uranium-bearing metasomatites is represented by numbers from 2 to 4, other albitite rocks being characterized by higher albite numbers.

5.Uranium minerals consist of oxides, silicates, uranotitanates in the form of fine impregnation among albite grains around dark-coloured minerals.

6.Through the data on gazeous-liquid inclusions the temperature of albitite formation ranges from 350-I50°C, that of uranium mineralization being 200-I20°C. Solutions are carbonaceous with the admixture of chlorides and sulphides. Solution concentration varies from I0 to 40 per cent, the ore formation pressure amounting to 600-900 bars.

7.Deposits of the above mentioned formation occur among metamorphosed rocks in amphibolite facies or in the granitized Proterozoic sedimentary-volcanogenic rocks, commonly consisting of rock beds and series, enriched by uranium.

8.Uranium mineralization resulted from residual metamorphogenic solutions within the broken down and mylonitized zones of Proterozoic protoactivization. It progressed during the final stage of rock metamorphism or granitization.

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ГЕНЕТИЧЕСКАЯ МОДЕЛЬ МЕСТОРОЖДЕНИЙ УРАН-АЛЬБИТИТОВОЙ ФОРМАЦИИ

1. На многих докембрийских щитах мира получили значительное распространение альбититы, имеющие гетерогенное образование: осадочно-диагенетическое, метаморфическое, магматическое и метасоматическое.
2. Ураноносные альбиты, составившие уран-альбитовую формацию, приурочены к метасоматическим альбититам в зонах катаклаза и милонитизации.
3. Ураноносные метасоматические альбититы от обычных отличаются повышенной на порядок проницаемостью, широким развитием бласто-катакластических структур, вкрапленностью гематита, эгрина, щелочного амфибола, хлорита, эпидота и карбонатов.
4. Альбит в ураноносных метасоматитах представлен номерами от 2 до 4, тогда как для других альбититовых пород характерен альбит с более высокими номерами.
5. Урановые минералы представлены окислами, силикатами, уранотитанатами в виде мелкой вкрапленности между зерен альбита или вокруг темноцветных минералов.
6. Температура формирования, по данным газово-жидких включений, альбититов 350-150°C, урановых минералов 200-120°C. Состав растворов карбонатный, с примесью хлоридов и сульфатов. Концентрация раствора варьирует от 10 до 40%, давление при рудообразовании 600-900 бар.
7. Месторождения уран-альбитовой формации приурочены к метаморфизованным в амфиболитовой фации или гранитизированным протерозойским осадочно-вулканогенным породам, часто имеющим в своем составе пласты и толщи пород, обогащенные ураном.
8. Урановое оруденение образовалось в завершающую стадию метаморфизма или гранитизации пород из остаточных метаморфогенных растворов в катаклазированных и милонитизированных зонах протерозойской протоактивизации.

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THE MINERALOGY OF URANIUM ORES OF THE ROLL-FRONT

The total uranium balance in the uranium ores of the roll-front (UORF) is formed by uranium minerals, accessory minerals and sorbent minerals. The finly dispersed character of UORF requires an application of new methods in the diagnoses of the mineral composition and especially mineral quantitative ratio. The complex electron microscopy *methods (CEMM) including suspension combined with microdefraction* and microprobe analyses proved to be of great use.Thus we are able to have data on morphology,structure and composition of particles 0.1 - 0.001 mkm in size.The basic uranium minerals in UORF are: nasturan,coffinite and ningyoite.In the last years there are traced a certain tendency (arising from the traditional methodes of the ores study with special stress on the x-ray-analises) to single out the monocoffinitic ores in the UORF.The analyses of the same ores carried out by means of the CEMM showed that the main reasons of erroneous diagnoses were the following: a strong capasity of nasturan for oxidation leading to its x-ray amorphousity,a high degree of cristalization of coffinite, the coffinite's ability to preserve its structure despite a considerable leaching of uranium, a close attachment of coffinite to the carbonceouse organic material easily found even in the most poor ores. The application of CEMM helps to find ningyoite in the UORF, to prove that the approach of Japanese researchers towards the ningyoite as mineralogical rarity, based on the idea of the extreme conditions of ningyoites formation was wrong, to find mononingyoitic ores in several regions, to find ningyoite in the *hydrothermal deposits.Besides the ningyoite* $Ca_{2x}U_x$ /$P(O,OH)_4/_2 \cdot n\ H_2O$ the CEMM helped to specify a new uranous phosphate - vyacheslavite with the ideal formula $UPO_4OH \cdot n\ H_2O$ and to show the individuality cf lermontovite (its composition is very similer to vyacheslavite the difference being amount $\sim$10% Tl. The P-bearing coffinite, the mineral with the structure of coffinite, the morphology of ningyoite and an intermediate composition - is a good indicatore of the change of the mineralisation.

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МИНЕРАЛОГИЯ УРАНОВЫХ РУД РОЛЛОВОГО ФРОНТА

Общий баланс урана в урановых рудах роллового фронта (УРРФ) слагается из минералов урана, акцессорных минералов и минералов сорбентов. Тонкодисперсный и тонкорассеянный характер УРРФ требует для диагностики минерального состава и особенно количественного соотношения минералов привлечения новых методов. Хорошо зарекомендовал себя комплекс методов электронной микроскопии (КМЭМ), включающий просвечивающую электронную микроскопию, микродифракцию и микрорентгеноспектральный анализ. Тем самым появляется возможность получать данные о морфологии, структуре и составе частиц размером в десятые и сотые доли мкм. Основными урановыми минералами в УРРФ являются: окислы урана, в основном настуран; силикаты урана, в основном коффинит; фосфаты урана, в основном нингиоит. Наметившаяся в последние годы тенденция к выделению в УРРФ монокоффинитовых руд связана с их изучением традиционными методами с упором на рентгеновский анализ. Анализ тех же руд с использованием КМЭМ показал, что основными причинами, влияющими на ошибочную диагностику, являются: легкая окисляемость тонкодисперсного настурана, приводящая к его рентгеноаморфности; высокая степень кристалличности коффинита; способность коффинита сохранять структуру при значительном выщелачивании урана; приуроченность коффинита к углефицированному органическому материалу, наиболее легко попадающему в поле зрения даже в самых бедных рудах. Использование КМЭМ позволило впервые спустя почти 20 лет после открытия нингиоита в Японии найти его в составе УРРФ; показать ошибочность представлений японских исследователей о нингиоите как минералогической редкости, связанной с необоснованными экстремальными условиями его образования; выделить мононингиоитовые руды в ряде регионов; установить нингиоит в гидротермальных месторождениях. Помимо нингиоита $Ca_{2-x}U_x[P(O,OH)_4]_2 \cdot nH_2O$ с помощью КМЭМ установлен новый фосфат четырехвалентного урана - вячеславит с идеальной формулой $UPO_4OH \cdot nH_2O$ и подтверждена индивидуальность лермонтовита, близкого по составу к вячеславиту, но отличающемуся содержанием около 10% Tl. Фосфорсодержащий коффинит-минерал со структурой коффинита, морфологией нингиоита и промежуточным составом является хорошим индикатором изменения условий минералообразования.

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MANYINGEE URANIUM DEPOSIT, WESTERN AUSTRALIA

Cretaceous conglomerates and sandstones of the Carnarvon Basin (Western Australia) rest unconformably on Proterozoic basement. They were deposited in a near-shore fluvio-deltaic environment.

The Manyingee palaeochannel in which the uranium concentration is located follows a sinuous course between the palaeohighs of the basement, with a maximum depth of 160 m below the surface and a width of 2 - 3 km.

The main uranium mineralization, coffinite and uraninite with pyrite, was discovered in the Birdrong sandstones unit which conformably overlies the conglomeratic and arkosic unit deposited on the basement. It is gradational upwards into the Muderong shale unit which separates the cenozoic unconfined groundwaters from the underlying confined cretaceous aquifer.

The 50 m thick Birdrong unit is characterised by vertical and lateral facies variations, from conglomeratic sandstones to carbonaceous shales.

The mineralization is associated with alteration of the originally reduced sediments by oxidizing groundwaters migrating along the channel. The roll-front type deposit was protected from superficial oxidation by the Muderong shale.

Uranium accumulation occurs mainly at two different levels separated vertically by approximately 20 meters. The radiochemical equilibrium is above one.

A lower front is locally developped in the conglomeratic unit mostly where this unit contains some finer grained levels.

Approximately 4 000 tonnes of uranium have been identified as leachable.

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GEOLOGIC ENVIRONMENTS FOR BASAL-TYPE URANIUM DEPOSITS IN SEDIMENTARY HOST ROCKS

Basal type uranium deposits are characterized by economic concentrations of unusual primary minerals such as ningyoite, francevillite, salleeite and uranocircite. These deposits occur within unconsolidated Tertiary fluvial sediments that overlie or are adjacent to major fault zones within igneous and metamorphic massifs. Host sediments, which comprise conglomerates, sandstones and mudstones containing abundant organic material as well as iron sulphides and/or iron oxides, generally occupy paleovalleys within the basement complex. Cover rocks are, with few exceptions, intermediate to basic volcanics representing Tertiary continental volcanism; the volcanics often contain intercalated sediments. Basement complexes consist of intermediate felsic intrusive rocks which have generally undergone a multiphase history of intrusion and an important period of extensional tectonism. The high density of fracture zones within the complexes and the high degree of fracture interconnectivity results in significant groundwater-rock interaction thus producing cold, bicarbonated, uraniferous ore-forming groundwaters. The compositional makeup of many basal type uranium deposits can be explained by preferential availability to groundwater leaching of such elements as Ca, Mg, K, Ba, Pb, P and V within the basement complexes and by recognition of redox pathways taken during precipitation of ore minerals and alteration of certain authigenic and allogenic minerals within the host sediments.

The genesis of this type of deposit requires a thorough understanding of the interelationships between the source of ore-forming elements, mechanisms of migration, paleoclimatology, environment of deposition and preservation. The entire ore-forming process must be initiated, promoted and preserved by favourable tectonic events of which the most important appear to be extensional tectonism and regional uplift.

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SURFICIAL URANIUM DEPOSITS IN AUSTRALIA

Surficial deposits of uranium mineralization, as carnotite, are found in predominantly granitoid terrains in the Yilgarn Block and Gascoyne Province in Western Australia, and in parts of the Northern Territory. The largest deposit is Yeelirrie, Western Australia, which has published reserves of 52500 tonnes of contained U_3O_8 at an average grade of 0.15% U_3O_8. Mineralization occurs in palaeo-drainage channels in now semi-arid deeply weathered terrain in undissected shield areas. The drainages, which have negligible surface flow other than in periods of exceptional rain, are choked by colluvial, alluvial and chemical sediments. Valley calcretes are situated in the axes of the major valleys. They are near-surface, elongate, tabular, semi-continuous bodies of limestone and/or dolomite, generally 2 - 15m thick, 0.5 - 4.0km wide and 30 - 150km long. The calcretes terminate in playas, commonly broadening into wide platforms and chemical deltas. Carnotite is always as a late stage precipitate at or just below the water-table. There are three main sites for deposition - (i) calcrete and underlying clay-quartz sediments in the main channel; (ii) in and beneath calcrete in the platforms and deltas, and (iii) clay-rich saline sediments in the playas.

Uranium released from weathering granitoids is transported in groundwater as uranyl carbonate complexes. Vanadium, probably derived from mafic minerals in the granitoids or secondary minerals in valley sediments, is solubilized as a 4-valent cation. Precipitation of carnotite occurs where concentrations of uranium and potassium have been elevated by evaporation and where V is oxidized to the 5-valent state. This may be where vanadium has diffused upwards from deep within the saturated zone under a redox gradient, or where a sub-surface bar has caused upwelling of such groundwaters to relatively oxidizing conditions - accompanying effects being mounding and lateral spread of calcrete.

Most of the deposits appear to be in or close to radioactive equilibrium, implying an age of about 1Ma, although a younger age would be consistent with geomorphological and geological evidence. Losses of uranium relative to thorium and radium daughter products due to episodic flushing could, however, result in apparent equilibrium, even though deposition may be no older than 40,000 years and is still continuing in some places.

Past exploration has predominantly been by airborne and ground radiometric surveys, followed by scout drilling supported by gamma-logging and geochemical analysis. Continued exploration has utilized Landsat imagery for area selection and hydrogeochemical surveys of groundwaters in the search for concealed deposits.

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ENVIRONMENTS AND CONTROLS FOR CALCRETE URANIUM DEPOSITION

Economic to near-economic concentrations of carnotite are found in both primary and detrital calcretes, dolocretes and gypcretes in fluvial channel fills, deltas, evaporative lacustrine basins, and alluvial fans. In every case the calcretes are nonpedogenic; Ca, Mg, U, V and K have been transported laterally from large areas of weathering rock, usually granitic. Ratios of source area to calcrete may be 1000 to 1. Commonly these host rocks are part of an orderly downdrainage sequence of authigenic deposits. Calcretes are

classified, examples cited, and criteria given for recognizing nonpedogenic varieties.
Important nonpedogenic calcretes develope under extremely arid climates in many cases with summer-only rainfall. Hyperaridic soil-moisture regime with localized areas of ascending groundwater are particularly favorable. Preservation requires long-term tectonic and climatic stability.

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GEOLOGIC ENVIRONMENT OF THE URANIUM DEPOSITS IN THE CARBONIFEROUS AND JURASSIC SANDSTONES OF THE WESTERN MARGIN OF THE AIR MOUNTAINS IN THE REPUBLIC OF NIGER

The main uranium deposits of Niger are resulting from complex interaction between paleogeographic, tectonic and petrographic factors and the movement of underground waters.
The tectonic framework of cristalline basement controlled the main sedimentation axis and created the favorable areas of reducing environment where large quantities of vegetal organic matter accumulated. The main source of uranium is probably constituted by the intense volcanism of Air Mountains. The first uranium deposits were formed in a fluviatile or fluviodeltaic environment during the deposition or the early diagenesis of sediments.
These deposits originally stratabound have been more or less remobilized by the flow of underground waters sometimes forming roll front-type structures particularly obvious in the Akouta deposit. The late tectonic movements induced gentle undulations in the sedimentary cover, concentrating and protecting the uranium deposits in synclinal axis. The uranium deposits already discovered on the western margin of the Air Mountains represent 160 000 tonnes of uranium (190 000 U_3O_8) with a grade ranging from 0.12 to 0.45 % U (0.14 to 0.53 % U_3O_8) depending on the mineralized host formations, Jurassic or Carboniferous.

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LE GISEMENT D'URANIUM D'AKOUTA

Le gisement d'uranium d'Akouta, découvert en 1967 par le CEA, a été mis en exploitation en 1977 par la compagnie minière d'Akouta-COMINAK (production nominale 2300 tonnes d'uranium en 1981).
Situé à 250 mètres de profondeur dans les grès fluvio-deltaïques

d'âge Carbonifère (grès du Guezouman - vise en superieur), le gisement a été reconnu par sondages de surface à maille carrée systematique 50 mètres et est exploité en mine souterraine par tracage au minérai à maille carée 24 mètres entre axes de galéries et reprise totale des piliers interieurs avec remblai cimente.
Au cours de l'exploitation et à la faveur d'un maillage regulier, des levers géologiques systématiques ont permis une analyse sédimentologique detaillée des grès hôtes, et la mise en évidence des relations entre la minéralisation uranifère, les figures sédimentaires et le phénomènes de couleurs liés à l'état d'oxydoréduction des sédiments.
Ces derniers phénomènes reflètent les resultats de l'action de fluides, circulant à la faveur d'une structure regionale, la flexure d'in azzawa, sur l'important potentiel réducteur constitué par les débris de végétaux superieurs accumulés à la base des stratifications des bancs de grès et épigénisés en sulfures de fer.
Il a été particulièrement mis en évidence:
-Une association géochimique U-Zr-Mo-Zn-V-Pb avec des variations spatiales liées à l'état d'oxydation des sédiments. Des structures mineralisées accessoires à Se ou Mn radifère sont attribuées à des remobilisations plus récentes,
-Une association minéralogique à pechblende zirconifère et vanadifère, coffinite, montroseite, argiles vanadifères, blende, jordisite et galène. Plusieurs phases de pyritisation ont été reconnues dont l'une est anterieure à la compaction et se developpe aux dépens des matières organiques.

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STRUCTURAL CONTROL OF URANIUM MINERALIZATION IN THE OBERPFALZ AREA, NORTH-EASTERN BAVARIA, FEDERAL REPUBLIC GERMANY

The Oberpfalz area under consideration here covers about 1800 km^2 in North-Eastern Bavaria near the Czechoslovakian border, about 170 km North of Munic.
The geological frame work of the area consists of Precambrian metasidements of the Moldanubian complex, mainly biotite-plagioclase-gneiss with subordinate cordierite and/or sillimanite.
During Variscan orogeny (330-280 Ma) large granite bodies intruded into the Moldanubian complex, e.g. Leuchtenberg-, Neunburg- and Oberviechtach granites. At the end of this period the Wölsendorf fluorite deposit was formed, and with this the first uranium mine-

ralization was found in the Oberpfalz area.
For the veintype fluorite deposit of Wölsendorf a tectonic control was clearly proven. Here the "Franconian" lineament (North-South) is intersected by the NW-SE running lineament of the "Pfahl", a massive quartz vein, which can be followed after in the field for more than 100km. Systematic exploration work - including all conventional methods like photo geology, airborne survey, geochemistry, raster scintillometry, ground geophysics, and emanometry - releaved for the Oberpfalz area a good potential of structurally controlled uranium mineralizations. Three types of structures were found:

a) 1st order main fault zone (North-South)
b) 2nd order faults, branching out NW of a)
c) 3rd order faults, branching out N of b)

Each of the zones shows different ore grade and contributes different reserves.

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ГЛАВНЫЕ ТИПЫ УРАНОВЫХ МЕСТОРОЖДЕНИЙ ЧЕШСКОГО МАССИВА В ЧССР

На территории ЧССР в пределах Чешского массива известны разнообразные типы рудных месторождений. Формирование этих месторождений связано с геосинклинальной, ранне- и позднеорогенной и платформенной фазами развития массива.

Гидротермальные месторождения урана известны в пределах ядра Чешского массива, в его складчатом обрамлении и связаны с поздневарисской эпохой минералообразования. С альпийским временем связывается формирование сложных по минеральному составу полигенных месторождений в осадочных породах платформенного чехла.

Известные в пределах массива месторождения урана характеризуются значительным разнообразием как генетических, так и морфологических типов. Выявленные особенности геологического строения месторождений, морфологии рудных тел и условий формирования руд позволили выделить 6 морфогенетических типов урановых месторождений.

Отмечается региональная рудоконтролирующая роль узлов пересечения глубинных разломов, вблизи которых сосредоточено большинство известных урановых месторождений разных морфогенетических типов. Позиция месторождений определяется структурами верхней части земной коры. Для гидротермальных месторождений характерен контроль орудfestнения разрывными нарушениями различных направлений; морфологические особенности рудных тел определяются влиянием структурных, литологических и физико-химических факторов, глубиной формирования, составом гидротермальных растворов и многостадийностью гидротермального процесса. Основные стратиформные месторождения урана являются полигенными, их формирование зависит от состава и свойств вмещающих пород и гидрогеологических условий, существенно влиявших на характер отложения и перераспределения рудных компонентов.

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GEOLOGICAL ENVIRONMENT OF THE URANIUM DEPOSITS IN THE PERMIAN OF LODEVE BASIN

The Permian deposits of the Basin of Lodeve are characterized by a biorhexistasic cycle producing fine alternating sequences of organic-rich sedimentary deposits in a basin ranging from lacustrine to a confined briny lagoon. The dismantling of the Hercynian massifs, origin of the sediments, along with the constant arrival of volcanic ash, assure a preconcentration in metallic ions, particularly uraniferous.

A continual subsidence permits a regular influx of sediments and a burial compatible with a genesis of hydrocarbons.

Post-sedimentary tectonics in extension as well as the fine bedding of certain layers, create drains that facilitate the circulation of fluids: the oils migrate, concentrating in petrol-type traps constituted by fault zones and the finely bedded layers. The intersticial waters, evacuated by compaction, are carriers of metallic ions in solution. They use the same drains as the oil, and the uranium is precipitated in the hydrocarbon traps which are strong reducing agents.

During diagenesis, an important physical and mineralogical evolution affects the surroundings and certainly played a role of prime importance in the "recycling" and precipitation of the uranium.

In the meantime, the circulation of meteoric water rising within the rock formations along the principal faults, develop, and are able to create - by influence of oxidizing fluids and of CO_2 - a complementary accretion process.

Classified into three principal types, the mineralizations are realized within the framework of a dynamic basin system which is induced by the conjunction of several factors - sedimentary, tectonic and physico-chemical - during diagenesis.

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A REVIEW CONCERNING THE ORIGIN OF THE ATHABASCA, SASKATCHEWAN, CANADA, URANIUM DEPOSITS

The uranium deposits which occur in the Middle Proterozoic Athabasca basin in northern Saskatchewan, Canada, collectively form one of the major uranium resources of the world. A minor occurrehce of uranium secondary minerals was reported in 1955 but the area attracted little exploration interest until 1967; in 1968 the first economic mineralization was found at Rabbit Lake. The genesis of the deposits has been discussed by many authors since 1971. Their proposals can be considered under four main headings: supergene, either contemporaneous with, or post-dating deposition of the Athabasca Group; magmatic-hydrothermal; polygenetic with in situ reworking; and diagenetic-hydrothermal. Ideas concerning the origin of the mineralization have evolved as new discoveries have been described, and detailed scientific studies completed. Some aspects of the mineralization have undergone reinterpretation as more evidence has been obtained, and additional characteristics have been recognized. Features now considered significant include its spatial form and distribution, especially its proximity to the basal unconformity; proximity to fractures; age; commonly multielement association; temperature of formation; alteration haloes; proximity to graphite; evidence of oxidising and reducing conditions.

As more data have become available the tenability of the earlier hypotheses, which emphasized supergene processes, has been diminished.

A comprehensive discussion of the origin of the deposits needs to take into account phenomena on several scales; the origin of the Athabasca basin within the craton, the localization of deposits within the basin, and the characteristics of individual ore pods within deposits. The existing literature contains evidence relating to each of these considerations, but gaps in knowledge remain, which must be filled before the origin of the deposits can be precisely established.

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FAULT CONTROLLED URANIUM BLACK ORE MINERALIZATIONS FROM THE WESTERN EDGE OF THE BOHEMIAN MASSIF (FR GERMANY/ NE BAVARIA)

Three different types of U vein-type occurrences may be distinguished within the NE Bavarian Crystalline Basement: fault zones with stockwork-like ore shoots, mineralized structure zones, veins s. str. They may be subdivided into two principal types of occurrences with respect to their source rock-host relationship. The element content of type I ore deposit has derived from the enclosing Paleozoic black shales and coal seams. The ore-bearing structures are restricted to that source rock lithology, whereas type II is genetically associated with Upper Proterozoic rocks of the "varied group", from which these elements were expelled by metamorphism and granitization. Uranium deposition is temporarily related with the Late Variscan thermal activity which was responsible for the formation of the "monotonous U paragenesis" (U, Si, Ti, Fe) and the "polymetallic U paragenesis" (U, As, Au, Bi, Co, Ni, Sb, Se, Cu, Fe, Pb, Zn). During Mesozoic and Cenozoic time U redistribution took place. The ore-bearing fault zones are generally enclosed by alteration envelopes (dolomitic, calcitic, zeolitic episyenites, argillation, silification). Carbonaceous matter plays a major part among gangue of mineralized structure zones. U ore minerals in vein-type occurrences s. str. are normally accompanied by baryte and fluorite.

DOLENEC TADEJ; LUKACS EGON; PEZDIC JOZE; Ljubljana, Yugoslavia

GENETIC CHARACTERISTICS OF THE URANIUM DEPOSIT ŽIROVSKI VRH

Pseudomorphs of pitchblende and coffinite after plant remains, a wide range of $\delta^{34}S$ values, and enrichment of sulfide sulfur with light isotope indicate formation during diagenesis of the uranium deposit Žirovski vrh in the reducing environment of Gröden sandstones.

Due to subsidence from Upper Permian to Cretaceous the deposit was buried 6000 m deep. Dissolution and precipitation of minerals occurred during epigenesis at higher temperatures. In the ore-bearing horizon rock minerals and sulfides were remobilized, but not pitchblende and coffinite.

Movements of the Miocene Rhodanian orogenic phase, to which the beginning of retrograde epigenesis is attached, uplifted the orebearing beds close to the surface and overthrusted them on autochthonous Triassic. Then formed the folded structure of the deposit cleavage and most of quartz-carbonate veins and nests. In the orebearing horizon during the retrograde epigenesis sulfides and barren minerals were intensively remobilized, and less pitchblende and coffinite.

By oxydation processes in the upper parts of the deposit started precipitation of cementation copper minerals and secondary uranium minerals.

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URANIUM MINERALIZATION IN RELATION TO THE ALTERATION AND SULFIDE PARAGENESES IN POLYMETALLIC ZONES OF IRAN

In certain zones of Iran the sulfide mineralizations are widely distributed and uranium as one of the lithophile elements with strong ionic affinity participated in different parageneses associated with metallic sulfide of Cu,Mo,Fe etc in vicinity of the polymetallic zones of Iran. This relation is limitted mostly to the acidic/potassic magmatisme as well as intermediate acidic intrusions particulary in two mica granite and also in subvolcanic andesites or trachyandesites. The evidence of such paragenesis have already been relevantly distinguished and fully studied on the basis of mineral determination especially in the area of East AZARBAIJAN (BAITCHEBAGH), Central Iran (Kalikafi, Talmessi) and turquoise mine of Iran in Eastern Khorasan. The evolution of post acidic magmatisme of tertiary age particulary in the middle of late Alpine orogeny the uranium mineralization manifested as pitchblende and coffinite together with sparse pyrite around the halos of the copper sulfides are to be seen with different hydrothermal alterations among which sericitization and chloritzation together with silicification are predominant. These alterations are associated with quartz-hematite as well as quartz-K,feldspar and quartz-sericite parageneses.

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SALT PLUGS AS A NEW URANIFEROUS FEATURES IN SOUTH EASTERN PART OF ZAGROS BELT. IRAN

The salt plugs as one of the interesting geological features in Iran have a vast distribution in certain zones of the Zagros range as well as North of Kerman and a large part of Central Iran and Azarbaijan too. In relation to the radioactive discoveries and the uranium prospections, the primary geological studies based on mineralogical and metallogenic evidences have lead the geologists to justify the presence of the different acidic magmatisme which gave rise the primary concentration of the uranium in high temperature first and then hydrothermally activity or any thermal fluids during the reactivation of the acidic extrusives preferentially rhyolitic and subordinate tuffaceous materials provided a large conspicuous uranium meneralization. It is evident that the basic extrusives and diabasic tuffs having no essential influence in uranium mineralization. In fact the primary evolution of the salt domes in the geosyncline complexes of the South Iran could be associated with the role of the high temperature magmatisme due to the immense tectonic trends of the OMAN - NAYBAND and ZAGROS thrust, the radioactivity mineralization and their similarities to the uraniferous area of the Madagascar region could emphasise the above mentioned tectonic, so that the intensity of radioactive mineralization in connection to the acidic/potassic volcanites are mostly limited to the main tectonic events and subduction zones particularly in the area of two major faults intersection. on the contrary a sensible decreasing of the uranium mineralization and acidic volcanites could be observed to the Eastern part of Zagros and generally far from these two major tectonic events.

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URANIUM IN THE PINE CREEK GEOSYNCLINE IN NORTHERN TERRITORY AUSTRALIA

The Pine Creek Geosyncline comprises about 14 km Early Proterozoic sediments, resting on granitic late Archaean complexes exposed as small domes. The sediments were regionally deformed and metamorphosed at 1800 Ma. Tightly folded greenschist facies strata in the centre grade into isoclinally deformed amphibolite facies metamorphics in the west and northeast, granulites are present in the extreme northeast. Pre and post-orogenic continental tholeiites, and post-orogenic granite diapirs intrude the Early Proterozoic metasediments. Cover rocks of Middle Proterozoic and younger ages rest on all these rocks unconformably and conceal the original basin margins. The Early Proterozoic metasediments are mainly pelites which are commonly carbonaceous, lesser psammites and carbonates. Volcanic rocks make up about 10 percent of the total sequence. The environment of deposition ranges from shallow-marine to supratidal and fluviatile for most of the sequence, and to flysch in the topmost part.
The Early Proterozoic strata are overlain with marked angularity by mostly subhorizontal fluviatile sandstone and basalt of Middle to Late Proterozoic age.
The uranium deposits post-date the ~1800 Ma regional metamorphic event; isotopic dating of uraninite and galena in the ore bodies indicates ages of mineralisation at ~1600 Ma, ~900 Ma and ~500 Ma. The ore bodies have a number of features in common; they are stratabound, located within breccia zones, are of a shallow depth, contained in rocks that underwent low-temperature retrogressive metamorphism and metasomatism, and occur immediately below the Early/Middle Proterozoic unconformity. It is suggested that these ore bodies were produced by downward percolating meteoric waters transporting uranyl complexes which due to reducing conditions in the breccia zones precipitated uranium oxide.

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ALTERATIONS AND STRUCTURAL SETTING OF AN URANIUM PROTEROZOIC UNCONFORMITY DEPOSIT: CLUFF LAKE D OREBODY (SASKATCHEWAN - CANADA)

The Cluff Lake D uranium deposit, occurs in the Carswell circular structure.This structure is considered to be the result of a meteorite impact during Cambro-Ordovician.
Main effects of the tangential tectonic, induced by the impact, led to reversed slices.In one of these slices,the uranium orebody,lies parallel to the inverted unconformity between Aphebian metamorphic rocks and Helikian Athabasca sandstones.
The main structural control displayed in the deposit,is a mylonitic zone transverse to the unconformity. At this intersection,occurs the bulk of the high-grade mineralization,where pitchblende form the enveloppes of "ball" rounded altered sandstones.
All the tectonic structures are associated with important hydrothermal fluid circulations,including an intense rock argilization,indicated by clay minerals zonation fitting with the deformation zonation. The mineralization zone is rich in magnesian chlorites which decrease for hyperaluminous chlorite and illite, in both basement and sandstone alteration halos. However,near the mineralization and tectonized zones of the sedimentary cover appear 3 T muscovite,result of high fluid pressures release. Isotopic data show that uranium mineralization,deformation and alteration correspond to one and same pervasive hydrothermal event at 1260 m.y.
This age is not perturbed by the meteoritic impact (480 m.y.) which uplifted at the actual erosion level the Cluff orebodies,covered by,at least 2000 meters of Athabasca sediments.

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URANIUM EXPLORATION IN SRI LANKA

Except for the few occurences of Gondwana (Jurassic), Miocene and later sediments the Island of Sri Lanka consists of Precambrian Crystalline rocks of Archean age. These Precambrian rocks were metamorphosed under granulite and amphibolite facies conditions about 2000 m.y. ago. Small granitic bodies and a number of dolerite dykes have been intruded into the Precambrian rocks.
Under Phase 1 of the Uranium Exploration Programma, a pleriminary regional geochemical survey of the entire Island was carried out in 1979 by the Geological Survey Department with the assistance of IAEA Vienna. A total of 1748 stream sediment and heavy mineral samples collected were analysed for Uranium and other base metals. At each sample point the scintillometer reading was recorded.

Nine areas were selected for further exploration for Uranium. It was observed that there was little or no correlation between the Uranium contents of stream sediment samples and heavy mineral samples. Also there was no correlation between the radiometric data and the geo chemical data.
The consistent low values of Uranium for the stream sediment samples suggests that the solution or hydromorphic dispersion is not a prominent mechanism for most of the country and that the Uranium dispersion is rather mechanical in nature.

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GENESIS OF SANDSTONE-TYPE URANIUM DEPOSIT OF SIERRA PINTADA DISTRICT, MENDOZA, ARGENTINA

The different process involving the genesis of the uranium deposits located in Permian sandstones (Cochicó Group) have been studied.

Precursor processes, host rock formation, preparation of host rock, uranium source development, transport of uranium, primary uranium deposition and post-deposition modification have been discussed.

The important role of the stability of grounwater level during the mineralizing process has been raised taking on account the distribution of organic matter, sulfides and chlorites.

The tuff beds deposited on the mineralized (aeolian) sandstones appear to be the source rock, but the contents of U and Th in these stratigraphic levels could suggest that both beds suffered uranium lixiviation.

A generalized paragenesis of alteration and mineralization processes is described: argilization, chloritization, pyritization, mineralization and associated carbonation. Geochronological determinations of associated formations have permitted support the idea that ore enrichment took place shortly after sandstones deposition, that is to say, in Permian times.

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SUMMARY OF NEW DEVELOPMENTS IN OUR UNDERSTANDING OF SANDSTONE-TYPE URANIUM DEPOSITS

Typical sandstone-type uranium deposits occur in fluvial-lacustrine molasse sequences formed either on a large foreland probably bordered by a magmatic arc subduction zone on one side and an intracratonic sea on the other or in intermontane basins within this broad tectonic environment. The two main ore-body forms are tabular and roll-front. The genesis of the latter is relatively well understood; new research by U.S. Geological Survey scientists has increased our understanding of the genesis of tabular ore bodies as well, particularly on the Colorado Plateau. New knowledge on sedimentary environments, paleohydrology, stable-isotope distributions, and host-rock and ore mineralogy of selected tabular ores has strengthened the two-solution (brine and infiltrating uranium-bearing) interface genetic concept. The role of vanadium as a reductant and the significance of clay mineralogy are important for vanadiferous uranium ores. A new paleo-flow model requires surface- or ground-water leaching of a large uranium source free of uranium precipitants and convergence of this water into a relatively smaller-volume setting having uranium precipitants and downstream diversions or impediments to flow. New information shows that Niger deposits are quite similar to Colorado Plateau deposits. Probable mechanisms of formation of ores in recently discovered "young" uranium deposits in surficial organic sediments offer new insights into the genesis of sandstone ores. Synthesis of knowledge on deposits in lacustrine rocks in the Western United States and Europe demonstrates a continuum from syngenetic to epigenetic processes for deposits in sandstone formations.

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GLACIAL OUTWASH URANIUM PLACERS? : EVIDENCE FROM THE LOWER HURONIAN SUPERGROUP, ONTARIO, CANADA

Uraniferous conglomerates present in the Elliot Lake mining area are contained within the middle and lower portions of the Matinenda Formation—the basal unit of the early Proterozoic Huronian Supergroup. The Supergroup forms a southward thickening wedge composed of three sedimentary megacycles. Each megacycle consists of a basal fluvial unit overlain by glacial-marine/lacustrine strata and capped by a turbidite to lenticular bedded assemblage. The juxtaposition of these depositional environments suggests: 1) glaciofluvial outwash accumulated in front of an ice mass to the north; 2) the outwash was overridden and isostatic depression initiated glacial-marine/lacustrine deposition; 3) after meltback of the ice openwater clastics accumulated. The Matinenda Formation represents the basal braided fluvial unit of the lowermost glacial megacycle. Glacial units of the Ramsay Lake Formation and marine/lacustrine strata of the McKim and Pecors Formations complete the assemblage.

Evidence of a glacial outwash origin for the Matinenda Formation consists of :1) glacial override features in the upper Matinenda; 2) glacial erosion and re-sedimentation of unconsolidated Matinenda material; 3) intimate association between small Matinenda deltas and subaqueous glacial outwash; 4) interbedding of glacial mixtite and fluvial quartzite; 5) Zr/Hf ratios indicating Matinenda sediments from differing source areas were well mixed prior to deposition. However, all criteria except numbers 2 and 5 apply only to the uppermost Matinenda and related, overlying deltaic units. If the uraniferous conglomerates are the product of glacial outwash deposition in a cold climate this would have serious implications in using these rock units as indicators of a reduced oxygen partial pressure in the early Proterozoic atmosphere.

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GENERAL TRENDS OF URANIUM-BEARING SANDSTONE BASINS

Continental basins with uranium bearing sandstones present some typical sedimentological and structural features. The basins are located within grabens associated with disjunctive tectonic activity.

In many cases, the evidence of acid volcanism on the borders of the graben structures is a significant feature of the geological environment. The paleoclimatic conditions induced a deep weathering of the older crystalline basement as well as of the new vented volcanics, having an important influence on the nature of the detrital and dissolved elements which reach the sedimentation area. The decay of organic matter and the evolution of brines in this peculiar climatic and sedimentary environment are of great significance for the precipitation of some rare elements such as Pb, Zn, Cu, V, F, Ba and particularly U. The late diagenetic and epigenetic evolution of the sediments is related to the burial of the material deposited in the graben and in some cases (China, Italy) to the influence of hydrothermal circulations as possible remnants of former magmatic activity. Such phenomenom are related to the deep seated structures which play a major role on the sedimentological geochemical and structural evolution of this type of basin.

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GEOLOGICAL ENVIRONMENT OF THE OKLO NATURAL FISSION REACTORS, DISTRICT OF MOUNANA, GABON

The Oklo natural fission réactors occurred in the proterozoïc non-metamorphic Francevillian series which overlies the Archean (2.7 Ga) basement unconformably. The sediments were deposited before 1.95 Ga, which is the age of the nuclear reaction, but diagenetic events continued to 1.7 Ga.

The series has beer subdivided into five formations (FA-E). The FA, about 1 000 m thick, consists of fluviatile and deltaïc sandstones and conglomerates, including both hematized, red-colored and reduced facies clearly discordant on the stratification, the hematisation having occurred during early diagenesis. The upper formations are mainly made up of black shales with interbedded sandstones and breccias (FB), dolomites and bedded cherts (FC), ingnimbritic tuffs (FD) and epiclastic graywackes (FE).

The Oklo ore deposits occurs at the top of the FA formation and consists of a sandstone layer, 4-10 m thick, containing uraninite associated with asphaltite. It is located in a reduced facies but red hematized patches are often found in the very high-grade óre. Close to the deposit a basement rise has induced a large fold structure in the sediments with a 40° axial plunge. The location of natural reactors is related to that structure.

In the vicinity of the reactors, extending over a few meters, an intense alteration was observed. This is expressed by quartz dissolution and clay development, namely Al-Mg-Chlorite and 2M -Illite, so that the reactors are made up of uraninite in an argilitic matrix. This alteration is attributed to the combined effect of neutron bombardment and hydrothermal action of convective circulation, triggered off by the thermal result of nuclear reactions.

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VEIN - TYPE URANIUM DEPOSITS IN YUGOSLAVIA

The uranium deposits and occurrences in Yugoslavia are related to granitic and volcanic rocks, as well as to Permo-Triassic and Tertiary sediments, and occur within the well defined metallogenic provinces and regions. The vein-type deposits related to fracture zones are concentrated in the Eastern Serbian and Serbo-Macedonian metallogenic regions. Some vein-type occurrences are present also in the Dinaric metallogenic region; however, these were not studied in adequate details, so only limited data are available.

In the granite of Janja, in the metallogenic region of Eastern Serbia, the uranium deposits are related to fracture zones, and occur in form of flattened lenses, pillars, and complex veins. These zones are up to 10 m wide, few kilometers long, trend generally northwestwards, and occur near the contact with gabbroid rocks.

In the Serbo-Macedonian metallogenic region the uranium deposits are related to fracture zones in granite /Bukulja/, and the volcanites of Kratovo-Zletovo area.

The mineralization in the fracture zone in granite of Bukulja can be traced for over a kilometer, and occurs in form of smaller and larger elongated lenses. The granite is hydrothermally altered and cataclized, and the uranium occurs within the cataclized granite as the disseminated concentrations, spatially related to pyrite concentrations.

The uranium mineralization in the Kratovo-Zletovo volcanic area is located in a fault zone trending generally ENE, abouth 200 m wide, near the contact of ingimrite and andesite. Uranium occurs as pitchblende, and the mineralization is localized in small fissures.

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MINERALOGY AND PETROLOGY OF GOLD OCCURRENCES WITHIN THE JABILUKA DEPOSIT, NORTHERN TERRITORY, AUSTRALIA

The Jabiluka "unconformity-type" uranium deposit, Northern Territory, Australia, contains anomalously high concentrations (>0.1 ppm) of gold. Although both the number 1 and 2 orebodies have anomalous values, economic gold concentrations (selected samples contain as much as 695 ppm) are restricted to the number 2 orebody. Gold distribution is independent of lithology and stratigraphic position.

Breccias (some cemented by uraninite), late-stage chlorite alteration, chlorite-rich veins, and uraninite-rich veins are present in varying amounts in the gold-bearing zones. Although no significant correlation was found between amounts of gold and uranium, concentrations of gold have been observed only within uraninite veins. A few small (<3 μm) grains of gold have been identified in chlorite that has replaced uraninite.

Uraninite veins and uraninite-cemented zones contain a complex mineral assemblage including uraninite-hosted coffinite, galena, galena with traces of Se, gold with traces of Ag, and phases composed of Bi-Te, Pd-Ni-Te, Fe-Ni-Co-S, and Fe-Ni-S. The veins and cemented zones have been partially replaced by chlorite-rich veins that also contain quartz, pyrite, chalcopyrite, covellite, chalcocite (?), and phases composed of Pb-Te, Ni-Te, and Re-Fe-S. The minerals of the uraninite vein assemblage are also present as corroded and embayed grains in chlorite.

Mineral paragenesis is complex. Within uraninite veins and cements, Bi-Te with intergrown gold is intergrown with uraninite. The sulfides and other tellurides form single and multiphase grains within the uraninite. During replacement of the veins and cements by chlorite, iron and copper sulfides were precipitated and most of the uranium and tellurium, and, possibly, gold were removed.

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ORGANIC MATERIAL FROM THE CLUFF LAKE (CANADA) URANIUM DISTRICT ITS NATURE AND PARAGENETIC IMPLICATIONS OF THE INCLUDED MINERAL ASSEMBLAGES

Organic material from the Claude and D orebodies (of the Precambrian Cluff Lake unconformity-type uranium deposit, Canada) was emplaced after a major uranium mineralizing event and prior to the formation of clay-rich veins. Emplacement may have taken place in fracture-controlled voids, but preexisting uraninite was also replaced.

The organic material has highly variable reflectance and anisotropism. Light-gray anisotropic organic material occurs as halos immediately adjacent to uraniferous phases. At the D orebody, an isotropic, inclusion-free, sulfur-rich form of organic material transects the earlier organic material. The sulfur content of matrix organic material in the two deposits is different. Bulk samples of organic material from the Claude orebody have an unusually light $\delta^{13}C$ of -44 permil; entrapped methane has a $\delta^{13}C$ of -48 permil. Pyrolysis of the organic material yields predominantly one- and two-ring substituted aromatics.

Inhomogeneously distributed mineral inclusions in the organic material are generally very fine grained (<50 μm), anhedral, and embayed. The inclusion assemblage is uraninite, coffinite, galena, galena (with traces of selenium and arsenic), pyrite, gersdorffite, and altaite (PbTe). For the Claude orebody, this assemblage indicates a more complex history than previously recognized or a remote source for the inclusions. Illite(?)-rich veins containing minor amounts of quartz, potassium feldspar, and pyrite; trace amounts of the inclusion assemblage; and corroded fragments of organic material cross-cut the Claude organic material.

The Cluff Lake organic material has many similarities to organic material from the Witwatersrand (South Africa) gold-uranium district, but, unlike most of the Witwatersrand material, was emplaced long after the main mineralizing event.

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TIME-BOUND CHARACTERISTICS AND TECTONIC CONTROL OF SOUTHERN AFRICA'S URANIUM DEPOSITS

Uranium deposits in southern Africa are chronostratigraphically equivalent to those of the rest of the world and display similar cyclic characteristics. The distribution of the uranium provinces is related to the occurrence of major tectonic and epeirogenic events. The quartz-pebble conglomerates of the Witwatersrand Basin were deposited between 2 800 - 2 300 Ma and constitute one of the most important uranium provinces of the world. This was followed by the intrusion of the Bushveld Complex (BC) and the uraniferous Phalaborwa Carbonatite Complex at about 1950 Ma. The BC has in places fumerolic vents with high concentrations of uranium which also intruded the base of the overlying Waterberg thus created a favourable target area currently being investigated.

During basement reactivation between 1 300 - 900 Ma the uraniferous Pilanesberg Alkaline Complex was emplaced in the stable Kaapvaal craton just prior to the formation the Namaqualand/Natal Metamorphic Complex. The latter contains subeconomic occurrences of uraniferous alaskite.

At about 500 Ma during the Pan-African event, post-tectonic uraniferous granites and alaskites were generated in the Damara orogenic belt forming the Rössing uranium province. In the Permo-Triassic Karoo Basins, sandstone uranium occurrences have been discovered over a broad arc of some 1 200 km in the Cape Province and also in the coal deposits of the central Transvaal. Surficial uranium deposits were formed between 10 - 0,1 Ma occurring mainly in the Namib Desert of South West Africa and the north western Cape Province.

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GEOLOGICAL ENVIRONMENT OF URANIUM DEPOSITS IN THE BEAUFORT GROUP, SOUTH AFRICA

The Beaufort Group of the Karoo Sequence is subdivided into the lower Adelaide and upper Tarkastad Subgroups (Late Permian), of which only the former is present in the south-western Karoo. Despite the fact that fluvial sandstones occur throughout the Beaufort Group in the entire Karoo basin, those in the south-western area host by far the majority as well as the largest uranium deposits. The sandstone is interbedded with mudstone and siltstone and the sedimentary sequence in the south-western Karoo consists of several megacycles of which the top three are economically the most important. Several lithofacies can be recognized and the sandstone has all the characteristics of a fluvial depositional environment. Reptile fossils serve as a useful aid in deciphering the lithostratigraphy and thus potential uraniferous areas.

Coffinite and uraninite are the primary uraniferous minerals and occur generally in calcareous pods and lenses which vary from less than one to several hundred of cubic metres. The uraniferous ore-forming fluids were presumably derived from either volcanic clasts and/or granitic detritus in mudstone and migrated towards, and along permeable channels in sandstone. The final site of ore-deposition was determined by sedimentological controls and the availability of a suitable reductant.

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THE DAVIDITE VEINS OF RADIUM HILL SOUTH AUSTRALIA

A steeply dipping vein-shear system occur pies the axial zone of a regional anticline in metasediments of lower proterozoic age (Willyama supergroup) adjacent to a faulted contact with upper proterozoic sedimentary rocks (Adelaide system).

Sericite-biotite shears which grade along strike into rutile-ilmenite-hematite-davidite lodes up to 1.5 m wide extend for over 7 km, approx. normal to the Willyama-Adelaidean contact.

Wall rock in the underground workings is predominantly a banded quartz-biotite gneiss but some bands of calc-silicate and fine to medium grained quartz-feldspar rock are present. Intrusive pegmatite masses occur.

Davidite, an iron uranium titanate with rare earths and vanadium, was introduced late in the metallogenic sequence and was dated in 1953 at 1730 m.y.b.p.

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DIAGENESIS, CLAY MINERAL ALTERATION AND URANIUM METALLOGENESIS IN THE ATHABASCA BASIN, NORTHERN SASKATCHEWAN

The metallogenesis of uranium in the Athabasca Basin is intimately tied to prograde and retrograde diagenesis of middle-Proterozoic, Athabasca Group red beds.

Primary ore formation took place during an advanced stage of basin development, approximately 150-100 Ma after deposition of the sediments, in response to sandstone-basement interaction under conditions of deep burial and high-grade diagenesis.

During the interval 1330-1350 Ma, diagenetic-hydrothermal systems were established throughout the basin, initiating the first stage of mineralization which is characterized by high-grade, arsenide-facies ore and extensive clay mineral host rock alteration (illite; chlorite). Reactivation of the hydrothermal systems at 1100-1050 Ma gave rise to the second stage of mineralization marked by sulphide-facies ore and extensive bleaching superimposed upon the clay alteration.

Much younger remobilization of uranium at 300-250 Ma is associated with intensive kaolinization and may be correlated with retrogressive diagenesis during uplift and unroofing of the basin, when surface waters regained access to the deep aquifer.

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РУДООБРАЗОВАНИЕ И ХАРАКТЕРИСТИКА НАТРОВО-МЕТАСОМАТИЧЕСКОГО УРАНОВОГО МЕСТОРОЖДЕНИЯ М

Урановое натрово-метасоматическое месторождение М обладает следующими характеристиками.

I. Натровый метасоматоз и урановая минерализация пространственно приурочены к региональным разломам.

2. Исходные продукты натрового метасоматоза могли быть дифференциатами мантии, частично смешанными с веществами земной коры, либо быть продуктами плавления нижней коры земли. Они характеризуются повышенным содержанием U, Be , пониженным Tr.

3. Урансодержащие натровые метасоматиты сопровождаются широкой гематитизацией, которая служит признаком низкой температуры, высокой активности кислорода и неглубокого происхождения.

4. Рудообразование происходило в условиях падения щелочности раствора и повышении активности кислорода, что проявляется в репидолитизации пород, развитии кальцита и монтмориллонита.

5. Для образования уранинита благоприятны условия относительно щелочной среды и невысокой концентрации урана, а настуран легче образуется в относительно кислой среде с большей концентрацией урана.

6. Основными парагенетическими элементами урановой минерализации являются кислородофильные элементы.

7. Источником рудных минералов могли быть главным образом мантия и частично материал земной коры.

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URANIUM ORE DEPOSITS IN SOUTH KOREA

Three major types of uranium ore deposits occur in South Korea. 1. Black shale type deposits in Ockcheon metamorphic belt, 2. Hydrothermal vein type deposits in Gapyong-Yangpyong massif, 3. Sandstone type deposits in Kyongsang basin.
Ockcheon metamorphic belt consists of limestone, phyllite, conglomerate, mica schist, and chlorite schist. The area is strongly deformed and metamorphosed. Uranium occurs in the graphite rich black slate within phyllite formation as lenses. Uranium content appears to be higher in lower grade metamorphic zone and difuses to the high grade metamorphic zone. Uranium content correlates significantly (over 99.0 % significant level) with Mo,V,Ag,Cd,P,and graphite. The uranium minerallized black shale extends more than 80 Km from Geumsan at the south-west to Chungju at the north-east end of Ockcheon metamorphic belt. KIER has been drilling $49,196^{m}$ (266 holes) in the Ockcheon metamorphic belt for uranium exploration.
Gapyong-Yangpyong massif is composed of highly deformed quartzite, limestone and amphibolite, gneiss, and schist, and intruded by younger granite. The area is regionally metamorphosed upto granulite facies of metamorphism. The uranium mineralizations occur in the chlorite schist layer (1) within quartzite conformable to the bedding, (2) at the contact between quartzite and gneiss, and (3) within gneiss along the gneissic foliation.
Kyongsang basin is composed of upper red Silla Formation and lower dark gray to green Nakdong Formation. All the sedimentary structures in these formations indicate that the formations are fluvial deposits. These formations contain abundant acidic to intermediate tuffs, vol-

canic flows, and organic materials. Uranium mineralizations in this basin, however, are very scare but systematic exploration was not attempted so far. KIER is, therefore, intending to explore the basin for uranium for the next few years.

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TECTONIC AND SEDIMENTOLOGICAL ENVIRONMENTS OF SANDSTONE-HOSTED URANIUM DEPOSITS WITH SPECIAL REFERENCE TO THE KAROO BASIN OF SOUTH AFRICA

The principal tectonic and sedimentological settings for sandstone-hosted uranium deposits are described. Back-arc basins filled with post-Silurian, fluvial sediments bordering subduction zone magmatic arcs of calc-alkaline composition are considered favourable tectonic environments. The basins should be closed to prevent excessive oxidation of the sediments. Uranium deposits are concentrated near basin rims in the transition zone between uplift and basin subsidence, because of favourable sedimentary facies in those areas. Syn- and post-depositional deformation could have affected the localisation of uranium orebodies, while intrusive centres or uplifted arcs commonly have surrounding aprons of potential host rocks. Stratigraphic zoning is also related to source area tectonics and can be used to predict favourable sedimentary environments. Sedimentological processes had a direct influence on the permeability and carbonaceous matter content of sandstones and therefore have often controlled the localisation of orebodies.

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A STUDY ON URANIUM MINERALIZATION AND U-Pb ISOTOPIC SYSTEM IN MASSIF M

The massif M is the oldest (760 m.y.) uraniferous granite known in South China. Although its average content of uranium is only 7.1 ppm, the average loss of uranium in rocks, determined by comparing the calculated uranium content with the measured one, is approximately 78%. The anomalous lead of K-feldspar implies that the source meterial from which the granite was derived is rich in uranium. The study on uranium partition in granite shows that disseminated uraninite was mostly transfermed to labile uranium in microfissures during various reforming processes. An investigation on evolution of U-Pb isotopic system of rock-forming K-feldspar and pyrites from earlier (330 m.y.) deposit B

of chlorite-vein type and later (47 m.y.) deposit of microquartz-vein type indicates the genetic relationship between rock and mineralization. On the other hand, no evidence shows successive evolution of uranium source material of deposit B after deposit A. Owing to the high percentage of initial lead in pitchblende of deposit B, the uranium mineralization was formed by convergence of descending water containing uranium with ascending solution from the depth. As to deposit A, it is characterized by hypogenic origin and short distance of transportation from the uranium source due to the low content of initial lead in pitchblende.

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GEOLOGIC ENVIRONMENTS OF URANIUM DEPOSITS IN QUATERNARY VOLCANO-SEDIMENTARY BASINS (Latium, Central Italy)

The Quaternary volcanic province, that extends along the coastal plain between the Apenninic Range and the Tyrrhenian Sea, has very high Uranium and Thorium contents. Even the less evoluted, mafic rocks display several ppm of U, whilst the most evoluted trachyphonolites reach mean values of 50 ppm. The petrochemistry of the province is perpotassic with a very characteristic positive anomaly in the concentration of incompatible elements. The clastic, volcanogenic continental sediments accumulating laterally to the volcanic belt contain uranium reconcentrations in the form of supergenic stratiform deposits.
The high Uranium concentration in the volcanites and the existence of uraniferous mineralisations make consider the alkalic volcanic belt as an uraniferous province. This province is very young and still in evolution, both in volcanic and in minerogenetic processes. It has therefore been considered as a suitable test bench for studying the origin of uraniferous provinces associated with alkaline rocks.
The Apenninic perpotassic volcanic province represents partial melts from the mantle, and its high content in incompatible elements is due to particular processes of mantle metasomatism. The geologic evolution of the area enclosing the volcanic belt (Tyrrhenian Basin and Apennines) is connected with the evolution of a metasomatised mantle dome. The control of primary processes of uranium introduction on the Earth's crust and the control of secondary reconcentration processes are discussed.

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URANIUM MINERALIZATION AT TUREE CREEK, WESTERN AUSTRALIA

Uranium mineralisation which appears to be unconformity related has been discovered at a contact between Middle Proterozoic sandstone and Early Proterozoic shale, greywacke, and dolomite in the Turee Creek area, W.A. The nature of this contact is controversial, it may represent a fault or an unconformity along which there has been minor movement. Although the mineralisation is still being evaluated and the ore controls have yet to be defined, a small uranium deposit consisting of approximately 643 000 tonnes grading 0.124% U_3O_8 has already been delineated. The mineralisation consists of uraninite, carnotite, phosphuranylite, and metatorbernite, and is hosted by clay zones, hematitic and/or carbonaceous shale and their brecciated equivalents, and chert breccias which form a sequence of uncertain age in the contact zone. Relationships are complex due to rapid facies changes within and between drill sections, and a tendency for units to pinch out along strike and down dip.

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URANIUM ENRICHMENT RELATED TO REJUVENATED FAULT AND SHEAR ZONES IN THE CENTRAL AND SOUTHERN PIEDMONT OF THE UNITED STATES

Uranium enrichment along major fault and shear zones in the central and southern Piedmont is related to specific tectonic, lithologic, and metamorphic settings. Ductile deformation along major fault zones occurred during the Taconian (400-450 m.y.) and Acadian (330-360 m.y.) orogenies, both of which are considered orogenic eras with prolonged deformational, plutonic, and metamorphic events. Brittle deformation along these fault zones occurred intermittently into the Mesozoic era. Uranium enrichment of probably Acadian age occurred in sheared syn-metamorphic granitic rocks which underwent ductile deformation and are adjacent to reactivated fault and shear zones. Stream sediment, ground water, aeromagnetic, and aerial radiometric data collected in the NURE (National Uranium Resource Evaluation) program were used in conjunction with other published geologic and geophysical data to identify and delineate environments favorable for uranium deposits. These areas, along the Chatham, Kings Mountain, Modoc, Brevard, Coat Rock, and Hylas fault zones, exhibit similar geochemical, radiometric, magnetic, tectonic, and lithologic characteristics. Estimates of the uranium endowment contained in these aeas exceed 200,000 tonnes U3O8.

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МЕСТОРОЖДЕНИЯ УРАНА ПЕСЧАНИКОВОГО ТИПА В КАЙНОЗОЙСКИХ ОСАДОЧНЫХ БАССЕЙНАХ БОЛГАРИИ

В Болгарии известны месторождения урана песчаникового типа, локализованные в наложенных депрессионных структурах древнего складчатого основания. Месторождения сосредоточены в отложениях эоцена, олигоцена и неогена. Тектоническая активность региона в кайнозое обусловила длительную и сложную историю формирования месторождений, разнообразие их генетических типов и морфологических особенностей оруденения. По совокупности признаков выделены: I.Месторождения в отложениях морской вулканогенно-осадочной формации эоцена - диагенетические в лагунных туфоалевролитах и туфопесчаниках на границе сероцветных и зеленоцветных их разностей, эпигенетические в белых кислых туфах с эпигенетическими восстановителями (сероводород и др.). II. Месторождения в отложениях аллювиальных, реже пролювиальных фаций молассовой сероцветной формации олигоцена и неогена с сингенетическими восстановителями (углефицированный детрит). Две группы месторождений различаются строением разреза. Для разрезов орогенного типа характерны большая мощность отложений, преобладание грубозернистых осадков, многоярусность рудных тел пластоволинзовидной формы; генезис оруденения экзогенный, полистадийный. В разрезах суборогенного типа мощность отложений небольшая, залегание их пологое, число рудных уровней невелико. Рудные тела пластово-линзовидной и ролловой формы. Оруденение эпигенетическое и экзодиагенетическое. По результатам изотопно-свинцового анализа, метода радиационных дефектов кварца и изучения состояния радиоактивного равновесия в рудах различаются месторождения: с оруденением, близким возрасту вмещающих пород, с незначительным перераспределением урана; с существенным перераспределением урана и разрушающиеся; молодые, формирующиеся в настоящее время.

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MINERALOGICAL AND GEOCHEMICAL ASPECTS OF URANIUM ALBITITE CREATION

Precambrian uranium and rare element albitite in zones of fundamental faults has been studied. The evolution of uranium albitite comprises several stages: ultrametamorfic /prealbititic/, albititic and postalbititic.

Potential ore types of the albitite are polyzonal, they have evidences of primary and secondary lateral and vertical metasomatic zoning /mineralogical, geochemical, radiochemical, isotopic and hydrochemical/. In contrast with ore albitite, barren one is not zoned, and rare element albitite is characterized only by primary lateral and vertical zoning.

Superimposed post-albitite processes lead to generation of secondary zoning that results in the formation of paragenetic hydrothermal mineral associations of different phases, including apatite chlorite, carbonate, sulphides, barite, hematite, quartz. These minerals are closely associated with economic uranium mineralization and reflect the evolution of cation and anion composition of altering solution.

Extension of uranium albitite mineralization is predetermined by extension of superimposed carbonatization. Carbon dioxide corrects pH of the system, plays significant role in complexing of uranium and accompanying elements, in dissolution and redeposition of the components, marks structural traps, where uranium accumulates. And hence it is the main geochemical control influencing ore formation.

Strong alteration of primary uranium minerals as deep as more then 1,5 km is considered to be the general feature of ore composition. Uranium redeposition within economic types of ores proceeded downward and affected albitite throughout its mass. It contributed to natural ore enrichment, that must be taken into consideration in prospecting slightly - developed albitite mineralization.

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МИНЕРАЛОГО-ГЕОХИМИЧЕСКИЕ АСПЕКТЫ ФОРМИРОВАНИЯ УРАНОНОСНЫХ АЛЬБИТИТОВ

Изучены ураноносные и редкометальные альбититы докембрия, приуроченные к зонам крупных тектонических нарушений глубинного заложения. Формирование ураноносных альбититов связано с длительной историей развития и происходило в несколько этапов: ультраметаморфический (доальбититовый), собственно альбититовый и постальбититовый. Перспективные типы ураноносных альбититов полизональны; они обнаруживают признаки первичной и вторичной горизонтальной и вертикальной метосоматической зональности (минералогической, неохимической, радиохимической, изотопной, гидрохимической). В отличие от ураноносных, альбититы безрудных формаций незональны, редкометальным свойственна первичная горизонтальная и вертикальная зональность. Проявление наложенных постальбититовых процессов, способствующих формированию вторичной зональности, приводит к образованию разностадийных парагенетических ассоциаций гидротермальных минералов, включающих апатит, хлорит, карбонат, сульфиды, барит, гематит, кварц, тесно связанных с развитием промышленной урановой минерализации и отражающих во времени эволюцию катионного и анионного состава метасоматизирующих растворов.

Масштаб наложенной карбонатизации предопределяет масштаб уранового оруднения в альбититах. Углекислота регулирует pH системы, способствует комплексообразованию урана и сопутствующих элементов, играет важную роль при растворении и переотложении компонентов, трассирует структурные ловушки-резервуары накопления урана и тем самым является главным геохимическим фактором, контролирующим урановый рудогенез.

Отличительной особенностью минерального состава руд является интенсивное изменение первичных урановых минералов до глубины свыше I,5 км. Процессы перераспределения урана в промышленных типах альбититов имеют нисходящий характер, затрагивают всю продуктивную толщу и способствуют естественному обогащению урановых руд, что необходимо учитывать при поисках слабопроявленного оруденения в альбититах.

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GEOLOGY OF SANDSTONE-TYPE URANIUM DEPOSITS OF THE WORLD: A NEW APPROACH

The sandstone-type uranium deposits form a group with world wide distribution and many common characteristics. They have yielded important amounts of uranium, vanadium, copper and radium, and account for at least one fourth of the worlds uranium reserves (excluding communist countries). About 95 percent of the uranium reserves of USA, one of the worlds major uranium producers, are found in sandstones. It is expected that most of the uranium required for the nuclear power programmes in the future would come from sandstones. The sandstone-type uranium deposits, therefore, are very important. The present paper describes the salient geological features of some selected peneconcordant and vein type uranium deposits of the world, and outlines some exploration guides for locating these deposits in favourable terrain.

Although these deposits are found in many formations, ranging from late Paleozoic to middle Tertiary in age, the more productive deposits are restricted to a few stratigraphic units of Mesozoic age. Most of these deposits are in lenticular fluvial sandstones. Uranium is also found in deltaic and littoral marginal marine facies, lacustrine facies, and red-gray transitional facies.

Most of these deposits are elongate tabular bodies in sandstone and are oriented roughly parallel to bedding and sedimentary trends, and for that reason are called peneconcordant deposits. In these the ore minerals mainly fill the pore spaces of the host rocks, but they partly replace the sand grains, plant fossils, and accessory and cementing minerals of these rocks; occupy sandstone lenses and channel fills; in some deposits the uranium occurs in asphaltic material that impregnates and partly replaces the sandstones. The mineralization is influenced by (i) interfingering and overlying lenses of finer-grained sediments and (ii) calcium carbonate cement. There is a total lack of any evidence of hydrothermal alteration or any zonal arrangement of uranium-vanadium-copper mineralization. It is possible that uranium and other extrinsic elements in the deposits could have been precipitated by reduction from ground waters peripherally drained during the uplifts.

The vein type deposits are mainly localized along fractures that are discordant to bedding. In these, the ore minerals occupy the fracture partings and impregnate the adjacent wall rock. The wall rocks around ore bodies are altered. The structural control, ore mineral assemblage and textures, wall rock alteration patterns, crystallinity and composition of vein-type uraninite, and the presence of mica polymorphs suggest that the vein-type deposits were formed by telethermal solutions.

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PRELIMINARY PETROGRAPHY OF ORE AND ALTERATION ASSEMBLAGES FROM THE JABILUKA UNCONFORMITY-TYPE URANIUM DEPOSIT, NOTHERN TERRITORY, AUSTRALIA

Uranium ore at the Jabiluka unconformity-type deposit is concentrated in chloritized and, to a lesser extent, sericitized schists composed of quartz + chlorite ± muscovite ± sericite ± graphite. Uranium occurs predominantly in veins and as disseminations of uraninite and coffinite. Coffinite locally contains uraninite cores. Near the western edge of the major orebody, minor uranium is concentrated in a brecciated carbonate sequence; uranium occurs as disseminations in chlorite schist fragments and as coffinite in silicified portions of the carbonate rocks.

Chlorite mineralogy at Jabiluka is complex, but crosscutting relationships suggest episodes of chloritic alteration. Ore is most commonly associated with light green cryptocrystalline chlorite and white chlorite ($<15\ \mu m$ in length). Septechlorite is present in both ore and barren zones; crosscutting relationships suggest that septechlorite formation was a late event. Potassic alteration, more common in barren zones, is indicated by matrix sericite and by muscovite locally replacing coarse chlorite.

Tourmaline alteration, consisting of sprays of fine-grained dravite, is widespread in the schists. The sprays are disseminated in matrix chlorite, are concentrated along cleavage planes of coarse-grained chlorite, and are in crosscutting quartz veins and breccia matrix. Dravite is only rarely associated with uranium.

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STRATA-BOUND URANIUM DEPOSITS IN THE DRIPPING SPRING QUARTZITE, GILA COUNTY, ARIZONA, U S A A MODEL FOR THEIR FORMATION

Uranium deposits in the Proterozoic Dripping Spring Quartzite are strata-bound in diagenetically altered, potassium-rich and carbonaceous volcanogenic siltstones. The deposits are localized near Proterozoic diabase intrusions and along monoclines that deform the essentially flat-lying sequence. Uraninite and coffinite occur both in vertical veins and in sub-horizontal to horizontal veins along stylolites and bedding planes, and as disseminations in fine-grained, potassium-feldspar-rich layers. The uranium deposits also contain high concentrations of copper and molybdenum.

The uranium deposits in the Dripping Spring Quartzite were diagenetic concentrations that were later remobilized during diabase emplacement. Uranium, which may have been released from the volcanogenic sediments during diagenesis, could have been transported and concentrated in carbonaceous volcanogenic siltstones at the time of diagenesis and stylolite formation. Circulating fluids associated with diabase emplacement remobilized and concentrated uranium in the carbonaceous volcanogenic siltstones close to diabase. Chloritic alteration, which followed diabase emplacement, caused only minor uranium remobilization.

The uranium deposits in the Dripping Spring Quartzite may be considered an intermediate stage between strata-bound sedimentary or diagenetic uranium concentrations and remobilized, high-grade deposits in metamorphosed and highly altered rocks.

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THE TYPES OF URANIFERROUS WALL ROCK METASOMATITES.

Uraniferrous oreforming hydrothermal-metasomatic process is complicated combination of mineralisation events. The most significant result of this process is a large scale preore stage wall rock metasomatites formation.

The uraniferrous metasomatites features are subdivided into formaticnal features and facial features. The former are connected with the hydrothermal solutiones properties and the latter - with lokal factors, the most importent of which is the composition of wall rocks. The following eight formational types of uraniferrous metasomatites have been established: hydrothermal argillisites, hydromical metasomatites, beresites, low-temperature sodium metasomatites (eisites), gumbeites, middle-temperature sodium metasomatites, high-temperature potassium metasomatites, allanite-bearing skarns; the first six being the chief, the last two being subordinate. Argillisites, hydromical metasomatites, beresites are connected with the processes of acidic metasomatism the other ones - with the processes of alkaline metasomatism. Since metasomatites can be mapped and the ores principal features are functionally connected with the metasomatism type altered rocks are important search and classification signs of uranium deposits. The metasomatites types consistency on large ore areas indicate a certain connection of their features with deep seated factors which determine the specific uraniferrous solutions characteristics for the ore areas as a whole. The metasomatik bodies central sones paragenises that reveal an aquilibrium between the rock and solution are the most informative as to hydrothermal solutions properties. The metasomatite type is determined by a total combination of the following characteristics: the place in the hystory of geologikal evolution, correlation with magmatism, mineral and chemical composition, the conditions of localization, metasomatic bodies zonning, metallogenic and geochemic cpecialization. The criteria altered rocks and ores consanguinity are as follows: close spatial connection, time-correlation availability, mineral composition likeness, uranium accumulation in metasomatic rocks.

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ТИПЫ УРАНОНОСНЫХ ОКОЛОРУДНЫХ МЕТАСОМАТИТОВ

Урановорудный гидротермально-метасоматический процесс представляет сложную совокупность явлении минералообразования. Наиболее значительным по масштабам результатом этого процесса является образование околорудных метасоматитов в предрудную стадию.

Особенности ураноносных метасоматитов подразделяются на формационные и фациальные. Первые связаны со спецификой гидротермальных растворов, вторые - с локальными факторами, из которых основное значение имеет состав вмещающих пород.

Установлено восемь формационных типов ураноносных метасоматитов: гидротермальных аргиллизитов, гидрослюдизитов, березитов, эйситов, гумбеитов, среднетемпературных натриевых метасоматитов, высокотемпературных калиевых метасоматитов, ортитоносных скарнов. Шесть первых типов являются ведущими, остальные имеют подчиненное значение. Аргиллизиты, гидрослюдизиты, березиты связаны с процессами кислотного, остальные типы - щелочного метасоматоза.

Так как метасоматиты поддаются геологическому картированию, а с типом метасоматоза функционально связаны главнейшие особенности руд, околорудные измененные породы являются важным поисково-оценочным и классификационным признаком урановых месторождений.

Выдержанность определенных типов метасоматитов в пределах крупных рудоносных провинций свидетельствует, что их особенности связаны с глубинными факторами, определяющими специфику ураноносных растворов для провинции в целом. Наиболее информативными в отношении свойств гидротермальных растворов являются парагенезисы внутренних зон метасоматических тел, которые характеризуют достигнутое равновесие между породой и раствором.

Принадлежность метасоматитов к тому или иному типу определяется совокупностью следующих признаков: местом в истории геологического развития, соотношением магматизма с минеральным и химическим составом, условиями локализации, закономерностями строения метасоматических тел, металлогенической и геохимической специализацией.

Критериями генетической связи измененных пород и руд являются: теснейшая пространственная связь, временная близость, сходство минерального состава, накопление урана в породах в процессе их метасоматического преобразования.

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НЕКОТОРЫЕ ОСОБЕННОСТИ УРАНОВОЙ МИНЕРАЛИЗАЦИИ В ЭКЗОГЕННЫХ МЕСТОРОЖДЕНИЯХ СРЕДИ КАЙНОЗОЙСКИХ ОТЛОЖЕНИЙ В БОЛГАРИИ

В экзогенных урановых месторождениях песчаникового типа Болгарии,локализованных в наложенных депресионных структурах древнего складчатого основания,выявлена урановая минерализация,отличная от указанной в литературе для такого типа месторождений.Оруденение приурочено к отложениям эоцена,олигоцена и неогена - к морским осадкам вулканогенно-осадочной формации,лагунным туфоалевролитам и туфопесчаникам и к аллювиальным фациям молассовой сероцветной формации.Для такого типа месторождений в литературе отмечается урановая минерализация,представленная урановыми чернями,коффинитом и настураном.В большей части указанных месторождений Болгарии урановая минерализация представлена только нингиоитом и иногда фосфорсодержащим коффинитом.До 1977 года нингиоит был установлен лишь в Японии.Нингиоит в наших месторождениях выявлен в тонкодисперсном виде.В единичных случаях встречается и железосодержащий нингиоит. Иногда нингиоит встречается с селенидами кобальта и никеля. Все эти минералы, диагностированные методом электронной микроскопии и микрозондовым анализом в сочетании с микродифракцией, представлены веретенообразными кристаллами размером 0,5 – I микрон. В рудах других месторождений обнаружены настуран и коффинит, которые тесно ассоциируют с углефицированным органическим веществом и часто встречаются вместе. Настуран диагностирован рентгеноструктурным анализом (a_0= 5,409). Иногда коффинит является единственным урановым минералом в рудах.

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SOURCES OF URANIUM IN ORE DEPOSITS

The evaluation of a new area as a source of uranium deposits should be based on knowledge of the distribution, chemistry, and crystallization history of igneous rocks and evidence for the release of uranium as fluids into older rocks. Lithologic and chemical data for the Southern California and Idaho batholiths indicate that uranium was released from the magma by explosive or tectonic disruption. This disruption also is marked by the presence of consanguenous dikes and unique textures in the igneous rocks.

In crystalline and sedimentary terrains these features can be used to select areas favorable for both syngenetic and epigenetic deposits in igneous rocks, such as binary granites, and in metamorphic, migmatitic, and alaskitic rocks, such as the Rössing deposit, and in sedimentary rocks, such as those of the sandstone and surficial types. The chemistry and differentiation history of a plutonic series also allows identification of those igneous units that contain uraniferous minerals and thus be sources of syngenetic deposits.

Low grade ores that result from marine processes rarely show a relationship to igneous sources. Higher grade uranium ores form, however, where these low grade deposits are host to uranium from other sources, as in some phosphate occurrences.

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MOBILIZATION AND PRESERVATION OF RADIOACTIVE AND RARE-EARTH ELEMENTS IN CANADIAN VEIN-TYPE AND GRANITE-HOSTED URANIUM DEPOSITS OF PRECAMBRIAN AGE

Associations of primary and secondary minerals were studied by high resolution electron micrographs and by their energy dispersive spectra and interpreted in terms of the evolution and alteration of their host radioactive granitoid rocks and veins. Associations of primary radioactive and rare-earth element (REE) minerals correlate with the evolution of granitoid rocks and their contained xenoliths as follows:

Uraninite-uranothorite-REE phosphate-zircon mineral associations crystallized in plagioclase-rich paleosome phases, whereas individual uraninite grains that are rimmed by phyllosilicates crystallized in microcline- and quartz-rich neosome phases, uraninite-pyrochlore-muscovite-sericite assemblages occur in hydrothermally altered granitoid rocks, and uraninite-zircon-allanite-titanite-biotite associations are common at contacts between granite pegmatites and mafic xenoliths.

In fractured rocks, disseminated radioactive and accessory minerals have been altered and the leached elements have migrated throughout the host rock, and in part, reprecipitated in fractures. These fracture fillings grade into vein-type granitoid deposits.

Vein-type deposits occur in fractures traversing diverse types of altered rocks. Veins containing several generations of Th-poor pitchblende also locally contain associated Co, Cu, Fe, Ni, Pb sulphides, arsenides and selenides, and here and there tellurides and gold.

As a result of recurring fracturing, penetration of uraniferous aqueous solutions and changes in pH and Eh, radioactive and accessory minerals undergo several stages of alteration following two principal trends, namely through lead-enriched or lead-depleted oxides, hydrated oxides, silicates, phosphates and carbonates to clays. The leached elements either reprecipitate or are removed from their original sites.

Significant roles have been established for mobilization and reprecipitation in the formation and alteration of the Precambrian radioactive and REE deposits studied. These processes are thus important in the metallogenic evolution of the deposits.

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THE OLYMPIC DAM COPPER-URANIUM-GOLD DEPOSIT, ROXBY DOWNS, SOUTH AUSTRALIA

The Olympic Dam copper-uranium-gold deposit is a new type of strata-bound sediment-hosted ore deposit. It is located 650 kilometres north-northwest of Adelaide in South Australia and was discovered in 1975. It has an areal extent exceeding 20 square kilometres with vertical thicknesses of mineralization up to 350 metres.

The deposit occurs in the basement beneath 350 m of unmineralized, flat-lying Adelaidean to Cambrian sediments in the Stuart Shelf Region of South Australia. The basement host rocks of the deposit are unmetamorphosed and are probably younger than 1580 Ma. The deposit is spatially related to coincident gravity and magnetic anomalies and the intersection of west-northwest and north-northwest trending lineaments.

The Proterozoic sediments comprising the host sequence are predominantly sedimentary breccias ranging from matrix-poor granite breccias to matrix-rich polymict breccias containing clasts of a variety of rock types. This sequence is over 1 km thick and has been divided into two main units - the Olympic Dam Formation and the Greenfield Formation. Pervasive hematite, chlorite and sericite alteration of varying intensity affects all the basement sequence. The localizing structure for the deposit is a northwest trending trough or graben which is arched about a northeast axis. Arching parallel to the graben long-axis also occurs in some areas. Strike-slip and dip-slip faults occur both parallel to and at a high angle to, the graben long-axis.

Two types of copper sulfide mineralization have been defined - a strata-bound type (bornite-chalcopyrite-pyrite), and a younger transgressive type (chalcocite-bornite). Uranium, rare earths, gold and silver occur with both types. Uraninite, with lesser coffinite and brannerite is very fine-grained and occurs in a variety of forms, and rare earths minerals, bastnaesite and florencite, occur in, and adjacent to, sulfide mineralized zones. In both types of mineralization, hematite, quartz, sericite and fluorite are the main gangue constituents with lesser amounts of chlorite, siderite, barite and rutile.

A detailed genetic model has not been developed. It is considered that the graben-fill sediments were deposited in an arid subaerial environment during rifting or strike-slip faulting. The strata-bound sulfide mineralization is syngenetic or syndiagenetic and is probably related to local volcanism. The younger transgressive mineralization is epigenetic and was introduced into favourable structural zones. The uranium and rare earths were deposited during and after the sulfide mineralizing phase.

The deposit is a very unusual example of sediment-hosted mineralization. The most unusual features are the association of copper, uranium, rare earths and gold, the association of reduced sulfur species such as chalcocite and bornite with high hematite concentrations; and the occurrence of strata-bound copper and uranium minerals in sedimentary rocks deposited in a very high energy environment.

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GEOLOGIC ENVIRONMENTS OF NINGYO-TOGE AND TONO URANIUM DEPOSITS, JAPAN

The geologic environments on Ningyo-toge and Tono deposits, the most remarkable uranium occurrences in Japan, have been summarized.

Despite the geologic ages of the host rocks in those two areas is different (in the late Miocene to early Pliocene age for Ningyo-toge deposit and in the early to middle Miocene age for Tono deposit), those two deposits have the close similarities in their occurrences as the sandstone-type uranium deposits. Namely, ore bodies have been developed in the basal conglomerate and arkosic sandstone resting on the biotite granite of Cretaceous age, with close-controlled layout by the drainage pattern on the paleosurface. The period of uranium precipitation from circulating groundwater seems not to be long after the deposition of host rocks.

The hydrogeologic survey around the deposits, especially in Tono area, reveals that high-alkaline, uranium- and fluorine-enriched groundwaters are confined into the fractures in the basement granite and permeable beds in the ore horizon. Uranium contents of the basement granites in both areas are relatively higher than the domestic averages, and assumed to be the potential source of ore uranium. Tuffaceous beds are also exist above the ore horizons, but no evidence as an effective uranium source has been found.

The favorable environments, such as fracture systems in the basement rocks and development of closed or semi-closed sedimentary basins, have been formed by the regional tectonic movements in the Inner Zone of southwest Japan since the Miocene period. Analysis of such phenomena is effective to get the useful informations for further exploration.

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STRUCTURE RELATED URANIUM MINERALISATION IN THE WESTMORELAND DISTRICT, NORTHERN AUSTRALIA

The Westmoreland uranium district straddles the boundary between Queensland and the northern territory of Australia some 100 km south of the northern coast. Middle proterozoic conglomerate/sandstone and basic volcanic sequences of the McArthur and South Nicholson basins unconformably onlap/overlap lower proterozoic acid volcanics and metamorphic pelites intruded by high level granites, which were uplifted to form an EW trending window within the basin cover. Basic dykes, suspected to be feeders to the multiple basic extrusions, were emplaced mainly along NE and EW trending structures which initially developed during the late stage of sandstone/conglomerate deposition.

High grade uranium mineralization in the district frequently occurs as vertical or sub-vertical, discontinuous sheets or lenses within and/or adjacent to basic dyke filled structures. Gold may occur incidental to the uranium in this type of mineralization. Contribution of the vertical type to the overall resources is relatively small. Preliminary mineralization consists mainly of pitchblende with minor protobrannerite.

The uranium derived from dirital uranium minerals and uranium bearing lithic clasts of the continental sandstone/conglomerate sequence, was mobilised by oxidising ground water circulation due to convection cells generated by the thermal energy of repeated dyke re-activation and substantial overburden, and was precipitated from oxidised waters by abundance of Fe against the geochemical barrier of the basic dyke.

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GEOCHEMICAL BARRIERS IN EXOGENIC URANIUM DEPOSITS; TYPES AND SIGNIFICANCE

Exogenic uranium deposits are formed by surface water and oxidizing aqueous solutions either of a porous (nearsurface and layer ground water) or a fracture type. They are subdivided into syngenetic (sedimentary) and epigenetic among those are nearsurface= layer= and fracture=infiltration deposits. Infiltration uranium mineralization is controlled by the edges of rock oxidation zones. High uranium content in oxidizing ground water (determined by favourable climate and presence of the source of uranium), high rate of filtration and a lasting period of epigenetic process are considered to be of great importance for mineralization.

Exogenic deposits represented by uranium oxide and coffinite mineralization are formed at the reduction geochemical barrier due to a drop in Eh up to negative values. Ore deposition takes place during interaction between oxidizing aqueous solutions and - 1) rocks abundant in syngenetic reductants (mostly carbonaceous organic material of low degree of carbonization); 2) rocks containing epigenetic reductants (bitumen, H_2S, H_2); 3) ascending reducing thermal solutions. The first group is characterized by direct correlation of uranium concentrations in the mineralized zone with organic carbon content. The second and the third groups are marked by relationship with reducing epigenetic alteration and by fracture tectonics as ore control. At the oxidation-reduction barrier Se, Re, Mo are sometimes observed to accumulate.

Primary uranyl mineralization (uranyl vanadate and uranyl phosphate)is formed due to a considerable change in pH at the neutralization geochemical barrier. It is represented by autunite-carnotite deposits in carbonaceous shales. These deposits are formed as a result of alkalization of infiltration fracture waters that were highly acidulous while oxidation of pyrite-bearing rock initially rich in uranium, vanadium and phosphorous. In contrast acidification of alkaline metal-bearing waters while interaction with products of lateritic residue is supposed to form carnotite "caicrete" and "gypcrete" deposits.

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РОЛЬ И ВИДЫ ГЕОХИМИЧЕСКИХ БАРЬЕРОВ ЭКЗОГЕННЫХ МЕСТОРОЖДЕНИЙ УРАНА

Экзогенные месторождения урана формируются поверхностными водами и кислородными подземными водными растворами порового (грунтового или пластового) либо трещинного типа.Соответственно они разделяются на месторождения: сингенетические (осадочные) и эпигенетические, в том числе грунтово-, пластово- и трещинно-инфильтрационные.Инфильтрационное урановое оруденение контролируется границами зон окисления пород. Для его формирования важное значение имеют: повышенное содержание урана в кислородных подземных водах (определяемое благоприятными климатическими предпосылками или наличием специфического источника рудного вещества), высокая скорость фильтрации и большая длительность эпигенетического процесса.

Руды экзогенных месторождений с окисной и коффинитовой урановой минерализацией возникают на восстановительном геохимическом барьере в результате резкого снижения Eh среды до отрицательных значений. Процесс рудоосаждения осуществляется при взаимодействии кислородных водных растворов: а) с породами, содержащими сингенетические восстановители (преимущественно углистое органическое вещество низкой степени карбонизации); б) с породами, содержащими эпигенетические восстановители (битумное вещество, H_2S, H_2); в) с восходящими восстановительными термальными растворами. Месторождениям первой разновидности свойственна прямая зависимость концентраций урана в рудной зоне от содержаний органического углерода, второй и третьей - связь с эпигенетическими изменениями восстановительного характера и контроль оруденения разрывной тектоникой. Вместе с ураном на восстановительном барьере иногда накапливаются Se, Re, Mo.

Руды месторождений с первичной уранильной минерализацией (уранил-ванадатные и уранилфосфатные) возникают на нейтрализационном геохимическом барьере в условиях резкого изменения pH среды. Их представители - отенит-карнотитовые месторождения в углеродистых сланцах. Они сформировались в результате ощелачивания инфильтрационных трещинных вод, резко подкислившихся при окислении пиритоносных пород, изначально богатых ураном, ванадием и фосфором. Предполагается, что противоположный механизм - подкисление щелочных металлоносных грунтовых вод при взаимодействии с продуктами древних площадных латеритных кор выветривания - характеризует образование карнотитовых месторождений в "калькретах" и "гипкретах".

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ГЕОЛОГИЯ И ГЕНЕЗИС УРАНОВЫХ МЕСТОРОЖДЕНИЙ ЧЕШСКОЙ МЕЛОВОЙ ВПАДИНЫ

Рудный район имеет блоковое строение, обусловленное пересечением зон глубинных разломов.

Нижний геосинклинально-орогенный структурный этаж представлен гнейсами, графитсодержащими филлитами, сланцами, гранитоидами верхнепротерозой-среднепалеозойского возраста, пермокарбоновыми угленосными и вулканогенными породами.

Платформенный этаж общей мощностью 1200 м слагают верхнемеловые осадочные и палеоген-неогеновые вулканогенные образования. В сеноманском водоносном горизонте широко проявлены изменения пород восстановительного класса и развиты зоны пластового окисления.

Месторождения локализуются в основании разреза пород сеномана, представленных речными, озерно-болотными, мелководно-морскими фациями, обогащенными органическим веществом и пиритом. Оруденение приурочено к обеленным породам, частично к зонам окисления. Преобладают пластовые рудные тела, встречаются линзы и роллы. Богатые руды образовались на границе водопроницаемых и водоупорных пород. В палеодолинах развито многоярусное оруденение.

Урановые и ураносодержащие минералы представлены тонкодисперсными урановыми чернями, настураном, гидроцирконом, нингиоитом, коффинитом, браннеритом, гельбадделеитом. Местами отмечены повышенные содержания циркония, титана, тория, ниобия, молибдена, цинка, мышьяка, стронция, рубидия.

Рудообразование происходило на нескольких этапах развития района. Повышенные концентрации урана образовывались уже при седиментогенезе- диагенезе осадков. Основная масса урана накапливалась в результате неоднократно проявленных эпигенетических процессов восстановительного и окислительного характера. Перераспределение урана, привнос ряда элементов из эндогенных источников происходили при многофазных проявлениях вулканической и поствулканической деятельности.

Стратиформные урановые месторождения Чешской меловой впадины по условиям образования можно отнести к классу полигенных месторождений с комплексными рудами.

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THE DISCOVERY OF URANIUM DEPOSIT IN THE METABASIC ROCKS IN THE RAJNANDGAON - DURG URANIUM PROVINCE IN MADHYA PRADESH - A CASE HISTORY OF URANIUM EXPLORATION

The paper deals with the geological criteria used and various exploration techniques adopted during uranium exploration programme leading to the discovery of the Bodal uranium deposit in Rajnandgaon District of Madhya Pradesh. Geological and genetic aspects of the uranium mineralisation are also presented.

Favourable regional geological criteria for identifying the Rajnandgaon - Durg uranium province include the assotoation of banded iron stone formation, bimodal andesite - rhyolite volcanism, development of regional and local faults and shears and intrusive granites with fluorite and sulphide mineralisation.

The Bodal uranium deposid is located in the meta-basics rocks in the above noted set-up around the southern margins of the Dongargarh system of rocks of lower to middle Proterozoic age. Surface shows of uranium mineralisation are very scanty and are confined only to the sheared matabasic rocks belonging to the green schist to epidote - amphibolite facies and which carry xenoliths of quartz porphyry. Generally uranium mineralisation occurs within about 150 m from the faulted contact between the metabasic and phyllitic shales trending NW - SE. The uranium zones dip steeply to the NE. Since most of the area is covered with thick soil cover, exploration was mostly carried out by intensive diamond drilling from the very early stages of exploration coupled with radon survey and other ground geophysical methods.

Uranium mineralisation with the metabasics which could be compared with the basaltic andesites of tholeiitic affinity with moderate iron enrichment is both structurally and lithologically controlled. Radioactivity is mainly due to uraninite, occuring as fine particles and veins along micro-fractures and cleavages in the amphiboles and biotite and intimately associated with iron oxides. Uranium mineralisation is probably related to the hydrothermal stage of the intrusive Dongargarh granites during the later part of the early Proterozoic (2200-2000 Ma). Igneous activity postdating the uranium mineralisation masks the uranium zones at a number of places. Block faulting has down-thrown the uranium zones along strice in a number of places where its manifestation in the form of anamalous uranium in soil zones over the metabasics, could

be detected with the help of detailed geochemical soil and radon surveys only and further detailed exploration is in progress to defi define the ore bodies.

The paper emphasises the importance of the geological favourability criteria in regional and local scale exploration for uranium and highlights the effective utilisation of core drilling in the early stages of exploration itself in areas where soil cover masks outcrops.

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GENETIC MODELS OF URANIUM DEPOSITS AND THEIR APPLICATION IN PRELIMINARY ESTIMATION THE URANIUM POTENTIAL OF REGIONS TO BE STUDIED

The development of genetic models of uranium deposits starts with studying the migration of uranium during the geological processes, includes formulation of genetic concepts and ends in building up principal models. They are also based on the genesis of known uranium deposits, and it should be noted that in a genetic model could be integrated the main formation conditions of several type uranium deposits. The presented eight genetic models and their modifications cover practically all known big uranium deposits.

The application of these genetic models in estimation the uranium potential of regions to be studied is possible through considering the evolution of the ore processes in seven geochronological stages: modification of the fundamental source of uranium; formation of the local source of uranium (rocks with ubnormal uranium content); deposition of host rocks; development of the local source of uranium; fixation of uranium; regeneration of the first ore concentrations and conservation of uranium deposits. According to the geological environment, each of these genetic models could have three modifications applicable to regions built up mainly by sedimentary, metamorphic or igneous rocks. The application of the genetic models to regions built up by igneous rocks in preliminary estimation their uranium potential, is considered.

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RADIOACTIVE ELEMENTS CONCENTRATION PROCESSES IN THE EARTH'S CRUST AND URANIUM METALLOGENY PROBLEMS

The uranium and thorium distribution in the Earth's crust results from physical - chemical and tectonic differentiation of sedimentary and granitic - metamorphic layers of the crust being related to the combined processes of metal migration and concentration within the broad range of geological phenomena of endogenous and exogenous cycles. The highest level of metal accumulation in lithosphere is associated with the processes of epigenetic rock transformation resulting from hydrothermal alkaline and acid metasomatism and infiltration activity of ground water.

The syngenetic processes of sedimentation and magmatic activity leads mostly to the formation of geochemically specialized rock complexes such as carbonaceous - siliceous shales, phosphorites, rare earth granites etc.

The main uranium are formations are represented by two groups, i.e.

a) relatively simple mineral formations resulting from predominantly single - event hydrothermal metasomatism or infultration activity of ground water.
b) complex mineral aggregates formed as a result of repeated superposition (telescoping) of various uranium concentration processes in geochemically specialized complexes.
   The second group usually represents polychronous type of ore formations.

The spatial distribution of elements of the uranium ore zonation has a complex diversified pattern which reflects latteral affinities of some large geological blocks belonging to different structural - compositional types, i.e. shields and boundary zones of ancient platforms, deformed portions of platform covers, geosynclinal - folded and activization areas, as well as geochemical specialization of lithosphere complexes of the Earth's crust. The uranium metallogeny problems are closely associated with the cardinal problems of geological science, i.e. study of the physical - chemical differentiation processes of the the Earth, sources of ore substance, interrelations between geological structural pattern of the Earth's crust and heterogeneities in composition and structure of the Upper Mantle.

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ПРОЦЕССЫ КОНЦЕНТРИРОВАНИЯ РАДИОАКТИВНЫХ ЭЛЕМЕНТОВ В ЗЕМНОЙ КОРЕ И ПРОБЛЕМЫ МЕТАЛЛОГЕНИИ УРАНА

Распределение урана и тория в земной коре обусловлено физико-химической и тектонической дифференциацией осадочной и гранитно-метаморфической оболочек коры и связано с совокупным проявлением процессов миграции и концентрирования металлов в ходе проявления широкой гаммы геологических явлений эндогенного и экзогенного циклов. Наиболее высокий уровень накопления металлов в литосфере связан с процессами эпигенетического преобразования пород в результате гидротермального щелочного и кислотного метасоматизма и инфильтрационной деятельности подземных вод. Сингенетические процессы осадконакопления и магматической деятельности приводят главным образом к возникновению геохимически специализированных комплексов пород типа углеродисто-кремнистых сланцев, фосфоритов, редкометальных гранитов и других.

Главные рудные формации урана представлены двумя группами:

а) относительно простыми минеральными образованиями, возникшими в результате преимущественно одноактного проявления гидротермального метасоматизма или инфильтрационной деятельности подземных вод;

б) сложными минеральными агрегатами, возникшими за счет неоднократного наложения (телескопирования) различных процессов концентрирования урана в геохимически специализированных комплексах. Вторая группа формаций обычно представляет полихронный тип рудных образований.

Размещение элементов урановорудной зональности в пространстве представляет сложную многоплановую картину, отражающую латеральные связи крупных геологических блоков различного структурно-вещественного типа (щитов и пограничных зон древних платформ, деформированных частей платформенных чехлов, геосинклинально-складчатых и активизированных областей), а также геохимическую специализацию литосферных комплексов земной коры. Проблемы металлогении урана тесно связаны с решением кардинальных вопросов геологической науки: изучением процессов физико-химической дифференциации Земли, источников рудного вещества, взаимосвязей геологического строения земной коры с неоднородностями состава и структуры верхней мантии.

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WORLD URANIUM RESOURCES: THE KNOWN AND THE UNKNOWN

The knowledge of the world uranium resource situation is far from complete. Though over three million tonnes of discovered resources were reported by the OECD (NEA) and the IAEA in 1983 a further substantial volume of resources have been discovered which are not well documented. In addition a major part of the world resources have yet to be discovered.

Every two years the Agencies distribute a questionnaire which asks National Authorities to assign their uranium resources to categories depending on the confidence in the existence and on their cost of recovery. Information is also collected on the geology of the deposits. These known uranium resources total 3.25 million tonnes of which 1.45 million tonnes are economic reserves. They are described in terms of their geological character, geographical distribution and economic importance.

The known resources have been reported by countries which represent only half of the land surface of the earth. Little detailed information is available covering the remaining half, although there are reports which indicate that at least 2 million tonnes of uranium have already been discovered in these areas, mainly in small vein and sandstone deposits. This is somewhat less than would be expected by analogy with the areas covered by the report "Uranium Resources, Production and Demand".

Estimates of the world's undiscovered resources fall within the range 9.6 million to 24.6 million tonnes, and most probably within the range 14.8 million to 18.6 million tonnes. The paper describes their geological and geographical distribution.

The total world demand for uranium through the end of this century will be around 1.2 million tonnes. There should be little difficulty in meeting this demand with the present resource base, but there will be the need for increased world trade in uranium. In the longer term substantial additions will need to be made to the resource base. The size of the additions, and the possibility of achieving them can only be estimated accurately if we improve our knowledge of the existing resource base. More information is needed on the size, geological character and geographical distribution of discovered resources.

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WORLD ENERGY RESOURCES AND THEIR DISTRIBUTION IN TIME AND SPACE

If the estimated total energy resource potential of the world is reduced to a common denominator, then the total resources are estimated at 20615 Terrawatt years (TWyr). Assuming that all these resources are recoverable, and applying today's technology, they would suffice for 1718 years under no-growth conditions and 133 years assuming an annual growth rate of 3%.

It should, however, be borne in mind that only about 15% (or 3093 TWyr) of the world's resources can be regarded as proved or partly proved and recoverable at current price levels and technology. Assuming a no-growth scenario, these resources will meet future energy requirements for a period of 257 years. At a 3% annual growth rate, resources will last for 72 years. The various resources would be depleted at the following rates: oil 32 years, gas 39 years, uranium 52 years, with coal bringing the total life expectancy of energy resources to 72 years. If due allowance is made for improved technology, a 15 % stretch-out could possibly be attained. This however, could, be negated by an increased growth rate.
In considering which areas of the globe represent the most promising target areas for prospection, it should be noted that the distribution of energy minerals is distinctly time-bound and occurs in a series of clearly defined rhythms ranging from the early Proterozoic to the Recent.

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LES GITES DE PLOMB-ZINC EN MILIEU CARBONATE DU NORD DE L'ALGERIE

Les minéralisations plombo-zincifères du Nord de l'Algérie appartiennent pour l'essentiel à 3 types de minéralisations:

1. Minéralisations en amas à Pb, Zn et barytine dans des environnements carbonatés d'âge mésozoïque (El-Abed, Takhemaret, Aïn Kahla, Kherzet Youcef, Dj. Ichmoul, Mesloula).
2. Minéralisations à Pb, Zn, Cu (Barytine) liées directement au volcanisme tertiaire (Oued El Kebir, Oued Amizour).
3. Minéralisations à Pb, Zn, Cu liées à des circuits hydrothermaux convectifs associés à des phénomènes de dômes thermiques (Aïn Barbar, Kef Oum Theboul).

Le premier type se présente en 4 districts:

a. Le district du domaine tlemcenien (Gîtes de El-Abed, Deglen dans la région des Monts de Tlemcen; indices de Oued Zebboudj, Khenifer, Takhemaret dans la région de Saïda; indices de la région de Filaoucène dans les monts des Traras). Ce district relaie en territoire algérien les gîtes marocains de Touissit-Boubekeur. La minéralisation est pour l'essentiel associée à une surface d'émersion karstifiée d'âge Bajocien supérieur.
b. Le district de l'Ouarsenis où les minéralisations en amas sont localisées dans des calcaires jurassiques qui apparaissent en extrusion dans la zone des nappes
c. Le district du môle de Aïn M'lila où les minéralisations en amas, à différents niveaux stratigraphiques, sont associées à des discontinuités physiques dans une série de dolomies épicontinentales du Jurassique et du Crétacé moyen (Aïn Kahla, Kherzet Youcef, Dj.Zdim, Chaabet el Hamra, Dj.Gustar).
d. Le district qui se poursuit en Tunisie (Dj.Adjered, Dj.Hamra) présente des minéralisations localisées dans des poches karstiques développées à l'Aptien supérieur (Mesloula, Bou Djaber).

Si pour le district de l'Ouarsenis, la position particulière rend difficile la reconstitution de l'environnement géologique originel, pour l'ensemble des autres districts on peut observer:

- A l'Ouest, une localisation des minéralisations sur une surface d'émersion développée sur des carbonates tidaux, d'épaisseur généralement inférieure à 100m.

- A l'Est, une association avec plusieurs surfaces d'émersion développées à l'intérieur d'épaisses formations carbonatées néritiques.

- Une dolomitisation et parfois une silicification des carbonates acquise proparte pendant l'émersion.

- Le caractère local des émersions est guidé par des éléments structuraux, hauts-fonds du socle à l'Ouest, diapirisme précoce au centre et à l'Est, actifs pendant la sédimentation et qui s'accompagnent de dolomitisation épigénétiques associées aux minéralisations.

Les minéralisations à Pb-Zn du domaine tlemcenien, du môle de Aīn M'lila et de l'Est, paraissent caractériser un même type de métallogénèse de plate-forme épicontinentale instable.

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CLAY MINERALS IN URANIUM DEPOSITS, COLORADO PLATEAU, U S A

The processes that produce deposits of uranium and vanadium also produce distinctive assemblages of clay minerals which may be used to infer geochemical conditions at the time of ore formation and, in some cases, geochemical processes subsequent to ore formation. For example, in the Henry Mountains, Utah, the formation of tabular uranium deposits was accompanied by the formation of a vanadium-rich chlorite within the ore, which grades into a mixed-layer chlorite-smectite in the unmineralized lateral extensions of the deposits. A sharp boundary between the chlorite-rich uranium ore zone and the overlying barren rock is inferred to be the position of an interface between meteoric waters and an underlying fluid derived from a closed basin evaporite environment, based on stable isotopes and other geochemical data. A similar scenario may have existed during mineralization in the San Juan Basin, New Mexico, but subsequent tectonism and fluid movement within the basin have overprinted the original ore mineralogy with authigenic and diagenetic clay minerals which suggest that warm, potassium-rich fluids have migrated updip within the uranium-bearing sandstone from deep in the basin.

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ON THE OCCURENCE OF URANIUM BEARING QUARTZ-PEBBLE CONGLOMERATES OF KARNATAKA, INDIA

The importance of Lower Proterozoic, pyritiferous, sometimes gold-bearing, oligomictic quartz-pebble conglomerate as in Canada and South Africa serving as important hosts for uranium is well known. In India, similar conglomerates have been located in the Archaean, granite-greenstone belts of Karnataka at the base of the Dharwar (Lower Proterozoic) metavolcanics - metasedimentary succession with overlying banded iron formations of the Bababudan Group of rocks. Investigations carried out by the Atomic Minerals Division have revealed that some of thehe carry significant uranium values of variable grade, thickness and depth persistence. Of the several locations discovered so far, the occurences at Walkuji, Yelakki in South Kanara and Chikmagalur in Chikmagalur District in Karnataka are significant.

The Chikmagalur conglomerate bed is exposed in six prominent but detached outcrops aggregating to a strike length of 32 km along the southern fringe of the Bababudan belt. Radiometric investigations followed by test drilling have indicated the presence of mineralised bands of variable grade and thickness without any thorium. Detailed investigations by exploratory drilling are proposed to be carried out after preleminary investigations by geophysical surveys are over for delineating economically viable deposits.

Similar uraniferous conglomerates are traceable intermittently over a length of 3 km along the western scarp of the Western Ghats near Walkunji about 60 km north-east of Mangalore port in South Kanara District. Uranium mineralisation has been encountered during exploratory drilling in recent investigations over an average thickness of 2 m. Yet another conglomerate bed has been located at 70 km NW Walkunji near Yelakki in a similar geologocal setting and strike extension.

The oligomictic conglomerates consist of sub-angular to rounded pebbles of quartz in siliceous and/or micaceous matrix. Fine to medium grained granulated quartz with sericite, fuchsite and biotite, associated with pyrite, pyrrhotite, chalcopyrite, uraninite etc., constitute the matrix, Gold content is poor, upto 1.5 ppm.

The basement granites underlying the uraniferous conglomerates have been dated at 2690±60 m.y. or earlier while the age of the metamorphism overlying the metavolcanic rocks is 2285±47 m.y. which suggest lower Proterozoic age for the conglomerates. The margins of the Bababudan Group extending over 1.000 km serve as a fertile ground for exploration to establish conglomerate type of uranium deposits.

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MINERALIZATION OF BRECCIA PIPES IN NORTHERN ARIZONA

The Paleozoic sedimentary rocks on the Colorado Plateau of northern Arizona are host to hundreds of breccia pipes. The uranium and copper deposits in these breccia pipes transgress formation boundaries from the Mississippian Redwall Limestone to the Triassic Chinle Formation. These breccia pipes are not classic breccia pipes in that there is no volcanic rock associated with them in time or space. They are the result of solution collapse within the Redwall Limestone and stoping of the overlying strata. The karst development in the

Redwall Limestone began in the Mississippian and apparently either continued to the Triassic, or was at least once again active during that time. The mineralization apparently occurred shortly thereafter, sometimes during the Mesozoic. Mining activity in breccia pipes of the Grand Canyon region began during the 19th century and continues today with the operation of the Hack II Mine, although the exploited commodity has changed from Cu to U. Although small in size, these pipes contain samples with up to 55 percent U_3O_8 and can yield ore averaging between 0.30 and 0.60 percent U_3O_8.
Mineralization commonly occurred within nodules and concretions associated with pyrite and geothite, within a sandstone matrix, and along fractures. Some of the nodules are encrusted with malachite and are exceptionally enriched in Ag. Pyrite is abundant and the organic carbon content of many rocks is suffiviently high to suggest it, along with the pyrite, may be a reductant for uranium. In contrast, it is possible, if uranium were transported as a bicarbonate or carbonate complex, that only a conduit of brecciated rock was necessary to release CO_2, disrupting the equilibrium and allowing uraninite to precipitate. An extensive suite of elements is significantly enriched in the mineralized rock: Ag, As, Ba, Cd, Co, Cr, Cs, Cu, Hg, Mo, Ni, Pb, Sb, Se, Sr, V, Zn, and the rare earth elements. Of these, Pb, Zn, and particularly As, appear to be the best geochemical indicators of mineralized pipes. At present the origin of the mineralizing fluids is not known. The lack of extensive silification within the breccia, along with the 60 to 110^{o} fluid-inclusion filling temperature on calcite, suggest relatively low temperature mineralizing fluids of unknown origin.

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ON THE SEDIMENTARY ENVIRONMENTS OF THE LATE SINIAN AND EARLY CAMBRIAN CARBONACEOUS FORMATION IN SOUTH CHINA AND THEIR RELATIONS WITH URANIUM MINERALIZATION

Uranium deposits located in Late Sinian and Early Cambrian carbonaceous formation in South China is a special type of stratabound and diplogenetic deposits in marine sediment. The preliminary studies indicated that the sedimentary environments and depositional conditions are the main foctors for the formation of Uranium deposits, which the detailed conclusions are as follows:

1) Areal depositional model has been established and there were four facies regions from northwest to southeast inverstigated district, facies regions of shallow water carbonate platform, of backisland shallow sea basin, of island uplift/ submarine uplift and of fore-island bathyal basin. Among them, the existence of island uplift/

submarine uplift resulted in the differentiation of sedimentary facies, separating the sea area and blocking the sea flow as a barrier for deposition.

2) The island uplift/submarine uplift facies region, both a transitional region of geologico-geochemical conditions and a organism-breeding region, led to the deposition of carbonaceous formation rich in uranium from which areal uranium metallogenic belt was formed.

3) The subdepression in island uplift/submarine uplift facies region playing a role of geochemical barrier provided the available sedimentary environments for localization of uranium deposits, as a efficient "ore trap".

4) Uranium enrichment in strata was related to stabilization of sedimentogeochemical barrier.

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GENESIS OF URANIUM DEPOSITS IN NEOGENE SEDIMENTARY ROCKS OVERLYING THE MENDERES METAMORPHIC MASSIF, TURKEY

Uranium deposits in the Köprübasi area of western Turkey occur in fluviatile sedimentary rocks which are underlain by high-grade metamorphic rocks of the Menderes massif. These deposits occur in Neogene conglomerate beds that contain a matrix of abundant silt and clay and are in beds of sandstone. Uranium is present as a matrix impregnation in tabular lenses within the conglomerate and sandstone beds. Both oxidised and unoxidised deposits occur. Oxidized deposits can be divided into jarosite-waylandite-rich and ilmenite-rich types, both of whith occur near exposures of metamorphic basement rocks. Uranium in the ilmenite-rich type is disseminated uniformly throughout the sandy matrix of the conglomerate. Uranium in unoxidized sandstone is disseminated throughout the clayey matrix and is associated with authigenic pyrite and siderite.

Ore-grade uranium concentrations in the unoxidized deposits are confined to pyrite-rich zones, whereas only low-grade mineralization occurs in siderite-rich zones. Authigenic pyrite formed during diagenesis. This pyrite subsequently reduced oxigenic uraniferous groundwater and induced precipitation of the uranium. Oxidized jarosite-waylandite-associated uranium deposits apparently formed by oxidation of reduced uranium deposits. Therefore, all the deposits are epigenetic ih origin, formed by precipitation of uranium by groundwater solutions that moved through the host rock. The basement metamorphic rocks are believed to have been the major source of uranium.

YOULES IAN

PAINTER URANIUM DEPOSIT

The Mt. Gee, armchair, streitberg ridge and radium ridge primary uranium deposits consist of uraninite, pyrite, chalcopyrite, molybdenite, monazite, fluorite and barite in a matrix of chlorite and hematite, which infilled and replaced as layers a potash rich (10% k20) partly sericitised granitic breccia in the radium ridge beds. Minor amounts of sandstone, siltstone, diamictite and arkose also occur. Uranium content averages 0,1 % along with Cu 0,05%, Mo 0,03%, Co 0,035% and Ce group 0,5%. Isotopic data indicate a magmatic origin and fluid inclusions show temperatures of 300-400 degrees C with aqueous solutions of low salinity.

Hodgkinson deposit consits of uraninite with silica, pyrite, minor arsenopyrite and trace sulphides in brecciated foliated granitic rocks which were silicified or kaolinised and sericitised: repetitive brecciation with infillings of uraninite, pyrite and chalcedony occurred, the latest being a secondary enrichment through downward leaching.

Early mine workings are in permeable zones usually faults in or adjacent to the primary deposits. Torbernite and autunite were deposited by groundwaters of probable tertiary age. Age of primary mineralization is not established.

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ИЗОТОПНОЕ ИССЛЕДОВАНИЕ УРАНОВОГО МЕСТОРОЖДЕНИЯ В КРЕМНИСТО-ИЗВЕСТКОВЫХ ПОРОДАХ И ГЕНЕЗИС МЕСТОРОЖДЕНИЯ

Урановое месторождение залегает в линзах кремнисто-известковых пород серии слабометаморфизованных обломочных отложений мелководно-морской фазы среднего Силура в Индийско-Китайских складчатых зонах. Рудоносными породами являются известняки, кремнистые породы, углеродистые сланцы и другие породы, составляющие линзы. Оруднение, очевидно, контролируется стратиграфией, литологией и межпластовыми нарушениями. В районе развиваются среднеосновные дайки и современные термальные источники.

Изотопное изучение показывает: I. Рудоносные кремнисто-известковые линзы являются системами, бедными торием и богатыми ураном. 2. Урановое месторождение было сформировано из вышеуказанных систем процессом многократного концентрирования урана (около

140,70,50,35,22,14 млн.лет). 3 . Уран в рудном растворе привносится не из мантии, а из земной коры с аномальным свинцовым составом, главным образом, из кремнисто-известковых линз. 4 . С понижением температуры рудоносного флюида, значение O^{18} явно уменьшается и изменяется. 5 . По изотопным составам серосодержащих и углеродосодержащих минералов, образованных в период минерализации, и парагенезисам минералов устанавливаются происхождение серы и углерода и физико-химические условия рудообразования. Формирование месторождения является главным образом результатом долговременных и многостадийных процессов, вызванных следующими факторами: многократными деятельностями структурных нарушений в Яньшаньской и Гималайской стадиях; восходящей миграцией глубинного раствора в область понижения нагрузки, смешением его с атмосферными осадками и экстракцией элементов из ураноносных геологических формаций; концентрированием и фиксацией урана при благоприятных геохимических условиях. Формирование месторождения происходило в связи с гидротермальным процессом и последующим преобразованием продуктов гидротермальной деятельности.

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ON THE GENETIC TYPES OF URANIUM-BEARING GRANITES AND THEIR RELATED URANIUM DEPOSITS

The hydrothermal uranium deposits which genetically associated with granitoid rocks are widely distributed in the world. Owing to different metallogenetic characteristics of these deposits, which lead various authors to put forward different opinions about their genetic origin. According to materials now accumulated, the source materials of mieralization and nature of ore forming solutions of these deposits are quite complicate. The author considers that, for further understanding of the origin of these types of uranium deposits is necessory to study the petrogenesis of related granite bodies and carry on comprehensive analysis and correlation. Based on these works, a more reasonable conception may bring out. This paper introduces mainly the result of research works engaged recently on uranium bearing granites and related hydrothermal uranium deposits distributed in South China by the present author and his colleagues, which indicate that the petrological, petrochemical, geochemical and the distribution of stable isotopes of different genetic types of uranium bearing granites are obviously different, and the characteristics of uranium deposits related to different types of granites are also different each other. These conception may also significant to the hydrothermal uranium deposits related to different types of granites distributed throughout other area in the world.

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