EDITORIAL

Looking at Soviet Geology

Twice in the past, in 1897 and in 1937, the U.S.S.R. has played host to the International Geological Congress. So as to set the scene for the 27th Congress, to be held this August once again in the Soviet Union, we devote the bulk of this special issue of Episodes to the geology and mineral resources of that country.

As R. Trümpy, the Past President of IUGS, has pointed out, geologists were among the first scientists to convene internationally in order to exchange ideas, to become acquainted with the natural framework of other areas and to establish scientific standards. From these early Congresses came a variety of commissions and other bodies, and as these organizations and their tasks became more numerous and complex, the need for liaison and coordination increased. IUGS was established in 1961 to meet these needs and, though originally a "child" of the Congress, the Union has now become its main sponsor. The key role of IUGS is to facilitate communications among geologists in a non-governmental framework. In sponsoring the Congress, IUGS does so with the view of maintaining scientific communications despite existing economic, social and political conditions.

Naturally, the gigantic task of organizing a Congress must be undertaken by the host country and its national institutions – in the present case, the Ministry of Geology and the Academy of Sciences of the U.S.S.R. The Union provides advice where needed, especially on the scientific programs, and many of the IUGS commissions, subcommissions, committees, and affiliated societies use this opportunity to hold their own business meetings and scientific sessions. For example, as reported elsewhere in this issue, the Commission on Stratigraphy, which is the largest member of the IUGS family, will hold its quadrennial meeting in Moscow, at which time many proposals for stratigraphic standards will be presented.

But the Congress is also a useful occasion for the host nation, as its scientists work feverishly to produce maps, reviews and field guides that might otherwise have waited for years. According to the President of the Congress, Ye.A. Kozlovsky, this is certainly true for the Soviet Union, which is offering many field excursions throughout its vast, varied and complex territory, as well as new and comprehensive publications describing its geology and mineral resources.

The reviews in this issue by leading Soviet geologists highlight some of the areas and topics of special concern to the U.S.S.R. Minister Kozlovsky and A.L. Yanshin give an overview of the main themes of interest to Soviet geologists, and papers by A.I. Zhamoida, B.S. Sokolov and M.A. Fedonkin, and A.Yu. Rozanov emphasize the importance of stratigraphy to their country and of Soviet strata to the world. Soviet approaches to metallogenesis are outlined by V.I. Smirnov and D.V. Rundquist. Two papers on regional geology by A.M. Dymkin and V.N. Puchkov (the Urals) and N.A. Logatchev (the Baikal rift), and the summary of lithospheric layering by S.V. Ruzhentsev and V.G. Trifonov provide a general look at the way in which Soviet geologists interpret the structure of their landmass. To underscore this aspect we include a recently released map of the U.S.S.R. showing the plate boundaries now recognized by some workers.

Many outsiders unfamiliar with Soviet geoscience may regard it as rather monolithic – an impression heightened by the language barrier, the characteristic style of scientific communications, and the very distinct structure of science. The short summary by D.P. Lobanov and E.D. Yershov of geological education in the U.S.S.R exemplifies the latter for many in the foreign geoscience community. Yet differences in interpretation among some of the authors in even this tiny sampling demonstrate the vitality of Soviet geoscience. Differences between many of their models and approaches and those popular elsewhere underscore the important contributions that geologists in the U.S.S.R. are making to the advancement of our field.

Naturally there are many important aspects to Soviet geology not included here: its massive oil and gas deposits, its surficial deposits, and the major contributions of Russian scientists to such disciplines as mineralogy, geochemistry and engineering geology. Some of these will be reviewed in forthcoming issues of Episodes, but the most comprehensive overview of Soviet geology will be available to those who attend the Congress in August, participate in the field excursions and exchange views with Soviet geologists.

This issue of Episodes would not have been possible without the cooperation and assistance of the U.S.S.R. National Committee of Geologists, headed by IUGS Vice-President V.V. Menner and R.I. Volkov, its Executive Secretary. IUGS is grateful to them, and to the staff of the Geological Survey of Canada who provided much of the necessary technical back-up, especially for the many illustrations that were redrawn in Ottawa. As regards terminology, we have retained terms defined in the AGI Glossary of Geology and attempted to explain those not included. We have also taken the opportunity to cite some of the recent geological literature on the U.S.S.R. that is available in English.

Finally, we note that this issue is being distributed by the Congress organizers to all registrants of the Congress. It is also going out, like all the 1984 issues, to over 200 geoscience institutions in developing countries, under the terms of a contract with Unesco for dissemination of geological information. This is the second year for this arrangement, which is a very practical example of international scientific cooperation. "Cooperation" because, despite the harsh economic conditions in many such regions, as IUGS becomes better known in Africa, Asia and Latin America, there is a tangible increase in participation by scientists there in the programs and activities of the Union and Unesco (e.g. IGCP, ICL, Geology for Development) and a corresponding advance in our knowledge of science and in our ability to manage natural earth resources.

FORTHCOMING ARTICLES

The PreCordillera of the Argentinian Andes

Precambrian Fossil Soils

Volcanic Hazards in Indonesia

The Caspian Basin

Sedimentary Precursors and Metamorphism

Soviet Geology: Achievements and Prospects

by Yevgeny A. Kozlovsky and Alexandr L. Yanshin

This article is a broad review of some of the major advances in unravelling the geology of the U.S.S.R. that have taken place since 1937 when the International Geological Congress was last held in that country. Not only has much progress been made in geological science but there has also been a great increase in the reserves of mineral raw materials and a major intensification in mining. References are given to some of the important recent Russian literature.

Geological Coverage

The U.S.S.R. is unique in size, occupying an area of 22.4 million km^2 or 1/6th of the total area of all the continents. It contains a variety of large-scale geological structures (Nalivkin, 1973 – Ed.), including the ancient platforms of Eastern Europe and Siberia with the Baltic, Ukrainian, Aldan and Anabar shields, and it also encompasses extensive portions of the Uralo-Mongolian, Mediterranean and Pacific fold belts of Phanerozoic age (Fig. 2; see also Fig.1 of Rundquist, this issue of Episodes – Ed.). Each of these megastructures can be subdivided into smaller regions distinguished by specific geological features, mineral assemblages, and geological history.

Much importance is attached in the U.S.S.R. to continuing regional geological, geophysical and geochemical studies (Figs. 1, 3). By 1940 only half of the country had been studied, mainly by small-scale geological surveys, but there is now complete coverage at a scale of 1:200 000. Some 30% of the Soviet Union has also been mapped to a scale of 1:50 000, including most of the major mining districts. Geological mapping follows a single, scientific and methodological approach that involves faunally characterized stratigraphic schemes, absolute age determinations, and the correlation of synchronous formations, igneous and metamorphic rocks.

Figure 1: A geological survey party of the Ministry of Geology at work in the Kirghiz Republic.

Stratigraphy and Palaeontology

Much work has been done on correlating large stratigraphic subdivisions within geological regions and across the whole country (see Zhamoida, this issue of Episodes – Ed.). Unified working approaches to the subdivision of Archean, Proterozoic and Phanerozoic complexes have been used as the basis for national geological maps at 1:1 000 000 and 1:200 000 (Nalivkin, 1963-1982). However, additional palaeontological and biostratigraphic data are needed to successfully complete this program.

The application of a variety of methods has enabled the development of both regional and global stratigraphic schemes. The integrated use of palaeontology (especially micropalaeontology), and palaeomagnetic and absolute age data has made it possible to extend stratigraphic correlation from regional to sub-global levels (e.g. Spizharsky et al., 1983; see also Sokolov and Fedonkin, and Rozanov in this issue of Episodes – Ed.).

Mineralogy

Soviet geologists have been able to penetrate the hitherto inaccessible internal structure of minerals, thanks to advances in solid-state physics, physical and crystal chemistry, as well as to modern techniques involving the electron microscope, the electron microprobe, and X-ray structural, laser-optic and spectroscopic studies. Associations of minerals, their composition, structure and other properties provide valuable information on the physico-chemical conditions under which they formed or were subsequently changed. These data have been used, for example, to develop the theory of endogenetic, exogenetic and metamorphogenetic mineral and ore formations (Lazarenko, 1963; see also Smirnov, this issue of Episodes – Ed.).

The work of A.E. Fersman on the typomorphism of minerals, has given rise to new mineralogical approaches that increase the effectiveness of prospecting for and evaluation of mineral deposits, especially when combined with geochemical and geophysical methods (Yushkin, 1977). These techniques have been of great importance in the discovery and commercial development of many new deposits including Al (nepheline syenite and alunite), Be (genthelvite and bertrandite-phenacite), B (datolite and danburite), Ta and Ni (microlite, rare-

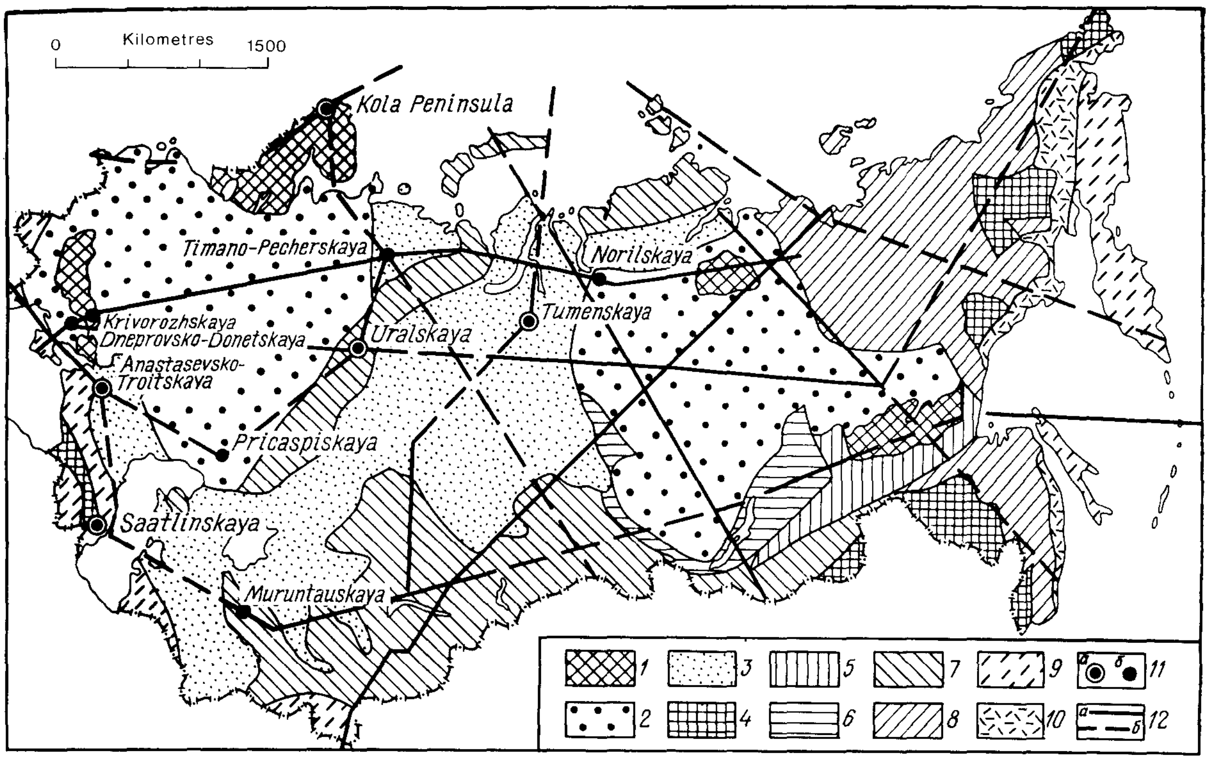

Figure 2: Major structural divisions of the U.S.S.R., showing the location of seismic profiles and deep drillholes. 1 – shield areas; 2 – ancient platforms; 3 – young platforms; 4 – median massifs; 5 to 9 – fold systems (5 – Pre-Baikalian; 6 – Baikalian; 7 – Palaeozoic; 8 – Mesozoic; 9 – Cenozoic); 10 – volcanogenic belts; 11– Deep (a) and Super-deep (b) wells; 12 – Deep seismic profiles (a – existing, b – planned).

earth plumbopyrochlore), Zr (baddeleyite) and non-metallic minerals such as zeolites, cryolite, brucite and wollastonite.

New methods of technological mineralogy have started to develop at the border between mineralogy and mineral processing. These techniques are intended to intensify the development and utilization of mineral deposits as progressively lower grades are being mined. Efforts are also being made to improve the recovery of all useful components, that is to devise a waste-free technology for mining. Finally, new ways of refining, altering and synthesizing minerals have been developed so that synthetic minerals like diamonds, gems and mica are now being produced on a commercial scale (Kalashnikov, 1980).

Petrography

The study of petrography and petrogenetic processes has been much advanced by the application of geophysical, geochemical and geomathematical methods, and through experimental studies of the thermodynamics of mineral-forming processes (Marakushev, 1979; see also Vistelius, 1980 – Ed.). Soviet and foreign petrographers have demonstrated clearly that the bulk of igneous rocks formed either from granitic magma formed in the crust, or from basaltic magma generated in the upper mantle. This conclusion has put an end to the long-standing debate on the nature of magma, and to the theory that all igneous rocks originated from a single parent magma. The works of Soviet volcanologists, particularly those dedicated to the study of acting volcanoes of Kamchatka and the Kuril Islands are well known (Dunichev, 1983; see also Fedotov and Markhinin, 1983 – Ed.). Much data has been obtained about the production of ore elements in the process of volcanic eruptions.

Soviet petrographers have also drawn important conclusions concerning the history of igneous activity throughout geological time, from the primitive komatiite-basite magmatism of Precambrian time to the strongly differentiated magmatism of the Phanerozoic, with its increase in the occurrence of calc-alkaline and alkaline series. Advances in modern planetology and the study of lunar rock specimens have also proved essential in understanding the early stages of the evolution of the Earth (see Barsukov and Basilevsky, 1983 – Ed.). It is assumed that at the first stages of its consolidation, the Earth's crust was similar to that observed today on the Moon.

The Soviet Union is largely composed of Precambrian metamorphic complexes, and the concept of metamorphic facies is thus of paramount importance. It has now been established that specific metamorphic rocks are formed only under specific PT conditions, and the stability ranges for individual minerals and mineral associations, metamorphic facies and subfacies have now been determined (Sobolev, 1972, 1974). Zoning has also been recognized from physico-chemical studies on metasomatic rocks formed under high PT conditions at the contacts between chemically heterogeneous rocks.

Lithology

Considerable progress has been made over the past 30 years in the field of lithology. One example is the development of the concept of a sedimentary formation as representing a natural rock association formed in specific climatic and tectonic environments, and containing a characteristic assemblage of minerals (Tseisler, 1977). More recently the concept of the formation has been extended by Siberian geoscientists to igneous, metamorphic rocks and related ore associations (Kuznetsov, 1964; Masaitis, 1979).

A classification scheme has been developed for ancient and modern sedimentation processes taking place in platform, geosynclinal and oceanic environments. The palaeogeographic and physico-chemical characteristics of each of these types have been established, as have the laws governing changes in composition and structure of sedimentary rocks at the diagenetic, epigenetic and early metamorphic stages. Important contributions also came from detailed studies of weathering processes under widely varying climatic conditions, and of the formation of mineral deposits (particularly placers of noble metals) associated with these processes (Perelman, 1972).

***Figure** 3: A helicopter is the best method for transportation over the vast Siberian territory.*

Lithology was the first among the earth sciences used to investigate the irreversible evolution of geologic processes, as demonstrated by variations in the composition of the atmosphere (gases) and hydrosphere (salts), and by the development of the organic world of our planet. Global studies in this field have established a number of regular patterns in time that govern the distribution of sedimentary mineral deposits, and these concepts have also been extended to igneous and metamorphic facies and to ore deposits (Bogolepov and Zharkov, 1981).

Geophysics

Thanks to major improvements in theory, techniques, facilities and data processing systems, geophysics is now widely used in regional geological studies and at all stages in mineral and petroleum exploration. Geophysical methods have also become an effective tool for studying deep crustal layers and upper mantle, and shelves of seas and oceans.

New advances in the last decade include the development of a seismic exploration system, which is now the basic method used to detect potential oil and gas structures on land and offshore areas (Kunin, 1983). Airborne gravity and electromagnetic methods are increasingly used, as are geophysical techniques from space. Airborne gamma-spectrometric and a range of nuclear-physical methods (Petrosyan, 1981) have also proved to be highly effective in prospecting for different mineral deposits. Borehole geophysical measurements, which permit effective correlation between drill holes, reduced the need for so many holes during exploration work, especially when defining oil and gas pools (Dyakonov et al., 1977).

Geo-, Bio- and Ecogeochemistry

In recent years geochemical prospecting methods have been greatly improved, and when used in combination with geophysical and geological approaches they have led to the discovery of many new deposits (Grigoryan, 1982). Concealed mineral deposits are searched for and evaluated by the use of primary and secondary lithochemical dispersion haloes of indicator elements. Work on the geochemical zoning of hydrothermal mineralization has led to a technique tc estimate the erosional level of a given mineral deposit and to help identify zones of scattered ore mineralization. A method has been developed for prospecting for ore bodies buried under thick overburden using "sorbtion-salt dispersion haloes" of indicator elements. High-sensitivity atomic absorption field and laboratory devices have been designed, assisting in the development of a prospecting technique for buried sulphides using mercury gas dispersion haloes. Automated systems and programs of computer-based processing of geochemical data have been developed to assist in this work.

***Figure** 4: Overlooking the Naryn Valley in the seismically active Soviet Kirghizia. Nearby and distant hills are composed of gypsum-bearing Neogene sediments.*

In the U.S.S.R. much importance is attached to the development of biogeochemistry, which deals with the processes of migration of chemical elements in the crust caused by the action of living matter. Likewise, geochemistry applied to the solution of environmental problems caused by the extravagant or harmful activities of man have led to the new study of ecological geochemistry or ecogeochemistry (Perelman, 1975; Glazovskaya, 1980).

Tectonics

Valuable data gathered during the study of the oldest geologic structures (Salop, 1983 – Ed.) have been used to reveal regular changes in the tectonic regimes of the Baltic, Ukrainian and Aldan shields, and to estimate the effect that the Precambrian basement had on the development of Phanerozoic mobile belts (Krats and Zapolnov, 1982).

It is now recognized that deep faults and a high degree of heterogeneity of the lithosphere play a significant role in the evolution of the planet (Puscharovksy, 1982). Studies of the tectonics (and metallogeny) of the basement of ancient mobile platforms, such as the Siberian craton and other massifs (e.g. Bureya, Khankai, Okhotsk and Omolon), have led to concepts about the processes of tectonic and igneous reactivation of structures stabilized earlier. Epochs of tectono-igneous reactivation coincided with periods of major crustal deformation during the transition between Archean and the Proterozoic, the early and late Proterozoic, the late Palaeozoic and early Mesozoic, and the late Mesozoic and Cenozoic.

Tectonics, as one of the major disciplines of geoscience, has served as a basis for the development of a well-substantiated global concept, which is bringing us closer to a fuller under standing of the structure and evolution of our planet (Sorokhtin, 1974; Zonenshain and Savostin, 1979; see also Artyushkov, 1984 – Ed.). Very popular is the plate tectonics concept based on the study of the ocean-floor structure by drilling and palaeomagnetic measurements. Plate tectonics, however, does not describe all tectonic processes of the geological past (see Dymkin and Puchkov, and Ruzhentsev and Trifonov, this issue of Episodes – Ed.). There is, for example, little doubt about the existence of independent vertical movement in the crust. These are caused by phase transitions at the Moho and Conrad discontinuities, by the rise to the base of the lithosphere of hot low-density mantle material, by isostatic compensation and by other factors. These vertical movements are responsible for the block structural pattern of the continental and oceanic crusts (Artyushkov et al., 1979). Many data on these and horizontal movements come from geodetic analyses on the ground and from satellites (Bulanzhe, 1981).

Advances in seismology have had a marked bearing on the field of tectonics (Fig. 4). Extensive data on seismic events within the U.S.S.R. and elsewhere have demonstrated a link between earthquake sources and zones of active deep faults. The expansion of seismic networks and geophysical polygons set up in active seismic areas of the country has permitted seismologists to work out a rather successful technique for long-term earthquake prediction, which has already been verified in a number of cases (Anon. 1982). A medium to short-term earthquake prediction technique is now being developed, based on types of movements along the deep faults.

Metallogeny

One of the important achievements of Soviet geoscience is the recognition of certain regular patterns in the formation and distribution of minerals (Shcheglov, 1980; see also Smirnov, and Rundquist, this issue of Episodes – Ed.). Formational analysis applied to metallogeny makes it possible to identify metalliferous associations (formations), and to determine the location of mineral deposits within these associations. This popular new approach to geological exploration permits us to single out and rank promising areas, and to provide a preliminary quantitative estimate of mineral reserves of both large and small areas.

Hydrogeology and Engineering Geology

Fundamental research in hydrogeology is aimed at revealing the laws governing the migration of ground water in the free-water exchange zone of the hydrosphere. This work contributes largely to the exploration for and estimation of the groundwater reserves, the prediction of water inflows into underground workings during mining, and the control of water-salt regimes on reclaimed lands (Kats and Shestakov, 1981). Work on the spatial variation in engineering properties of rocks assists hydrogeologists to define regional characteristics, to develop the theoretical basis for predicting exogenetic processes, and to construct maps showing the predicted development of geodynamic processes to the year 2000 (Artyshkov, 1982; Sergeyev, 1976-1978).

Mineral Resources

The U.S.S.R. possesses large reserves of oil and gas (see Meyerhoff, 1981, 1983 – Ed.), including one of the world's largest oil and gas provinces, that of West Siberia. This latter region has been rapidly developed, from an output of 200 tons of oil in 1964 to the present figures, which represent over 60% of the total volume of oil and 50% of the gas produced in the U.S.S.R. The largest oil and gas provinces within the Russian platform are represented by the Volga-Ural, Timan-Pechora and Caspian provinces. Large gas fields have been explored in the Amu-Darya region of Central Asia, and considerable oil and gas potential is associated with the Lena-Tunguska, Yenisei-Laptev and Lena-Vilyui provinces of East Siberia.

The Soviet Union is rich in reserves of bituminous and brown coal (Anon, 1962-1978). The major Donbas basin provides one-third of the Soviet production of coal, almost half of which is of coking quality. The Kuznetsk basin of West Siberia has become the largest source of high-quality power-generating and coking coals; coals from this basin are distinguished by their high quality and great variety in rank. The Kansk-Achinsk basin is unique in its large brown coal reserves and favourable mining conditions; the development of this basin is one of the most important energy goals of the U.S.S.R. Sizeable coal deposits have also been explored in the Pechora, Karaganda, Ekibastuz and South Yakutia basins, among others, and there are immense resources in the as yet poorly studied Tunguska and Lena basins of Siberia.

Figure 5: *Drilling for groundwater in Central Asia.*

The supply of ferrous metals is well provided from mineral resources (Smirnov, 1974). Iron ore deposits of the Krivoi Rog basin in the Ukraine and of the Kursk Magnetic Anomaly area occupy leading positions both in identified reserves and production. Large iron deposits are also mined in the Urals and the Kola Peninsula, in Karelia, Kazakhstan, and West and East Siberia, and new districts are being explored in South Yakutia. The Soviet Union possesses considerable resources of manganese ores in the Ukraine, Georgia and central Kazakhstan, and chromium ores in northwest Kazakhstan.

Large reserves of non-ferrous metals have also been established. Copper deposits are being worked in Kazakhstan (cupriferous sandstones, Cu sulphide and Cu porphyry ores), Uzbekistan (Cu porphyry), the Urals (Cu sulphides), the area of the Baikal-Amur Railway (cupriferous sandstones) and together with Ni in the Norilsk district and the Kola Peninsula. Pb and Zn are mined in Rudnyi Altai and central Kazakhstan, Uzbekistan, Tadzhikistan, Transbaikalia, Azerbaijan and in the Krasnoyarsk region. Al comes from bauxites of the Urals, Timan, Kazakhstan, the Kursk Magnetic Anomaly area and the Arkhangelsk region as well as from nepheline-bearing rocks of the Kola Peninsula and West Siberia. There are also the alunite ores of Transcaucasia, W in the North Caucasus, Kazakhstan, Transbaikalia and Far East, Sn in the Far East and Kirgizia, and Mo in East Siberia, Kazakhstan and Armenia. The development of the diamond deposits of Yakutia represent a remarkable achievement (Anon, 1967).

Large reserves of raw fertilizer materials have been discovered in the world-famous apatite deposits of the Khibin group on the Kola Peninsula, in phosphorite deposits of Kazakhstan, central areas of the European part of the U.S.S.R. and Estonia, and in potash salts of the Perm area Byelorussia, Western Ukraine, Turkmenistan, and East Siberia.

Groundwater provides the water supply for some two-thirds of the towns in the U.S.S.R. (Fig. 5). More than two thousand deposits of fresh water and over 400 of thermal, mineral and technical waters have been discovered and are used for domestic and technical water supplies as well as for medicinal (balneological) purposes.

A Look at the Future

The program of economic and social development for the period from 1981 to 1990, which was adopted by the 26th Congress of the Communist Party of the Soviet Union, directs Soviet geologists to speed up their study of the country and to locate additional mineral reserves, primarily those of fuel and energy. The program lays out measures to discover new oil and gas deposits in West and East Siberia, in the European portion of the country, in Central Asia and Kazakhstan, as well as on the continental shelf. Mineral reserves will be expanded in the areas of existing mining centres, especially in the areas where territorial production complexes are located.

Exploration efforts will be intensified for rich and easily beneficiated ferrous and non-ferrous metals, coal, bituminous shale, raw materials for nuclear energy, building materials and mineral fertilizers, as well as for groundwater. Large mineral exploration programs will also be carried out on the continental shelf and in the oceans. Successful fulfillment of these tasks will require the rapid development and improvement of fundamental and applied research, primarily in the field of exploration and economic evaluation of mineral deposits. Experimental work is now underway to investigate the conditions of formation and migration of deep mineral deposits and hydrocarbons.

Figure 7: *The "Three Brothers," Kamchatka Peninsula*

The large-scale prospecting programs planned for regions of unexposed mineral deposits demand first the preparation of large-scale geological maps to serve as a reliable base for exploration efforts. Preparation of a stratigraphic basis for these maps is a complex problem, for regional stratigraphical schemes must be, on the one hand, as detailed as possible reflecting local characteristics, while on the other hand, allowing for reliable correlation with stratigraphical subdivisions of other regions. Of particular importance is the detailed stratigraphical subdivision of the Precambrian, which has considerable mineral potential.

Figure 6: *The Kola super-deep borehole.*

Evolution of the material in the Earth's interior is considered to be a driving force for geological processes, determining thermodynamic regimes for sedimentation, igneous activity and metamorphism. This deep-seated regime also controls the material composition of the crust, its tectonic framework and the conditions under which mineral deposits are formed. For these reasons a systematic study of the deep crustal structure of the entire U.S.S.R. territory has been launched. A network of mutually linked geophysical profiles supported by deep and super-deep drill holes provides a key observation system for this study, backed up by data from satellites and airborne surveys (Fig. 2, and Kozlovsky, 1982a). The first of these drill holes, the Kola Super-deep (Fig. 6) has now reached a record depth of over 12 km (see Kozlovsky, 1982b – Ed.), and the second, the Saatly SG-1 Super-deep of the Southern Caucasus, is now at 8.5 km. Other deep and super-deep holes will be drilled in the West Siberian, Caspian and Dnieper-Donets oil and gas provinces, and also in the Urals, Noril'sk, Muruntaus and Krivoi Rog ore districts.

The search will continue for an optimum set of geological, geophysical and geochemical techniques for mineral exploration. Much work now is being directed towards the development of new geophysical prospecting equipment, using the latest achievements of mathematics, physics, automation, telemechanics and instumentation, and cryogenic and microprocessor technology. Great emphasis is being placed on direct methods of prospecting, including three-dimensional seismic exploration surveys that utilize principles of holography. Powerful energy sources for deep crustal studies are being developed, such as magnetic hydrodynamic generators

(Volkov, 1983), and vibroseismic and laser systems. Updated telemetry systems using satellite communication links are being devised to improve the transmission of geophysical information.

In the field of exploratory drilling, efforts are being directed to the development of new and more effective rock-crushing techniques, to the optimization and automated control of technological processes by means of microprocessors and mechanization (robots and manipulators), and to the field management of drilling operations.

One of the current trends in research is the development of the scientific basis and technology for predicting changes in the geological environment brought about by human activity. This work is being carried out within the framework of an international project with Unesco and UNEP entitled "Protection of Lithosphere as Component of Environment." This includes a long-term integrated program on the "Scientific Basis and Development of Lithomonitoring of the U.S.S.R," which is working out a unique system of estimation, prediction and control of changes in hydrogeological and geotechnical conditions resulting from industrial and other human activities. The problem of environmental protection is closely connected with the need to protect mineral resources, which are great but not unlimited, and whose rational utilization is becoming more and more vital today.

Further progress in geosciences will require, first, a thorough study of the outer part of the Earth, both on the surface and in depth, using the entire arsenal of scientific and technical facilities available; second, specialized experiments; and third, extensive generalizations of the accumulated data. Modern geology must not confine itself only to the qualitative characteristics of events and processes, but must produce quantitative estimates as well. In this way we can raise the study of the Earth's interior to new levels.

Finally, we in the Soviet Union are very pleased that the 27th Session of the International Geological Congress is being held in the U.S.S.R. in 1984. Foreign participants will have an opportunity to acquaint themselves with the achievements of Soviet geology. Soviet geologists in turn will welcome an exchange of ideas and methods with their foreign colleagues. The scientific proceedings of the Congress will undoubtedly contribute to the development of a common view about the geological structure and evolution of the Earth.

Prof. **Ye.A. Kozlovsky** is Minister of Geology of the U.S.S.R., President of the Scientific Council on the "Investigation of the Earth's Interior and Super-deep Drilling," scientific leader of the international program on the "Protection of the Lithosphere as a Component of the Environment," and President of the Organizing Committee for the 1984 International Geological Congress. The author of over 200 scientific publications, he has studied for many years problems of the global mineral resources economic evaluation of mineral deposits, and the optimization and automatization of drilling technology.

Academician **A.L. Yanshin** is Vice-President of the Academy of Sciences, Chairman of its Earth Sciences Section and the Director of the Institute of Lithosphere. One of the senior geoscientists of the Soviet Union today, he is the recipient of many awards and honours. His main research concerns the tectonics of platform covers and recent marine basins, and the geological evolution of the crust.

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Comparing the Soviet Stratigraphic Code with the International Guide

by Alexandr I. Zhamoida

This article discusses similarities and contrasts between the stratigraphic classification used in the U.S.S.R. and that recommended in 1977 by the IUGS Commission on Stratigraphy. In pointing out a number of important differences, the author urges the development of an authoritative international code to "legitimize" a universal nomenclature and terminology.

Introduction

The development of stratigraphic classification in the U.S.S.R. began in 1952 under the guidance of L.S. Librovich (1954). Following much work by Soviet geologists on terminology and ordering, the first stratigraphic code for the U.S.S.R. was published in 1977 (see Zhamoida, et al. 1979; hereafter referred to as the Code).

One year earlier the International Stratigraphic Guide was published (Hedberg, 1976; referred to in the following as the Guide). The preparation for this had also begun in 1952 when the Subcommission on Stratigraphic Classification headed by Hollis Hedberg was formally created, to become later with its parent Commission on Stratigraphy the largest statutory body within the International Union of Geological Sciences. Although Soviet stratigraphers actively participated in the preparation of the Guide they do not agree with all of its statements.

There is much in common between the various national stratigraphic codes, including that of the U.S.S.R. However, whereas the latter follows the traditions of European geology, the Guide appears to the author to be based on American stratigraphic concepts as formulated by Schenck and Muller (1941). Nevertheless both the Guide and the Code outline the principles of stratigraphic classification for all intervals of geological time. The present paper deals with similarities and differences between the Soviet Code and the International Guide, and updates an earlier comparative study by Zhamoida and Moiseyeva (1980).

The general purpose of both the Code and the Guide is to arrive at an agreement in understanding, as well as in usage of stratigraphic terms and names that will make stratigraphic works and geological surveys more effective. The Guide is, of course, set within an international context but, apart from differences in terminology, it is similar in structure to the somewhat more concise Code.

Principles of Stratigraphic Classification

There are certain basic differences between the Code and the Guide with regard to their definitions of stratigraphy (Zhamoida and Menner, 1974). A starting point for the Code is the definition given in the second draft (1974, p.5): "Stratigraphy is a part of geology dealing with the sequence of rock strata formation in the Earth's crust, their original relations in space, and the recognition of stages in geological history." Hence, only those geological bodies whose properties permit the succession of their formation and their position in a stratigraphic section to be established can be named "strata."

The basic concept of the Guide is expressed in the definition of stratigraphic classification as the descriptive science of strata, the systematic organization of rock strata with reference to any of the characters, properties or attributes that rocks may possess. The author takes this to indicate that any geological body different from another is a stratigraphic unit. Stratigraphy thus becomes almost a synonym for geology, at least where stratified rocks are concerned. Moreover, because "the stratigraphic position of change for any one property or attribute does not necessarily coincide with that for another" (Hedberg, 1976, p.7), different independent categories of stratigraphic units are envisaged. The Guide also implies that the concept of stratigraphy should be supplemented by consideration of different rock characteristics. This is of great importance because, in fact, it acknowledges the complex character of most stratigraphic units as discussed in the Code and as used by European, Soviet and American geologists.

The Code specifies three categories of principal stratigraphic units (Table 1; underlined in the following): general, regional, and local (in order of decreasing geographic scope, with regional units extending over a whole continent or a major part of it – Ed). Divisions based on specific characteristics, such as zonal biostratigraphic units, are also recognized, as are auxilliary stratigraphic units. The Guide recommends the same categories (italicized in the following) except that in broad terms, *chronostratigraphic* and *lithostratigraphic* replace respectively general and local units (Table 2). Regional units, treated as important in the Code, are broadly equivalent to units of *regional chronostratigraphic* scale, mentioned in passing in the Guide.

Thus both the Code and the Guide deal with stratigraphic categories of similar type. These are interpreted in the Code as individual but not independent (Yarkin et al., 1971), and a similar wording is used in Chapter 8 of the Guide. However the relationships between these categories are interpreted quite differently in the Guide and the Code. In the former *litho-* and *biostratigraphic* units are considered as relatively objective, and *chronostratigraphic* units as interpretative ones. In the Code the relation between local, regional, and general units is that of the particular to the general, all the categories including general divisions being objective ones.

Terminology and Nomenclature

Some terms in the Code and the Guide coincide, though some of them have different meanings (Tables 1 and 2). In the Guide for example, there are at least 14 different kinds of *zone*, with appropriate prefixes and modifiers. There are also many kinds of *horizons*, for example a very thin bed, a surface or a stratigraphic level. Soviet geologists would agree on the use of geographic modifiers for *series* and on non-palaeontological terms for *chronozones*, as well as on the

TABLE 1: Main stratigraphic units used in the Soviet Code.

I Principal Stratigraphic Units Based on the Total Combination of All Characteristics

Category of general (standard) stratigraphic units*	Category of regional stratigraphic units	Category of local stratigraphic units
Eonothem (Eon) Erathem (Era) System (Period) Division (Epoch) Stage (Age) Zone (Phase) Zveno*** (Pora)	Stratohorizon Lona (Provincial zone)	Complex Series** Suite

II Stratigraphic Units Based on a Specific Characteristic

Category of zonal biostratigraphic units: biostratigraphic zones of different kind

III Auxiliary Stratigraphic Units

Category of lithostratigraphic units: body, member, band (bed), marker horizon

Category of biostratigraphic units: beds with fauna (flora)

*Geochronological units.
**To this stratigraphic unit, which may comprise several formations, the West European and American authors apply the name "group."
***For use in Quaternary stratigraphy

unusual terms *biozone* and *Oppel-zone* (Menner, 1978). However we do not regard terms such as *interzone, intrazone, interval-zone*, and *interbiohorizon-zone* as necessary in geological practice.

It should be noted that requirements for establishing, naming and describing stratigraphic units are the same in both publications. Similar rules of nomenclature are envisaged for new units, based on already existing units of the same rank. Formal and informal units of the Guide are consistent with principal and auxiliary units of the Code. There are some recommendations in the Guide as regards the question of priority, but the Soviet Code deals with this in much more detail in a special chapter discussing the rights of authorship. For example, "the right of priority ensures that valid stratigraphic units retain their original name and stratigraphic scope as determined by their author, which in future cannot be changed but only defined more exactly" (Zhamoida, et al., 1979, p. 109). "The author of a stratigraphic unit is a person or a team who were the first to publish its name and description in accordance with the requirements of the present Code" (ibid, p. 108).

Establishing Stratigraphic Types

The concept of stratotypes, their purpose, requirements for description, identification, marking, accessibility and so forth are similar in both the Guide and the Code. The basis for this concept is well explained by Librovich and Ovechkin (1963).

The present author prefers the definition of boundary stratotype as given in the Code – "a section chosen as a typical one in which the position of a stratigraphic boundary between two adjacent units is fixed unambiguously" (Zhamoida et al., 1979, p. 114). The Guide defines this rather lamely as a "specific point in a specific sequence of rock strata" (Hedberg, 1976, p. 24). According to the Guide, each *chronostratigraphic* unit should have a standard (stratotype) for its definition, and because no section can entirely reflect all the characters of a chronostratigraphic unit of any rank, the scope of the unit is better defined by a boundary-stratotype than a unit-stratotype. However, the author believes that even the most reliable stratigraphic boundaries can be defined by the study of overlying and underlying beds, that is by two adjacent stratigraphic units.

According to the Guide, the stratotype for a *lithostratigraphic* unit is based exclusively on the lithological character of the unit, without taking into account its palaeontological and other characteristics. This concept differs greatly from the requirements of the Code for stratotypes of local units similar in meaning. The Guide permits the use of lecto-, neo- and hypostratotypes beyond the limits of the original type area, but this is only permitted by the Code for a hypostratotype.

General and Chronostratigraphic Units

The concept and terminology for general and *chronostratigraphic* units are similar. However, the extent and rank of the former refer to divisions of geological time (Table 1), whereas the latter refer to rock strata formed during a specific interval of geologic time (Table 2). The Guide proposes the following methods for tracing the (isochronous) boundaries of *chronostratigraphic* units: physical interrelations of strata in a section, lithological and palaeontological characteristics, isotopic age determinations, geomagnetic reversals, eustatic changes in sea level, palaeogeographic and palaeoclimatic changes, orogenic processes, unconformities and other mineralogical, geochemical and geophysical features of the rock strata.

At the same time, these methods are widely used not only with respect to global but also to the regional and local units of the Soviet Code. The recognition in the Guide of *regional chronostratigraphic* units, appears to invalidate the uniqueness of *global chronostratigraphic* units, and the statement that "isochronous boundaries of chronostratigraphic units are inherently independent of all other kinds of stratigraphic boundaries, except as these may serve as local guides to chronostratigraphic position" (Hedberg, 1976, p. 86) becomes outdated.

The Guide presents a Standard Global Chronostratigraphic Scale in which it is stated that "only the units of higher rank lend themselves at present to worldwide application" (ibid. p. 78). The geographic extent of a *chronozone* has worldwide application only in theory, although that of a *stage* could be established in the future. The Guide also recommends procedures for the further refinement of the standard scale. In contrast, the Code accepts a prospective worldwide application for all the units of the standard stratigraphic scale, including even the phase, and defines their stratotypes as standards for tracing certain stratigraphic levels.

Regional Stratigraphic Units

The vast territory and variety of geological structures in the U.S.S.R. have led to the establishment of regional units (Table 1), which can be considered as intermediate between general and local stratigraphic units (Librovich and Ovechkin, 1963). Regional units are confined to a geological region, sedimentary palaeobasin or palaeogeographic realm. These are bodies of rock strata whose time of formation was determined by geological history, which reflected regularities of sedimentation and successive changes in faunal and floral assemblages of major sections of the Earth's crust.

The main taxonomic unit, the stratohorizon, is a correlatable grouping of coeval suites formed in different parts of a single palaeobasin. Subordinate to a stratohorizon is a lona (provincial zone), which is defined by a faunal or floral assemblage reflecting the most common features of palaeobiocenoses within a given palaeobiogeographic province or realm.

Regional stratigraphic units, as a formal category, are not envisaged by the Guide, though it does include a brief section on regional chronostratigraphic scales. The Guide also accepts the need for local and regional units as a basis for a standard global chronostratigraphic scale.

Local and Lithostratigraphic Units

Lithostratigraphic units were introduced into the Guide from the American Stratigraphic Code (ACSN, 1970), and there have been many comparisons with local units of the Soviet Code (Yarkin et al., 1971; Zhamoida and Menner, 1974; Zhamoida, 1980; see also Holland, 1983 – Ed.).

The main local unit is the suite, which is characterized by specific lithological-facies or petrographic features. The lithostratigraphic equivalent is the *formation*, determined only by lithologic character, although in practice American geologists may also use other characteristics. Lithostratigraphic classification is the first step in stratigraphic studies, and the *formation* "continues always to be an essential element of the stratigraphy of the area. Likewise, it is always an important key to geologic history" (Hedberg, 1976, p. 30). In the Soviet Code the suite is as important as the *formation*, and both units should be recognized in the field, though in the Code this condition may be relaxed.

If a geological body is recognised exclusively on lithologic characters, it will be classified as an auxiliary lithostratigraphic unit in the Code, a grouping which includes both the *member* and the *bed* of the Guide.

Discussion

The compilation and publication of the International Stratigraphic Guide was of great importance. The general framework of similar documents has now been worked out, and rules for stratigraphic classification established in a number of countries with many recommendations on practical approaches to stratigraphy. The detailed systematizing and application of stratotypes, and the introduction of the important concept of a boundary-stratotype are major contributions of the Guide, which also sets forth the multicharacter classification of biostratigraphic units and expands the classification of chronostratigraphic units.

The shortcoming of the Guide is that it ignores concepts of stratigraphic classification based on a century's experience in a number of European countries, including the U.S.S.R., as well as decisions adopted earlier by various sessions of the International Geological Congress. The author does not believe that the time has passed for compiling national stratigraphic codes. The distinctive geological features of individual states, their traditions and problems still necessitate the compilation or improvement of national codes (viz. Holland, 1983 – Ed.). However national codes should take into full account the global recommendations stated in the Guide. Further improvement of the Soviet Code, for example, will find useful the recommendations of the Guide concerning bio- and lithostratigraphic units, zones of facies changes and the chapters dealing with climato-, rhythmo-, and magnetostratigraphic units.

Soviet geologists believe that it is necessary to develop an international stratigraphic code based on the existing Guide.

TABLE 2: Major categories and units used in the International Stratigraphic Guide (Hedberg, 1976).

Stratigraphic Categories	Principal Stratigraphic Unit-Terms	Equivalent Geochronologic Units
Lithostratigraphic	Group Formation Member Bed(s)	
Biostratigraphic	Biozones: Assemblage-zones Range-zones (various kinds) Acme-zones Interval-zones Other kinds of biozones	
Chronostratigraphic	Eonothem Erathem System Series Stage Chronozone	Eon Era Period Epoch Age Chron
Other stratigraphic categories (mineralogic, environmental, seismic, magnetic, etc.)	-Zone (with appropriate prefix)	

Only such a code could make legitimate universally accepted categories or sections, classification of general (*chronostratigraphic*) units, terminology and application of biostratigraphic units and stratotypes, as well as principles of stratigraphic nomenclature. Such an international code should also set out the two main classifications of local and *lithostratigraphic* units discussed above and should provide a multilingual glossary. It would be useful to include sections on the special problems of classifying Precambrian and Quaternary strata, of oceanic sediments and volcanic rocks, and of climatic and magnetostratigraphic units. Some of these tasks are now being carried out by the IUGS International Subcommission on Stratigraphic Classification.

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The Vendian as the Terminal System of the Precambrian

by Boris S. Sokolov and Mikhail A. Fedonkin

The Vendian has been recognized for some time in the U.S.S.R. as the oldest stratigraphic division of the sedimentary cover to the crystalline basement and Proterozoic aulocogenes of the Russian Platform. The authors summarize here recent studies on the Vendian of the U.S.S.R. as a preview to a major discussion to be held during the Moscow Congress of this potential new system in the standard stratigraphic column.

Background

The Vendian was recognized early in the 1950's on the Russian Platform as the oldest stratigraphic subdivision of the sedimentary cover. Extensive work since then has shown that for the first time since 1879, when Lapworth proposed the term Ordovician for the second system of the Palaeozoic, there is now a need to distinguish a major new time division in the evolution of the biosphere and the planet as a whole – the Vendian Period.*

The program of deep drilling in the 1940s played a very important role in studies of the Russian Platform. Information from these boreholes and from exposures of the oldest sedimentary units in the Baltic and the Dniester regions allowed us in 1950 to separate the Vendian from the Cambrian, to correlate the Vendian with the Upper Sparagmite of Scandinavia and with the Sinian of China, and to prepare lithologic and palaeogeographic maps of the Valdai and Baltic series for the Russian Platform. The main features recognized for the Vendian indicated a close link with the Cambrian (which is why it was then called the "Precambrian Palaeozoic") and a structural position at the base of the sedimentary cover overlies either crystalline basement or older Proterozoic deposits confined to narrow tectonic zones – aulacogenes (Sokolov, 1952, 1958).

Since then much progress has been made in the development of the Vendian concept (Sokolov, 1964, 1972, 1973, 1976, 1980; Keller, 1968; Keller et al., 1974; Khomentovskiy, 1976; Rozanov and Sokolov, 1982). During this time a long term program was carried out by the Polish-Soviet working group within the "Precambrian-Cambrian boundary" project, and accounts of the palaeontology, stratigraphy, lithology and palaeogeography of the Upper Precambrian and Cambrian deposits of the western part of the East-European Platform have been published (Volkova et al., 1979; Aren et al., 1979; Fedonkin et al., 1983). Recently the Laboratory of Precambrian Palaeontology of the Academy of Sciences completed another extensive work entitled "The Vendian System: Historical-Geological Substantiation," to be published during the forthcoming Congress in connection with Symposium S.01.2.2 (see Coming Events, this issue of Episodes). This account of the new stratigraphic system will embrace worldwide material, including primary basic data from the U.S.S.R.

Outside the U.S.S.R., important work on the Vendian and similar stratigraphic units is being carried out in Australia (Ediacaran), in China (the "Sinian System" sensu stricto) and in a few other countries. The recognition of the Vendian is now arousing worldwide interest in geologists, tectonists, stratigraphers, palaeontologists, specialists on biochemistry and the biosphere, and naturalists in general. In this paper however, we do not attempt to compare or contrast the Vendian with the Ediacaran or Sinian, but concentrate on the data from the U.S.S.R.

General Stratigraphic Aspects

The Vendian System in the territory of the U.S.S.R. can be illustrated by two types of sections: a terrigenous type on the Russian Platform (from Western Podolia in the south to the White Sea in the north), and a carbonate type on the eastern Olenek Uplift of the Siberian Platform. The first (Fig. 1) is characterized by tillites and basalt sheets in the lower part of the section. The second is characterized by a transgressive overlapping of older Precambrian deposits. The richest localities of soft-bodied Metazoa, their trace fossils, remains of macroflora, various microphytoplankton and other groups of organisms are confined to the Middle Vendian in both regions. Remains of vendotaenid flora, trace fossils of benthic Metazoa, and microfossils are abundant in the Upper Vendian. The Vendian sections in both regions are terminated by characteristic associations of Sabelliditida, Anabarites, numerous diverse trace fossils, and rare remains of medusoids. The base of the Lower Cambrian (Tommotian stage) is characterized by abundant small skeletal organisms that comprise a completely new biota.

The Vendian on the Russian Platform

The Russian Platform, and in particular its southwestern part, is a stratotype locality for the Vendian, which here includes three series (Fig. 1). The *Vilchan series* (lowermost) is mainly composed of tillites (Laplandian horizon) deposited following a major glaciation about 700 Ma ago. Traces of this glaciation are, of course, well known on other continents, and tillites provide a good means of stratigraphic correlation (Chumakov, 1978). The *Volhyn series* is composed of volcanogenic and sedimentary deposits, which may have been deposited rapidly. The Volhyn-Vilchan deposits are confined to aulacogenes, filling the extensive Orshan depression and laterally distributed in Byelorussia and adjacent regions of Poland.

The *Valday series*, which is sometimes called the Upper Vendian or the Vendian sensu stricto, is more widely distributed and has a similar character throughout the platform (Aren et al., 1979; Bessonova et al., 1980). Two distinct horizons can be distinguished within the Valday series. The older of these, the *Redkino horizon*, is widely distributed

**Editor's Note:* There have also been recent calls for a new period and system – the Ediacaran (or Ediacarian) – older than the conventional Cambrian and broadly similar to the Vendian (see P. Cloud and M.F. Glaessner, in Science, August 27, 1982, p. 783-792).

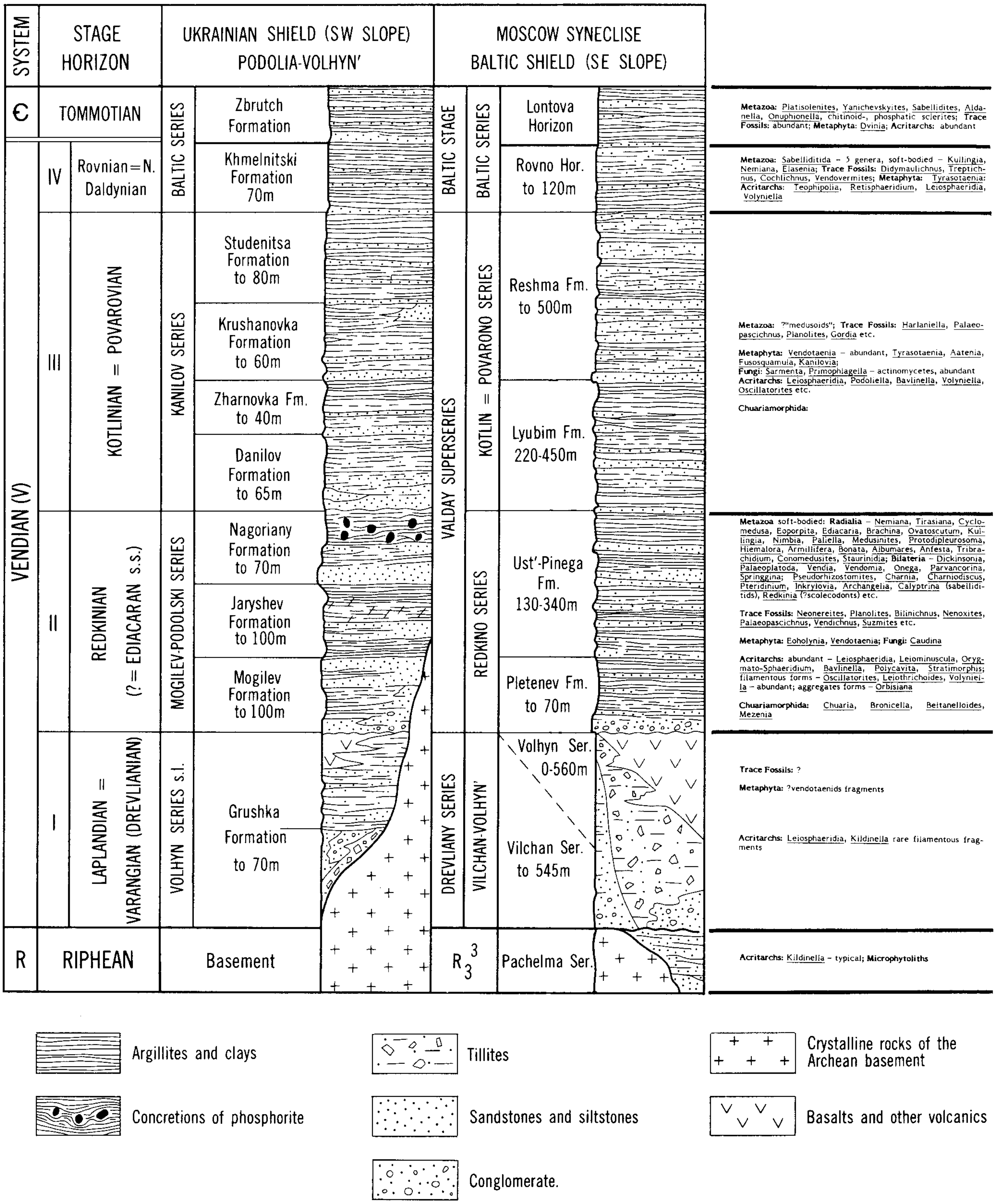

Figure 1: General stratigraphy and palaeontology of the Vendian in the Russian Platform. Roman numerals indicate major faunal divisions. Right-hand column lists the characteristic fossils.

within the Platform and is represented by sand and clay deposits containing several ash tuff and tuffite members that allow correlation of the Redkino beds over large areas from the Dniester region of Podolia in the west to the Perm region over 2000 km to the east. These tuffs and tuffites are also distinct in the northern part of the Platform. In contrast to the Vilchan-Volhyn beds, the Redkino horizon and the Valday series as a whole extend beyond the limits of aulacogenes to fill syneclises, which outline the epicontinental basin.

The overlying *Kotlin horizon* has a similar distribution to rocks of the the Redkino level. Composed of argillites, siltstones, and a minor number of sandstones, the Kotlin horizon lies with an erosive base on the Redkino beds and sometimes rests on even older deposits.

The Vendian of the Russian Platform is terminated by terrigenous beds of the *Rovno horizon*, which are characterized by a specific assemblage of acritarchs, remains of numerous Sabelliditidae, rare Platysolenites, Aldanella and also by numerous trace fossils of Palaeozoic type (such as Phycodes, Treptichnus, and Gyrolithes) left by benthic invertebrates (Fedonkin et al., 1983). The stratigraphic position and paleontology of the Rovno horizon allow us to compare and correlate it with the Nemakit-Daldyn horizon of Siberia, which is also considered as terminating the Vendian.

It is clear now that the Vendian as a whole is a post-aulacogene formation of the Russian Platform. Although the Vilchan-Volhyn deposits are confined to aulacogenes, the pre-tillite break seems abrupt everywhere, whereas the pre-Redkino break is a transgressive disconformity.

The Vendian on the Siberian Platform

The stratigraphic equivalent of the Vendian in Siberia is the *Yudomian*, composed mainly of carbonates which unconformably overlap the underlying beds. Finds of soft-bodied Metazoa in the Upper Precambrian of Siberia show this to be a region where the Vendian system is widely distributed. The richest known locality for Vendian fauna was discovered in 1981 by us in the Khatyspyt Formation on the Olenek and Khorbusuonka rivers of northern Siberia. In the middle reaches of the Khorbusuonka River the Yudomian deposits can be divided into three formations (Fig. 2): the Maastakh (oldest), Khatyspyt, and Turkut (youngest), which succeed each other within the Khorbusuonka series (Komar, 1966; Shpunt et al., 1979).

The 52 m-thick *Maastakh Formation* lies with an erosive contact on Riphean dolomites and is composed of variegated volcanogenic rocks with laminae and cross-laminae, and containing beds of fine conglomerates. The upper 25 m is composed of yellow-grey thin-bedded dolomites.

The basal 12 m of the 120 m-thick *Khatyspyt Formation* consists of sandstones and siltstones, but the major part of the unit is composed of limestones and light brown to black bituminous dolomites. Massive beds alternate with thin ones; these are sheared and contain many imprints of Metazoa. Trachybasalt tuff-breccias and tuffaceous siltstones occur in the upper part of the formation.

The *Turkut Formation* lies disconformably on bituminous carbonates and siltstones of the Khatyspyt Formation. It consists of alternating dolomite members, some containing stromatolites and lenses of microphytolites as well as layers of conglomerate, siltstone and tuff. The formation is 170-230 m thick.

The *Kessiusa Formation*, which overlaps the Turkut dolomites, is composed mainly of clayey sandstones, siltstones with thin shales (in its lower part), and lenses of carbonates. Abundant and diverse trace fossils occur in this formation as do the oldest small shelly fossils (Missarzhevskiy, 1982).

Analogues of the Vendian are known practically on all continents, not only on platforms but also in geosynclinal regions. Everywhere they occupy the same stratigraphic position – higher than the tillites of the last Precambrian glaciation and lower than Cambrian deposits characterized by mass appearance of diverse skeletal fauna. Radioisotopic data show that the duration of the Vendian is similar to that of Phanerozoic periods and is not more than 100 Ma; the lower boundary has been dated at 650-680 Ma and the upper at 550-570 Ma (Keller and Krasnobayev, 1983). Although more work is needed, it is clear now that in the hierarchy of subdivisions of geological time the Vendian and the Cambrian have an equal status. This conclusion is based not only on historic and geological but also on palaeontological data.

Palaeobiological Aspects

Studies of the Vendian biota have opened a new and very important chapter in the palaeontological record, for these biota differ sharply from all later ones, in particular from those of the Cambrian. The latter are characterized by the abrupt appearance in the palaeontological record of various groups of Metazoa with a mineralized skeleton in the broad sense (for example, spicules, shells and tests) and, of course, the development of classical palaeontology was based mainly on studies of such skeletal remains.

The Vendian fauna as a whole are characterized by the diversity of taxa of high rank, though species diversity was low in the majority of groups. Reliable data on the divergence or origin of major groups are absent, and all phyla and classes of the Vendian fauna appeared abruptly.

At present the following groups of fossils have been established as occurring throughout the Vendian: procaryotes and life products of procaryotes such as stromatolites and microphytolites, acritarchs (microphytoplankton in the broad sense), unicellular and multicellular eucaryotes (fungi, multicellular vendotaenid algae with a non-mineralized thallus, calcareous algae in the uppermost Vendian, soft-bodied Metazoa, and groups of unclear systematic position), the oldest Metazoa with skeletons based on an organic matrix (Sabelliditida with a chitinous segmented tube), and trace fossils of benthic animals.

The first mineral skeletons, mainly tubular forms, appeared at the end of the Vendian. The biological uniqueness of the Vendian is emphasized by the occurrence of non-skeletal metazoans and macrophyte flora. Over the last ten years extensive localities containing the Vendian fauna have been discovered, in particular in the southeastern White Sea region, the Dniester region of the Ukraine and in Yakutia in the Olenek Uplift. The fossils collected in these regions now exceed in number and diversity all remains of Precambrian animals discovered outside the U.S.S.R, and a major collection is housed in the Palaeontological Institute of the Academy of Sciences in Moscow.

Vendian Metazoa (Fig. 3) are characterized by several peculiar features. Unlike all subsequent Phanerozoic fauna, those of the Vendian are represented by animals that do not have mineralized skeletons. The first small, simple forms with a tubular mineral skeleton appear only at the end of the Vendian. Abundant well-preserved imprints of soft-bodied animals indicate that during this period microphagous organisms were dominant among predators and necrophagues. There is every reason to suppose that relatively short food chains existed in the Vendian and, judging by trace fossils, the infauna did not constitute a large part of the benthic communities. Only in rare cases was the sediment subjected to biological processing. These peculiarities promoted the undisturbed preservation of soft-bodied Vendian organisms.

Gigantism is one of the typical features in several important Vendian faunal groups. This phenomenon is especially striking when non-skeletal Vendian animals are compared with small skeletal fossils of the Early Cambrian. Medusoid forms with a diameter of more than half a meter were not rare in the Vendian, and some feather-shaped colonial polyps reached one meter or more in length. It is possible that gigantism of

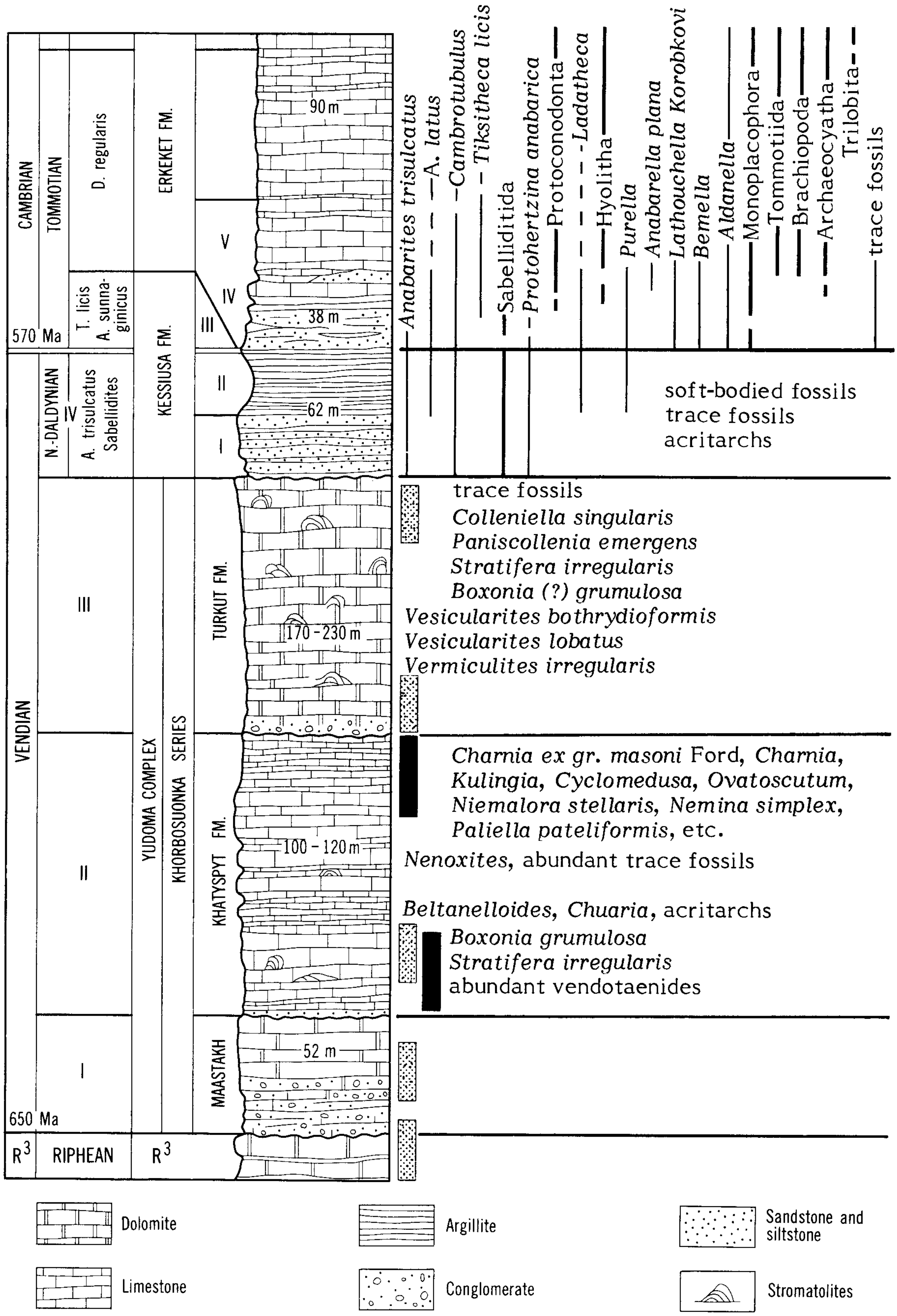

Figure 2: *Vendian and Tommotian sequences and palaeontology, Olenek Uplift, Northern Yakutia, Siberian Platform. Stippled bars indicate stromatolites.*

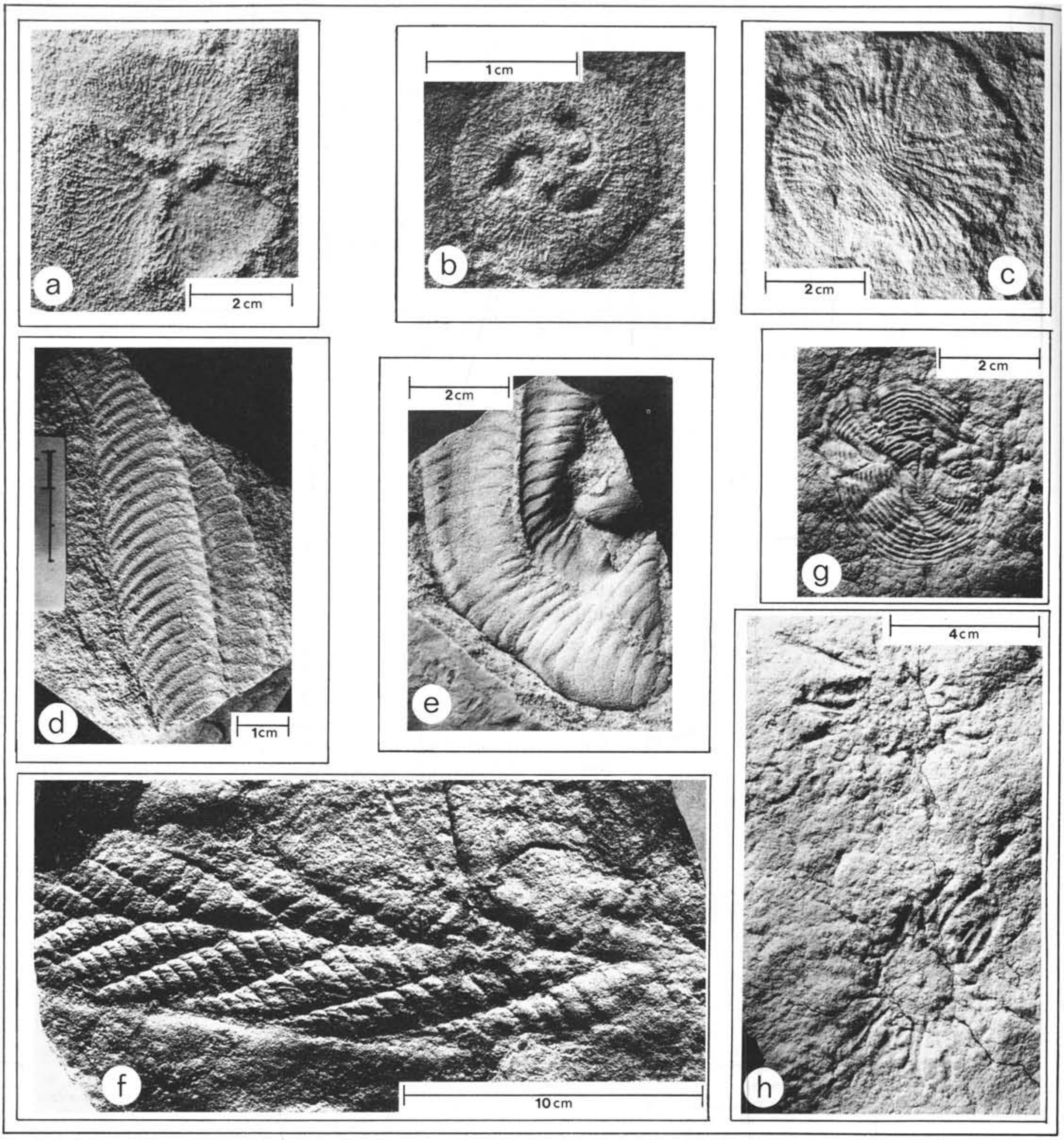

Figure 3: *Some typical representatives of the Vendian soft-bodied metazoans from the Ust-Pinega Formation (Redkino horizon, Valdai series), White Sea region: a) Albumares brunsae Fedonkin, b) Tribrachidium heraldicum Glaessner, c) Dickinsonia costata Sprigg, d) Pteridinium nenoxa Keller, e) Inkrylovia lata Fedonkin, f) Charnia masoni Ford, g) Ovatoscutum concentricum Glaessner et Wade, h) Hiemalora stellaris Fedonkin.*

some Vendian Metazoa is indicative of the phylogenetic termination of their evolution, for such cases are known later in the palaeontological record. In fact, in the majority of cases, we cannot find direct descendants of the Vendian Metazoa among Cambrian organisms. Many typical Vendian forms appear to have been blind alleys in metazoan evolution. However, small non-skeletal or weakly skeletized organisms did exist in the Vendian together with gigantic forms. Some of them, or to be more exact their descendants, promoted the abrupt appearance of skeletal invertebrates at the beginning of the Cambrian.

In the fossil record of Vendian macroscopic metazoans, various Coelenterata were evidently dominant. Medusoids and solitary and colonial polyps constitute 70% or more of the species in some of the associations (Glaessner, 1971a; Fedonkin, 1981; Anderson and Conway, 1982). Though it cannot be ruled out that the preservation potential of Radialia was increased because of the large size of many forms, and because numerous polyps produced imprints while in their life position, the predominance of Coelenterata in the Vendian can be considered as a sign of the great age of this phylum. This conclusion supports models that place Radialia at the base of the metazoan phylogenetic tree.

Diversity of symmetry in the Vendian Coelenterata reflects an initial radiation of the phylum. The most primitive forms have an infinitely high order of symmetry and concentric body plan, such as Nemiana, Beltanelliformis, Tirasiana, Cyclomedusa, and Kullingia. Flat plate-like polyps (or sedentary medusoids) lying on or attached to the bottom were very common. Many of these forms show various methods of asexual reproduction. They passively collected small food particles on their broad oral surface. High population density of such forms as Nemiana and Ediacaria may indicate that this mode of life was very successful in the Vendian. All these plate-shaped or cup-shaped forms with thick mesogloea, concentric body plan, simple gastral cavity and lacking both distinct radial gastro-vascular canals and reproductive organs, can be united in a specific class Cyclozoa (Fedonkin, 1983a, b), which for the most part became extinct in the upper part of the Vendian.

Precambrian Coelenterata with radial body plan are more advanced, and real medusoids are dominant among these forms. Many different organisms such as Hallidaya, Bonata, Hiemalora and Elasenia increase their degree of radial symmetry during ontogeny. This phenomenon seems to be a very primitive, but necessary, stage in the evolution of many lines of early cnidarians.

Among Radialia with stable symmetry the most common are three-fold (e.g. Skinnera, Albumares and Tribrachidium) and four-fold forms (e.g. Rugoconites, Conomedusites and Persimedusites). Those with three-fold symmetry may represent either a special sub-class of Scyphozoa or a separate class of Coelenterata. This group possibly gave rise to the small conical skeletal forms of the order Angustiochreida (Valkov and Sysoyev, 1969; Valkov, 1982) at the end of the Vendian and the beginning of the Cambrian (Fedonkin, 1983a). Some four-fold Radialia could in parallel have given rise to Conulariida (Glaessner, 1971b). One could suppose that many tubular skeletal forms, which first appear at the Precambrian-Cambrian boundary, represent some groups of primitive Coelenterata.

The vast majority of Vendian bilateral metazoans are characterized by a flattened segmented body. This seems to indicate that the bilateral symmetry and segmented character (metamerism) in many groups of Metazoa could have evolved simultaneously (Fedonkin, 1983a). Among macroscopic Bilateria it is possible to see the phenomenon of imperfect metamery, both in many-segmented forms like Dickinsonia, and in forms like Vendia with few segments.

Most of these species had poor organization and cannot be attributed to any known metazoan taxa of high rank. For example, the flat leaf-shaped segmented form Dickinsonia has been considered as a representative of Coelenterata, Plathelminthes or Annelida. Its ontogeny indicates a possible close historical relationship with Radialia. We suspect that Dickinsonia represents one of the most primitive branches of Bilateria, which possibly did not have any phylogenetic continuation. In this case as in many others, we prefer to speculate about the level of organization rather than about the systematic position of the Vendian metazoans. In some forms it is difficult even to imagine the mode of life (such as feeding and reproduction) and the functional value of some characteristic features. This is true, for example, of the enigmatic Petalonamae.

The Vendian flora are represented by abundant and diverse micro-plankton and non-mineralized strap-like macroscopic algae. The latter belong to the oldest macrophytes and are united in the formal group Vendotaenides (Gnilovskaya, 1971, 1979). Strap-like bifurcating plants up to 150 mm long and 0.5-3.5 mm wide, or cord-like bushy forms 10 mm high, are the most typical ones. Some forms of the genus Vendotaenia have sporangia of two types ranging from 54 to 94 mm and arranged in longitudinal rows. The form of the thallus and the position of sporangia allow us to suppose that vendotaenids are brown algae.

In addition to the vendotaenids, a group of micro-organisms discovered in the Vendian of the East-European Platform is now definitely assigned to the oldest Actinomycetes (genus Primoflagella). They are simple microscopic, tubular organisms with a wide "head" (sporangium) and long "tail." They form dense clusters, and some occur on the surfaces of vendotaenid thalli and on sapropelic films. They are typical epiphytes.

Biostratigraphic Features

Unlike the remains of multicellular animals which are most numerous in the Redkino horizon, the distribution of the Vendian macroflora shows a certain regularity that allows us to use them for biostratigraphy (Fig. 4). In the type-section of the Vendian, the Lower Vendian (Redkino) is characterized by the genus Eoholynia, whereas in the Upper Vendian the forms of the genus of Vendotaenia are widespread, and Aataenia are rare. In the uppermost Vendian the vendotaenid flora are replaced by the Tyasotaenia flora, which occur in the Rovno horizon terminating the Vendian section on the Russian Platform.

For division and correlation of the Vendian deposits, Soviet specialists in recent years have used acritarchs (Volkova et al., 1979). These are mainly the remains of microscopic organic walled algae, but they also include representatives of other groups of procaryotic and eucaryotic organisms. The ease of their extraction as well as their diversity gives every reason to consider them as one of the guide fossil groups for stratigraphic study of the Vendian and also the Upper Precambrian in general.

Summary

The studies of Vendian biota are very important for understanding the development of life in the Late Precambrian, its main features, and the earliest pathways of animal evolution, all of which are difficult to predict theoretically. Indeed, the recent Soviet work on Vendian palaeontology and stratigraphy is of global importance, because it extends by one hundred million years the time range of application of classical palaeozoological methods in biostratigraphy.

These investigations are especially significant, because they reveal a new geochronological stage (Fig. 4), one with non-metallic and other mineral resources necessary for industry and agriculture such as phosphorites and oil. International cooperation in studies of the Vendian system, taking into account the Soviet experience, will be of decisive importance for new advances in the study of the latest Precambrian and of the evolution of life over the last 700 million years.

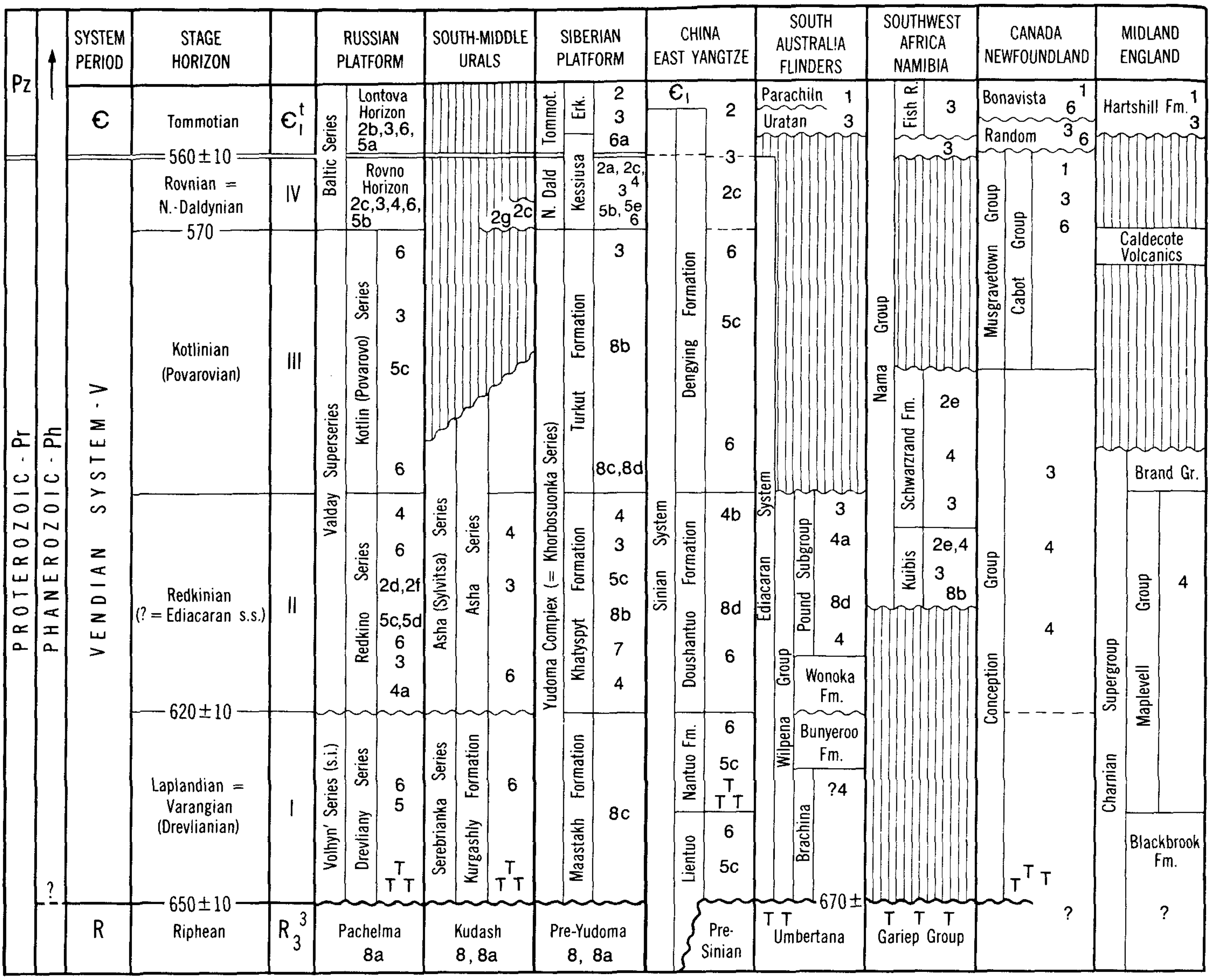

Figure 4: Correlation of the Soviet Vendian with the most important Upper Proterozoic sequences elsewhere. Key to fossils: 1 – skeletal Metazoa, 2 – Tommotian assemblages (2a – Anabarites tris., 2b – Platysolenites, 2c – Sabelliditida, 2d – Calyptrina, 2e – Cloudina, 2f – Redkinia, 2g – Sabellitidita beds of East Urals slope); 3 – trace fossils; 4 – Vendian soft-bodied fossils (4a – Type assemblage: Cyclozoa, Dickinsoniidae, Vendomiidae, Charniidae, Pteridiniidae, Tribrachidium; 4b – Liaoning assemblage); 5 – algae, Vendotaenides (5a – Dvinia, 5b – Tyrasotaenia, 5c – Vendotaenia, 5d – Eoholynia, 5e – Korilophyton); 6 – acritarchs (6a – Lontova assemblage); 7 – Chuariamorphida; 8 – stromatolites (8a – microphytoliths, 8b – Yudomian assemblage with (8c) stromatolites and (8d) microphytoliths); T – tillites.

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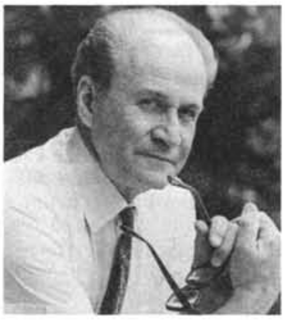

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The Precambrian – Cambrian Boundary in Siberia

by A. Yu. Rozanov

For more than ten years, the difficult problem of the Precambrian-Cambrian boundary has been intensely studied by a Working Group of the IUGS Subcommission on Precambrian Stratigraphy together with IGCP Project 29. Candidates for the stratotype boundary have been narrowed to localities in China, Newfoundland, and Siberia. Although there are, naturally, arguments for and against each section proposed, it is expected that a final choice will be made within the near future. In this article, the author describes key sections in Siberia, Kazakhstan and Mongolia, including one of the main boundary candidates on the Aldan River of Western Siberia, in the Ulakhan-Sulugur section at the base of the Aldanocyathus sunnaginicus zone of the Tommotian stage.

Fundamental Considerations

Since the Precambrian-Cambrian boundary is rather special, suggestions have long been made for its establishment based on geological or physical characteristics rather than on purely palaeontological criteria. However, it is now clear that only biostratigraphical criteria will lead to a solution of this problem. With such profound differences between late Precambrian and Cambrian biotas, it was necessary to accept the principle that "the Precambrian-Cambrian boundary stratotype point should be placed as close as is practicable to the base of the oldest stratigraphical unit to yield Tommotian (sensu lato) fossil assemblages" (Cowie, 1978). This principle was based on the idea that the boundary should be along the base of the first zonal assemblage bearing abundant skeletal fossils, in this case archaeocyathids, gastropods, hyolithids, tommotiids and brachiopods (e.g. Rozanov, 1966, 1967; Rozanov et al., 1969).

The appearance of a wide variety of skeletal fauna in the early Tommotian does not, of course, mean that those groups arose here for the first time. This was the time when many groups of animals first developed the ability to form skeletons, although the cause of this instantaneous geological phenomenon is not yet clear.

There are also certain interesting connections with global abiotic changes associated with the transition from the Vendian to the Cambrian. These include a decrease in dolomite accumulation, a sharp drop in stromatolite formation, the first widespread appearance of red biogenic limestones, and a global accumulation of phosphorite – the largest and richest deposits in the U.S.S.R., Mongolia and China are Tommotian (Fig. 1). Although the causes for these events are not yet clear, the finding of what is regarded as the earliest rich Tommotian association in a particular section does not lead us to suspect a migration effect or the presence of another rich assemblage in older layers elsewhere.

Of course the process of skeletalization, in the broad sense, was probably prolonged. Moreover, there was first a long period (probably the major part of the Vendian) when all skeleton formation was just partial scleritization of certain body-parts, and only in the Tommotian (or a little earlier in a few groups) did the formation of "real" skeletons begin, for example, in molluscs and brachiopods.

Palaeogeographic considerations are also of great importance (Fig. 1). By the early Tommotian, the palaeogeographic situation was such that normal marine carbonate sedimentation was localized primarily in eastern Siberia. Consequently, sections with the richest faunas are located there, and it is there that the centres of origin and initial diversification of a number of skeletal-forming groups were located.

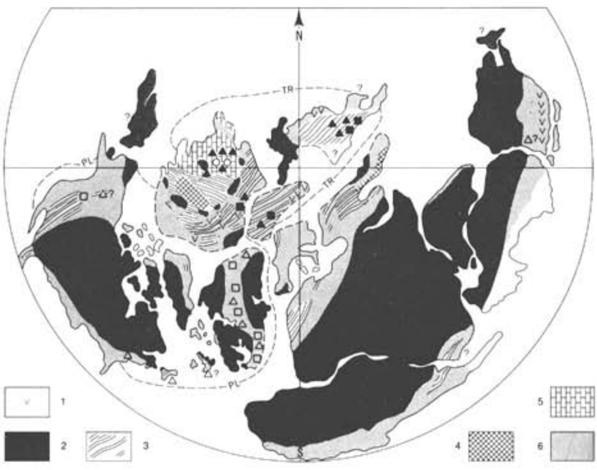

***Figure 1**: Tommotian palaeogeography: 1 – volcanic rocks; 2 – land; 3 – dolomites; 4 – evaporites; 5 – limestones; 6 – terrigenous rocks. Open circles – archaeocyathids; solid triangles – rich associations of small shelly fossils (SSF); open triangles – poor associations of SSF; open squares – Platysolenites; solid squares – the richest deposits of Tommotian phosphorites. PL-region of Platysolenites distribution, and TR-region of rich Tommotian associations of SSF.*

Most other localities are characterized by terrigenous or dolomitic sediments.

The other basic consideration in establishing a boundary stratotype concerns the kind of section in which a specific level can be established. Almost all the scientists involved in the discussions agree on the importance of monofacial continuity of section and the presence of the maximum possible number of features for correlation. A minority view is that the boundary should be drawn along the base or the top of layers that reflect some global abiotic event, such as glaciation or palaeomagnetic reversal.

The Northern Platform of Siberia

In Russian literature the sections in the northern part of the Siberian Platform in the Anabar Massif, the Olenek Uplift and on the Igarka-Norilsk dislocation along the Sukharikha River have long been considered as locations for a possible stratotype (Fig. 2). These sections, especially in Anabar, were regarded as suitable because it is here that the type section of the Nemakit-Daldyn horizon is located (Fig. 3). Moreover, these sections appear to be more monofacial than the Aldan River sections in the southern Siberian Platform, and a number of scientists believe that a rich skeletal fauna of the pre-Tommotian age is present (e.g. Valkov, 1975, 1978, Missarzhevskiy, 1982).

The sections on the Sukharikha River (Rozanov et al., 1969) are of special interest because they contain zones of archaeocyathids similar to those in the Lena-Aldan region. Other associated fossils here also make it possible to establish an analogous succession of zones. In addition sabelliditids, as well as the Nemakit-Daldyn complex of microphytolites, may be observed in the pre-Tommotian strata.

It is significant that the transition from the Nemakit-Daldyn stage to the Tommotian stage takes place in limestones that are only slightly dolomitized. The basal 1.5 m of the lowest Tommotian zone (Aldanocyathus sunnaginicus) are light-coloured limestones of the upper part of Sukharikha Formation, while the upper 0.9 m is represented by red argillaceous limestones typical of the Tommotian and Atdabanian strata of the Krasny Porog Formation. This section is, however, located in a region in the far north to which access is very difficult. Although it is not, therefore recommended as a possible type-section, it is of great importance because it indicates that the analogous succession of assemblages at the Precambrian-Cambrian boundary in the dolomites of the Aldan River is a reflection of general, not local, conditions.

On the Olenek Uplift (Fig. 2) there are also very interesting sections in which the transition from the Precambrian to the Cambrian is observed in terrigenous-carbonate facies (Rozanov, 1976, Missarzhevskiy, 1980). The lower zone of the Tommotian stage can be readily established here by non-archaeocyathan fauna, and in the underlying rocks Anabarites and Cambrotubulus are present. In addition, the rocks of the Al. sunnaginicus zone contain acritarcha typical of the Lontova level of the East European Platform (see Sokolov and Fedonkin, this issue of Episodes). Further down section in the Kotlin level, acritarchs, and below these vendotaenids, and a rich Vendian-Ediacaran fauna have been

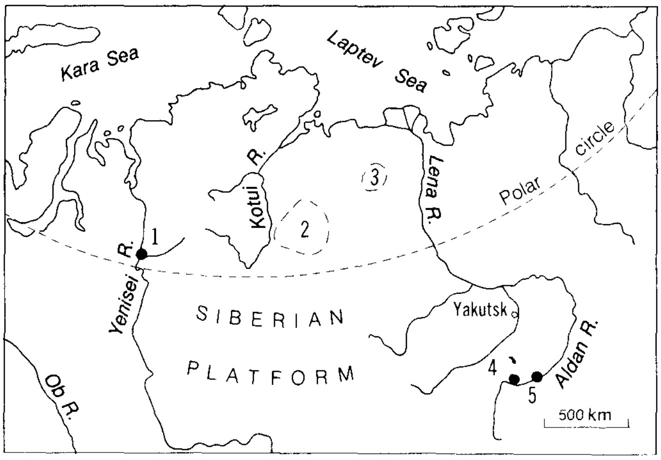

Figure 2: Locations of key areas discussed in this paper.1 – Sukharikha River; 2 – Anabar region; 3 – Olenek Uplift; 4 – Tommot; 5 – Ulakhan-Sulugur section.

discovered (Rozanov & Sokolov, 1982). However, this section not only has some deficiencies but is also situated in a region that is very difficult to reach. Nevertheless, the presence of both rich Vendian and Tommotian faunas, together with acritarchs typical of the East-European Platform make this a good supplement to the Aldan River section, and we can estimate the possibilities of intracontinental correlation for the Vendian and early Cambrian.

The suggestion to use a section in the Anabar Uplift as a stratotype has caused some debate. In the best outcrops, it is possible to observe an upward transition from dolomites of the Starorechinskaya Formation with Yudomian phytolites,

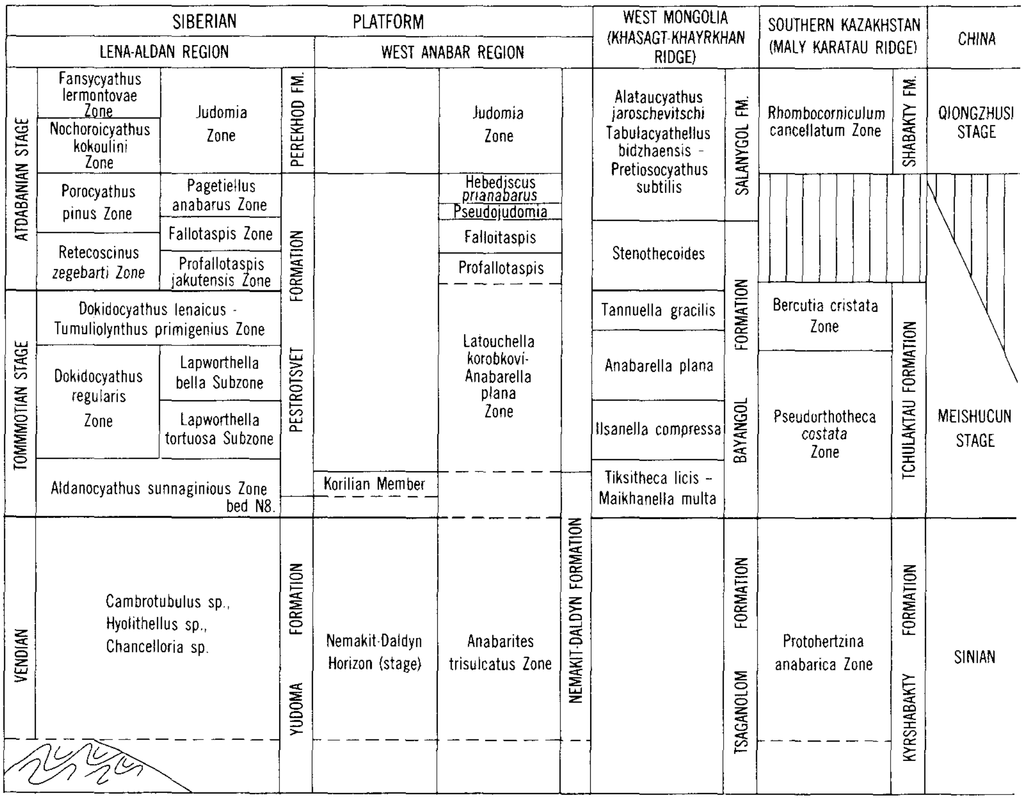

Figure 3: Correlation of the Precambrian-Cambrian boundary deposits of the southern and northern Siberian Platform with those of Kazakhstan, Mongolia, and China.

Figure 4: General view of the Ulakhan-Sulugar section on the Aldan River. Light-coloured dolomites at water level belong to Yudoma Formation. Brick-red limy mudstones in lower half of section belong to the Petrotsvet Formation, and the overlying white carbonates to the Tulmuldur Formation. Height of cliffs about 300 m. (Photo by W.H. Fritz)

through the thinly interbedded terrigenous and carbonate rocks of the Nemakit-Daldyn Formation with its poor fauna, to vari-coloured carbonates, which contain a typical Tommotian fauna (Fig. 3). First, Savitskiy (1959, 1975) assigned all the Nemakit-Daldyn Formation to the Cambrian and stood his ground for a very long time, considering the Nemakit-Daldyn horizon (defined on the basis of the Formation) to be pre-Tommotian. Then Zhuravleva (1975) proposed that the Nemakit-Daldyn horizon corresponds to the Sunnagin horizon of the southeastern Siberian Platform. By 1969, a strong belief had developed that all the Nemakit-Daldyn Formation was pre-Tommotian in age (Missarzhevskiy in Rozanov et al., 1969).

Later work by B.B. Shishkin (1974) and others showed that the upper 11 m of the Nemakit-Daldyn Formation contains a number of fossils, such as Cambrotubulus decurvatus, Conotheca sp., Circotheca sp., Hyolithellus sp., Anabarites sp. and unidentifiable gastropods. This fauna made it possible to suggest that the upper part of the formation belongs to the Tommotian. The concensus in 1979 was that these Anabar sections correlated with those of the southeastern Siberian Platform, the latter being considered the type-sections.

The composition of the fauna of the upper part of the Nemakit-Daldyn Formation is, however, too poor to allow firm conclusions to be drawn. Precisely for this reason V.V. Missarzhevskiy has stated that these beds belong to older, pre-Tommotian deposits, which he called the Manykai stage. The concept of the Manykai stage and its subdivision into zones is based on the correlation of sections between the Kotuykan and Fomich rivers. According to this view, the Koril limestone marker-bed is considered constant in lithology and thickness (5-10 m) over the vast region adjacent to the Anabar Uplift, whereas the overlying beds are diachronous. Thus, faunal complexes, which were previously considered to be of the same age (Rozanov et al., 1969), are now regarded as being superimposed on each other (Missarzhevskiy, 1982). The main objection to this concept is that the correlation of sections is unproved and that the zonal subdivision in the new stage cannot be observed in any of the sections known today.

Figure 5: Close-up of bed 8 (marked by pencil in lower part of photo) in the upper Yudoma Formation Ulakhan-Sulugur section. (Photo by W.H. Fritz)

The Southeastern Siberian Platform

There has been a long history of intense study of the Aldan River sections (Fig. 1) (e.g. Rozanov et al., 1969; Cowie and Rozanov, 1973). Here numerous outcrops extend over 100 km and expose the transition from the Precambrian to the Cambrian (Figs. 4, 5, 6). The section at Ulakhan-Sulugur was chosen as the key section for two reasons. First, it was here that the rich fauna of the upper part of the Yudoma Formation was first discovered and, second, in the lowest part of the outcrop the boundary can be observed over a lateral distance of 1 300 m. (The Ulakhan-Sulugur section will be visited by Excursion 053 of the 1984 Geological Congress).

A short description of the boundary strata of the Ulakhan-Sulugur section follows, beginning at the river level and continuing stratigraphically upwards (Figs. 5, 6):

Yudoma Formation

1. Yellowish and light-grey, fine-grained, laminated dolomites with lenses of oncolitic limestones.
2. Medium-grained, laminated light-grey dolomites, brecciated in the lower half, oolitic in the upper part.
3. Fine-grained, light-grey, oolitic dolomites with a thin layer of becciated dolomite in the upper part.
4. Fine-grained, thick- to thin-bedded, light-grey dolomites.
5. Yellowish-grey dolomitic breccias, with oolites.
6. Dolomite.
7. Dolomitic breccia with oolites and/or oncolites.

   In Beds 1-7 fragments of Chancelloria, probably Cambrotubulus and the microphytolite Nubecularites abustus Z. Zhur. occur. (In the type-section of the Tommotian stage at Dwortsy, upstream from Ulakhan Sulugur, older beds crop out and Chancelloria, Hyolithellus, and Cambrotulubus have been discovered 20 m below the base of the Cambrian).

8. With traces of slight reworking the surface of the preceding bed is conformably overlain by a laterally

impersistent layer of glauconitic-calcareous sandstones, with an admixture of quartzose material and abundant fossils. *This layer is proposed as the base of the Cambrian.* Aldanocyathus cf. virgatus (Zhur.); Spinulitheca kuteinikovi (Miss.), Turcutheca crassecochlia (Sys.), Laratheca nana Miss., Exilitheca multa Sys.; Bemella jacutica (Miss.), Aldanella rozanovi Miss., Philoxenella ex gr. spiralis Vost., Barskovia sp., Hyolithellus tenuis Miss., Torellella curva Miss., T. cf. lentiformis (Sys.), Cambrotubulus decurvatus Miss., Coleoloides trigeminatus Miss., Tiksitheca licis Miss., Sunnaginia imbricata Miss., Sachites sacciformis Mesh., Chancelloria ex gr. lenaica Zhur. et Korde, and Nubecularites abustus Z. Zhur.

9. Light-grey laminated dolomites and sandy brecciated dolomites.

10. Light-grey, coarse-bedded, sugary dolomites with thin layers of sandy dolomite. Turcutheca crassecochlia (Sys.) fragments of brachiopods and the microphytolite Nubecularites abustus Z. Zhur. occur.

11. Light-grey, sugary, cross-bedded dolomites, with thin layers of sandy and brecciated dolomite.

Pestrotzvet Formation

12. Grey limestones, sometimes tinged with green or pink, highly glauconitic. At the base of the bed there is much clastic material, and the top of the underlying Yudoma Formation is uneven and pocketed. Small bioherms with archaeocyathids occur throughout the entire bed: Archaeolynthus polaris (Vol.), Cryptoporocyathus junicanensis Zhur., Dokidocythus sp., Aldanocyathus sunnaginicus (Zhur.), A. virgatus (Zhur.), A. belvederi (Roz.), Nochoroicyathus aldanicus Zhur., Paranacyathus tschuranicus (Zhur.), Okulitchicyathus disciformis (Zhur.); hyolithes: Exilitheca multa Sys., Turcutheca crassecochlia (Sys.), Laratheca nana Miss., Spinulitheca kuteinikovi (Miss.), Allatheca sp.; molluscs: Aldanella rozanovi (Miss.), B. parula Miss., B. septata (Miss.); skeletal problematica: Hyolithellus tenuis Miss, H. vladimirovae Miss., Torellella lentiformis (Sys.), T. curva Miss., Coleolella billingsi Miss., Cambrotulubus decurvatus Miss., Coleoloides trigeminatus Miss.. Coleolus trigonus Sys., Tommotia admiranda (Miss.), Camenella garbowskae Miss., Sachites sacciformis Mesh., Sunnaginia imbricata Miss., Tumulduria incomperta Miss., Fomitchella sp., Chancelloria ex gr. lenaica Zhur. et Korde; algae: Renalcis jacuticus Korde.

13. Argillaceous red and cherry-red, bedded limestones with admixture of glauconite in the lower part of the bed. Hyolithes: Spinulitheca sp., Allatheca corrugata Miss., A. concinna Miss., Ladatheca annae (Sys.), Laratheca nana Miss.; Molluscs: Bemella jacutica (Miss.), B. septata (Miss.), Igorella monstrosa Miss., Latouchella korobkovi (Vost.), Anabarella indecora Miss., Aldanella rozanovi Miss., Heraultipegma sibirica (Miss.); skeletal problematics: Anabarites sp., Coleolella billingsi Miss., Coleoloides trigeminatus Miss., Tommotia kozlowskii (Miss.), T. plana (Miss.), T. admiranda (Miss.), Camenella garbowskae (Miss., Lapworthella cf. tortuosa Miss., Sachites saccifor Mesh. have been defined from the lower half of the bed.

14. Red argillaceous bedded limestones, with rare thin layers of grey and greenish-grey limestones. Numerous bioherms with archaeocyathids occur throughout the entire bed.

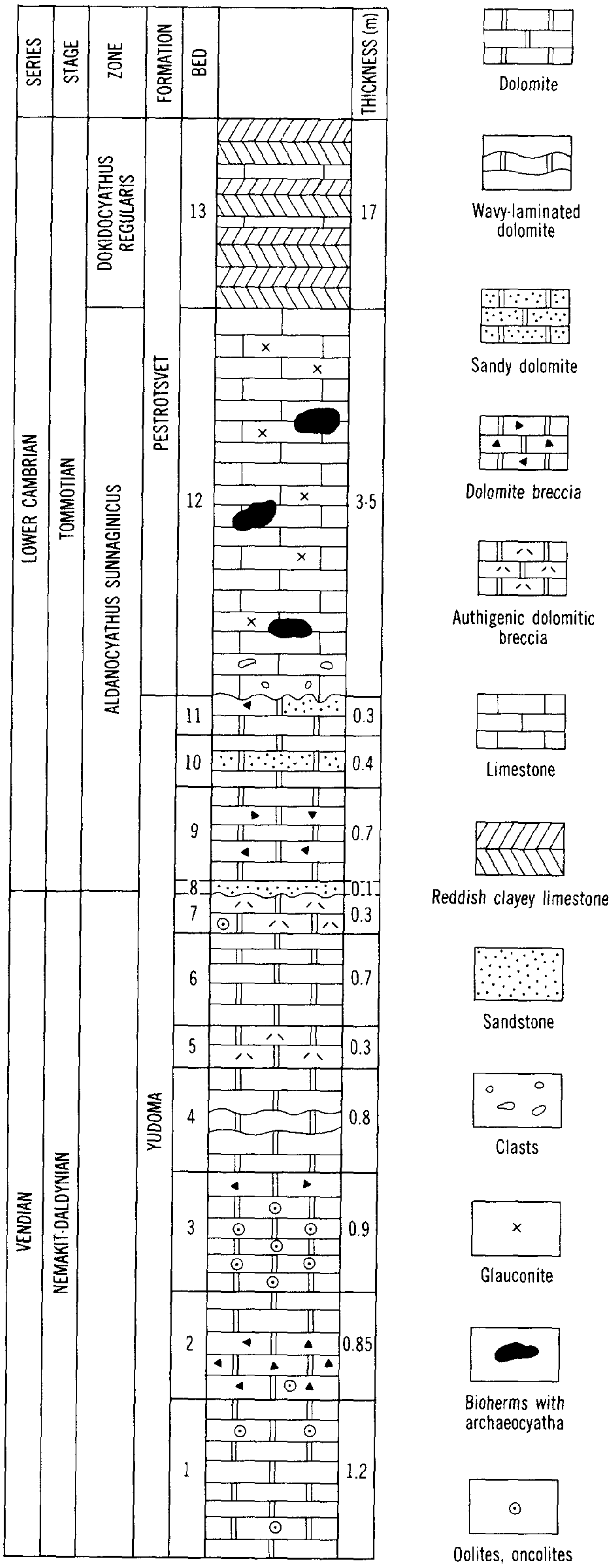

Figure 6: Stratigraphic column of the Ulakhan-Sulugur section.

In addition to the lithological and palaeontological characteristics given above, palaeomagnetic data from the Aldan and Lena sections make it possible to create a preliminary palaeomagnetic standard for the Upper Yudomian, Tommotian and Atdabanian stages (Kirschvink and Rozanov, 1979, 1984). Recent analyses of iridium (Nazarov et al., 1983) show an increased content associated with the bottom of bed 8. However, so far this has only been ascertained in one section, and the importance of this phenomenon is not yet clear. However, if it does reflect some global event it would provide a good additional criterion for establishing this boundary.

A review of geochronological data shows that, as elsewhere, only approximate ages can be given, and these are of no use for precise correlation. Trace fossils are also relevant to problems of sedimentology and ecology, but they can not be used for exact zonal correlation either.

Correlation with Other Asian Sections

IGCP Project 29 has stimulated the study of the boundary problem in many countries, and many new results and comparative data have been obtained, especially from candidate sections on the Asian continent (Figs. 1, 3). A brief review of some of these follows.

Recent studies of the Maly Karataŭ in southern *Kazakhstan*, very successfully carried out by Missarzhevskiy and Mambetov (1981; see also Korolev and Ogurtsova, 1983 – Ed.), have made it possible to distinguish a succession of fossil assemblages at the Precambrian-Cambrian boundary that is easily compared with those of the Siberian Platform (Fig. 3). For example, the Upper Precambrian Protohertzina anabarica zone in the upper part of the Kyrshybakty Formation is comparable with the Nemakit-Daldyn stage, and P. unguliformis Miss. is also found. The next assemblage (zone of Pseudorthotheca costata) occurs in the main part of the phosphoric Chuluktaŭ Formation and contains well known Siberian genera such as Tiksitheca, Conotheca, Allatheca, Hyolithellus, Protohertzia, Fomitchella, Kijacus and Anabarites, which permit comparisons with the early Tommotian assemblages of the Siberian Platform.

A detailed description is also available of the deposits at the Precambrian-Cambrian boundary in *western Mongolia* (Fig. 2), where they are characterized by a rich fauna (Rozanov, 1982). Here in the upper part of the Yudomian stromatolites and microphytolites occur, and rich associations of small shelly fossils in the Tommotian make correlation possible with the Siberian Platform. The lower part of the section here is called "the beds with Tiksitheca licis-Maikhanella multa." This part contains Tiksitheca licis Miss., Cambrotubulus decurvatus Miss., Anabarites trisulcatus Miss., Rozanoviella atipica Miss., Sachithes sacciformis Mesh., tommotiids and others. These rocks may also be compared with the Al. sunnaginicus zone and the lower part of D. regularis zone, which is substantiated by the presence in the overlying beds of Ilsanella compressa, together with numerous molluscs such as Latouchella Anabarella and Barskovia, and the Siberian zonal species Lapworthella tortuosa.

This Mongolian section is of interest not only because it is possible to recognize the same level chosen as the Precambrian-Cambrian boundary on the Aldan River, but also because it contains the fauna observed in sections of both China and the Siberian Platform together with its surrounding folded regions.

Key sections of *southern China* have been studied in detail in recent years (Yin Jicheng et al., 1980; Luo Huilin et al., 1982; see also Xing Yusheng et al., 1982 – Ed.). Earlier, Qian Yi (1977) and Zhong Hua (1977) concluded that the lower stage of the Cambrian (Meishucun) corresponded generally to the Tommotian and, consequently, that their lower boundaries could be correlated (Fig. 3). Chinese scientists subsequently proposed the idea of an older age for the Meishucun stage in part or as a whole. In the author's opinion this is incorrect, and the general correlation between the base of the Meishucun and the base of the Tommotian is certain.

The interpretation of the upper part of the Meishucun stage also changed significantly, and the lower part of the Qiongzhusi Formation was sometimes included in it and sometimes not. It is interesting to note that the lower part of the latter formation contains the fauna that appear in the upper half of the Atdabanian stage in Siberia and on the East European Platform. Moreover, as more of the fauna of the lower Meishucun stage are studied, more elements in common with Siberia and Mongolia are being found.

Tommotian deposits can thus be distinguished with precision in Asia, and this has led to strong suggestions for the choice of the Precambrian-Cambrian boundary stratotype in this part of the world (Cowie and Rozanov, 1983).

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Ore Deposits of the U.S.S.R: Some Theoretical Aspects

by Vladimir I. Smirnov

This brief note reviews the Soviet scheme for classification of ore deposits. The author also summarizes their approach to metallogenic regimes and epochs, a subject dealt with at greater length in the following paper by D.V. Rundquist. Finally the author comments on the debate concerning global mineral resources, arguing strongly that mankind is not threatened by a shortage of minerals.

Classification of Ore Deposits

The genetic classification of ore deposits used in the U.S.S.R. differs somewhat from that adopted elsewhere. We recognize three series of deposits: endogenetic, exogenetic and metamorphogenetic. These are divided into groups, then classes and finally formations (Table 1).

The **endogenetic series** is subdivided into seven groups: magmatic, pegmatite, carbonatite, skarn, albitite-greisen, hydrothermal and pyrite. Included in the magmatic group are the Cu-Ni sulphide deposits of the liquid immiscibility (liquational) class, which occur on the Kola Peninsula (Pechenga) and Siberia (Norilsk), and the Siberian diamondiferous kimberlites and the Uralian chromites and titanomagnetites of the early magmatic (cumulate) class. The magmatic group also includes the larger chromite, titanomagnetite and apatite deposits of the Khibiny massif (Kola Peninsula) of the late magmatic (hysteromagmatic or fusional) class. The pegmatitic group embraces the micaceous and rare-metal deposits found in pegmatites of the crystalline Precambrian of Siberia, the Ukraine, and the eastern part of the Scandinavian shield.

Deposits of the carbonatite group, discovered mainly in the northwestern and eastern U.S.S.R. since 1950, include Fe, apatite, phlogopite, rare metals and rare earths. An extraordinary diversity is exhibited by the skarn group, which comprises iron ores in the Urals, Siberia and the Caucasus, W (scheelite) in Central Asia and the Far East, boron in the Caucasus and the Far East, and also Cu, Co, Sn and rare earths (Figs. 1, 2). The deposits in albitites and greisens form a special group containing rare metals such as Sn, W and Mo and found in Kazakhstan, Transbaikal, the Far East and East Siberia.

Hydrothermal deposits in the U.S.S.R are not subdivided on the basis of the temperature of the ore forming process, but rather into plutonogenic, volcanogenic and amagmatic classes. These include ores of non-ferrous, rare, noble and radioactive metals known mainly in the Phanerozoic geosynclinal fold complexes of the Caucasus, the Urals, Central Asia, Siberia and the Far Northeast. Finally, the pyrite group comprises deposits of Cu, Pb and Zn associated with the geosynclinal ophiolites of the Urals, Rudnyi Altai, Caucasus and Central Asia.

The **exogenetic series** consists of three groups. The lateritic group is subdivided into residual and infiltrational deposits. Typical representatives of the residual variety are the Ni silicate ores in weathered Palaeozoic apo-dunitic serpentinites of the South Urals; lateritic bauxites are not characteristic of the U.S.S.R. In the infiltrational category are the peculiar deposits of native sulphur found in anhydrite-bearing carbonates of the Volga basin, in Central Asia and on the north slope of the Carpathians. The placer group is represented mainly by gold-bearing alluvial deposits (channel, valley, terrace and delta) of Quaternary age developed in the eastern U.S.S.R. Contemporary beach placers are not typical, but Palaeozoic and Tertiary analogues with ilmenite, rutile and zircon have been found in the southern and northern Soviet Union.

The sedimentary group comprises deposits of Fe, Mn and Al (bauxites). Sedimentary iron ores of Palaeozoic age occur in the Urals and Kazakhstan, of Jurassic age on the Russian and Siberian platforms, and of Neogene age on the Kerch Peninsula in the Crimea. Sedimentary Mn deposits of Palaeogene age are represented by the remarkable Chiatura deposits in the Caucasus (Fig. 3) and at Nikopol in the Ukraine. The most important bauxites are the Devonian ones in the Urals.

The **metamorphogenetic series** includes the large middle Proterozoic deposits of ferruginous quartzite in the Ukraine (Krivoi Rog) and on the Russian Platform (the Kursk Magnetic Anomaly). Also included in this series are the widely distributed, mainly micaceous pegmatites.

Metallogenetic Epochs

The U.S.S.R. contains rock formations, geological structures and ore deposits formed at all stages of geological history, from the Archean to the Holocene (Smirnov, 1982). The two

Table I: Genetic classification of ore deposits used in the U.S.S.R.

SERIES	GROUPS	CLASSES
Endogenetic	Magmatic	Liquid immiscibility (liquational) Early magmatic (cumulate) Late magmatic (fusional or hysteromagmatic)
	Pegmatitic	
	Carbonatite	
	Skarn	
	Albitite-Greisen	
	Hydrothermal	Plutonogenic Volcanogenic Amagmatic
	Pyrite	
Exogenetic	Lateritic	Residual Infiltrational
	Placer	
	Sedimentary	
Metamorphogenetic		

Figure 1: En route to the Tyrnyaus Mo-W-Cu skarn deposits, 150 km NW of Ordzhonikidze in the Caucasus. (Photo by G. Leech)

Figure 2: Participants in the 1982 IAGOD excursion examining specimens in the Mukulan ore body of the Tyrnyaus field (Photo by G. Leech)

major events in the development of endogenetic ore deposits were at 3 800 Ma, when the magmatic and pyrite deposits of a basaltoid association and the metamorphogenetic pegmatites began to form, and 2 500 Ma, when postmagmatic granitoid deposits first appeared. Typical representatives of the basaltoid association are magmatic deposits of chromite, titanomagnetite and Cu-Ni sulphides, whereas granitoid complexes are characterized by postmagmatic pegmatite, albitite, greisen, skarn and hydrothermal deposits of non-ferrous, rare, noble and radioactive metals.

These ore deposits recurred later in geological time, basaltoid ores forming during phases of crustal tension and granitoid deposits during compressional cycles. The regular repetition of these pulses makes it possible to divide the history of ore formation into 10 metallogenetic epochs (Fig. 4, and see Fig. 4 of Rundquist, this issue of Episodes – Ed.). The Kolan (3800-2800 Ma) marks the onset of formation of the oldest endogenetic deposts associated with greenstone belts and granite-gneiss domes. The Belomorian (White Sea) epoch, from 2800 to 2300 Ma, ago embraces the first half of the protogeosynclinal period and corresponds to the birth of the ancient geosynclines.

The Karelian (2 300-1 800 Ma) marks the peak and decline of the protogeosynclinal period, and the Gothian epoch (1 800-1 500 Ma) corresponds to an intergeosynclinal period with a temporary lull in active endogenetic mineralization. A new period was then ushered in during the Grenvillian (1 500-1 000 Ma) when geosynclinal regimes were restored. Succeeding phases, the Baikalian (1 000-600 Ma), the Caledonian (600-400 Ma), the Hercynian (400-250 Ma) and the Cimmerian (250-100 Ma) were distinguished by mature geosynclinal mineralization. Finally, the Alpine epoch (less than 100 Ma) is characterized by the cessation of geosynclinal activity leading to the development of rift tectonics controlling endogenetic ore formation.

Throughout this long history, none of the endogenetic groups experienced any pronounced qualitative changes, since magmatism recurred throughout. Basaltoid mineral associations formed from the outset of each phase or epoch to be succeeded by granitoid associations by the end. Representatives of the groups and classes of endogenetic deposits formed throughout the entire span of crustal evolution, without any appreciable change from the early to the late epochs.

Environmental Regimes of Ore Formation

Endogenetic deposits formed not only during the transformation of mobile geosynclines into stable platforms, but also in other geological environments. Four regimes can be distinguished: geosynclinal, platformal, transitional to oceanic, and oceanic. Each of these is marked by different degrees of magmatic differentiation and corresponding abundance of ore deposits, and their sequence corresponds to the series of decreasing magma-generating subcrustal systems proposed by V.V. Beloussov (1976).

The geosynclinal regime (Fig 4) is distinguished by the most complete and comprehensive magmatic differentiation from ultrabasic to ultra-acidic rocks and by the most abundant mineralization. In the U.S.S.R., the full geosynclinal cycles of the Caledonides, Hercynides, Cimmerides and Alpides are

Figure 3: A close-up of the Chiatura manganese deposit of the south slope of the Caucasus about 150 km north of Tbilisi (Photo by G. Leech)

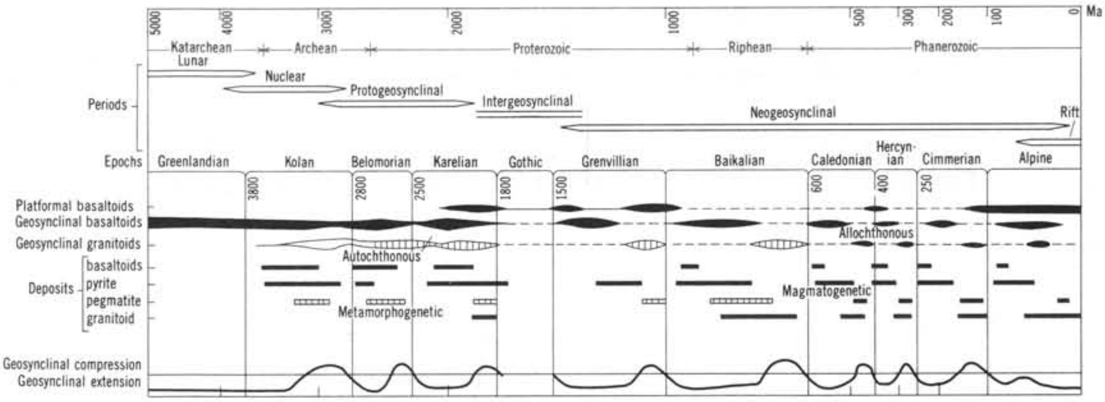

Figure 4: History of formation of endogenetic ore deposits.

represented by the following highly important magmatic formations and their associated endogenetic ore deposits:

- dunites with magmatic deposits of chromite and platinoids,
- pyroxenites with magmatic deposits of titanomagnetites,
- plagiogranites with skarn deposits of Fe and Cu,
- basalt-liparites with pyrite deposits of Cu, Zn and Pb,
- granites with pegmatite, albitite and greisen ores of rare metals,
- granite porphyries with plutonogenic hydrothermal deposits of non-ferrous, rare and noble metals,
- andesite-liparites with volcanogenic hydrothermal deposits also of non-ferrous, rare and noble metals.

The platformal regime is marked by less comprehensive magmatic differentiation. Within the Siberian platform and associated with Palaeozoic and Mesozoic tectonic and magmatic activity can be found:

- traps with magmatic Cu-Ni sulphide deposits,
- kimberlites that are locally diamondiferous,
- carbonatites with ores of Fe and rare metals,
- alkaline granites with hydrothermal deposits of non-ferrous metals, rare metals and Au.

Active continental margins are transitional from platformal to oceanic regimes. Their volcanic arcs are represented in the U.S.S.R. by the western margin of the Pacific Ocean, which is distinguished by more limited magmatic differentiation and a still narrower range of ore deposits. Associated with its basalt-andesite magmatism are mainly insignificant volcanogenic hydrothermal and pyrite deposits of non-ferrous metals. Finally, the oceanic regime of the Pacific with its primitive basalts bears only traces of pyrite mineralization.

A Comment on Global Mineral Resources

Metals are being extracted from the earth at ever increasing rates. For example, world Cu production more than doubled between 1960 and 1980, while in the same period Zn production increased by a factor of 1.85 and Pb production by 1.4. One would have thought that the metal reserves in mineral deposits would be sharply declining, but strange as it may seem this is not the case. On the contrary, reserves are increasing. As an illustration, whereas the global production of Cu grew by 3 million tons between 1960 and 1980, the total reserves increased by 280 million tons; the increase in reserves was thus 100 times greater than the growth in production. In the 1950s it was estimated that the reserves of copper would last for 30 years, until the 1980s. But the thirty years have already passed and the reserves are now good for another 55 years.

This paradox can be explained by the fact that the stock of commercially viable minerals is being continually increased by the discovery of new types of deposits that have, as a rule, lower concentrations of metals but greater reserves. For example, since the 1920s in the U.S.A. and the 1930s in the U.S.S.R., the small, rich vein deposits of Cu have been replaced by the larger leaner Cu porphyries, whose share in both production and reserves is growing. Stratiform deposits have also been discovered, and pyritic deposits, which also contain large reserves of Cu at low concentrations, have become very important.

Moreover, at the beginning of the nineteenth century the concentration of Cu in mined ore was 10%, in 1890 it was 5%, in 1910 2%, in 1930 1.5% and in 1980 it dropped on occasion to 0.3%. Over the same period world Cu reserves increased by at least 400 million tons. Thus as Cu grades fell, the reserves grew to outstrip the increasing production of the metal.

In exploiting large ore deposits of low metal concentrations, the profitability of the mining operations has also increased. This is because the working of large masses of ore have made it possible to introduce new and more productive techniques of mining and primary processing, especially with the move away from underground to open-cast mining.

Of course only a small proportion of total metals available are found within the world's ore deposits; most are disseminated throughout ordinary rocks, as measured by their average abundance in the crust. For example, the clarkes for Zi, Cu, and Pb are 0.62%, 0.01% and 0.0016% respectively; these values are approximately 100 times lower than the average concentration of these metals in commercial ores. The reserves of such disseminated metals are vast. Thus the known reserves of Sn in all known ore deposits are only equal to the amount of Sn contained in 30 km^3 of average rock. For Mo and Zn the equivalent volume is 200 km^3 and for Cu 800 km^3. Therefore by improving mining and processing techniques we will be able to extract ever increasing amounts of rock with declining metal concentrations, so that we will be able to meet all our needs for an infinitely long period of time. Mankind is certainly not threatened with a shortage of minerals.

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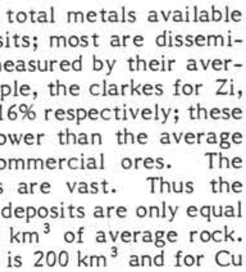

Metallogenic Belts, Provinces and Epochs of the U.S.S.R.

by Dmitry V. Rundquist

Many metallogenic units are recognized in the Soviet Union, each characterized by different ore deposits whose main features reflect the geological evolution of the geological environment in which they occur. The author reviews here some major concepts in metallogeny and their application to the development in time and space of ore deposits.

Introduction

All types of major structures, from old greenstone belts to areas of recent volcanism, are found in the U.S.S.R., and this varied geology is accompanied by a diversity of mineral resources. Studies by Soviet geologists over many years have led to the recognition of metallogenic provinces and regional distribution patterns for mineral deposits. A variety of metallogenic maps has also been compiled (Grushevoy et al., 1971). The principles and methods of metallogenic studies were worked out in the 1950s and 1960s by leading Soviet scientists such as S.S. Smirnov (1944), Yu.A. Bilibin (1955), P.M. Tatarinov (et al., 1957), K.I. Satpayev (1963), V.I. Smirnov (1963), A.I. Semenov et al. (1967), E.D. Karpova (1973), I.G. Magakyan (1974), V.A. Kuznetsov (1975), G.A. Tvalchrelidze (1977) and A.D. Shcheglov (1980).

Metallogenic studies in the U.S.S.R. are based primarily on a thorough analysis of formational and geological history. This approach requires definition of geological and ore formations based on characteristics that are constantly repeated in the rock and ore associations of different regions. The facies and age links between geological and ore formations permit palaeo-reconstructions to be made for the period of ore genesis. Various types of structural-metallogenic zones can be established, together with their evolutionary succession in the development of fold belts and platform areas of tectono-magmatic activity (Rundquist, 1981).

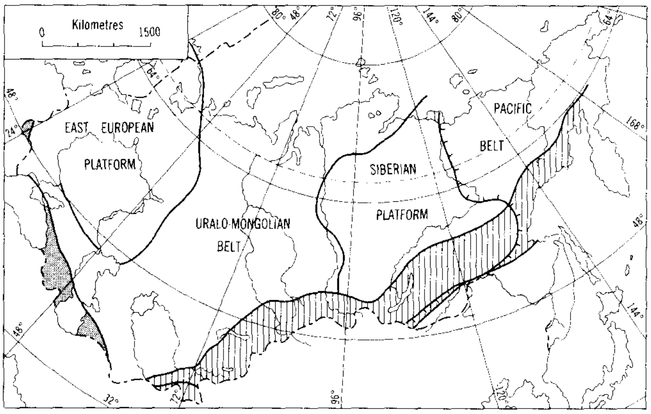

Figure 1: *Major metallogenic divisions of the U.S.S.R. Mediterranean Belt – shaded, Afro-Asian Belt – vertical lines.*

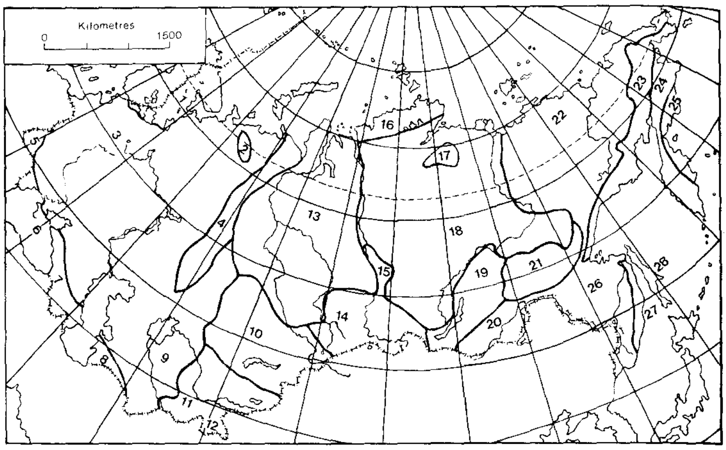

Figure 2: *Metallogenic provinces of the U.S.S.R. 1– Karelia-Kola; 2– Timan, 3– East-European platform, 4– Urals, 5– Carpathians, 6– Crimea, 7– Caucasus, 8– Kopet-Dag, 9– Scythian-Turan Platform, 10– Kazakhstan, 11– Tien-Shan, 12– Pamir, 13– West Siberian platform, 14– Altai-Sayan region, 15– Yenisey Range, 16– Taimyr, 17– Anabar shield, 18– Siberian platform, 19– West Transbaikal area, 20– East Tansbaikal area, 21– Aldan shield, 22– Verkhoyansk-Chukotka area, 23– Okhotsk-Chukotka area, 24– Koryak-West Kamchatka area, 25– Olütor-East-Kamchatka area, 26– Primorye, 27– Sikhote-Alin volcanic belt.*

Metallogenic Belts and Provinces

The largest units distinguished in the course of regional studies are metallogenic belts and provinces. The former are composite, linear, elongated fold systems, which can be traced for many hundreds or even thousands of kilometres (Fig. 1). Metallogenic provinces, in contrast are equant structures corresponding to blocks of early consolidation (platforms), which comprise extensions of the folded basement (Fig. 2).

Widespread in the U.S.S.R. are portions of the Uralo-Mongolian, Mediterranean (Alpine) and Pacific belts, as well as the Cenozoic Afro-Asian Belt. The whole of the Siberian and most of the East European platforms are also located in the Soviet Union. The zoning of these large metallogenic units reflects major features in the geological evolution of the U.S.S.R.

Shields and the basement of platforms characterize the pattern of Early Precambrian (Archaean to Lower Proterozoic) metallogeny (Fig. 3). Within the Uralo-Mongolian Belt there is a distinctive character to emplacement and metallogenic events, which took place between approximately 1 000 and 200 Ma ago (Late Riphean to Palaeozoic). The Mediterranean Belt displays the structural and ore patterns of fold belts with a long evolution, ranging from 1 000 Ma ago to the Holocene.

In the Palaeozoic, the structures of the Pacific Belt passed through an aulacogene-pericratonic evolutionary stage with a somewhat contrasted tectonic character. Not until the Mesozoic-Cenozoic did this region experience typical geosynclinal evolution, with early and late rifting and initial and subsequent orogenic magmatism.

In general, these regional metallogenic units permit the distinction between major periods in geological history, based on differences in their formations and ore deposits (Fig. 4). Of particular significance in this respect are boundaries at 1 800 and 200 Ma ago that mark the beginning of evolution of the mantle of old and young platforms.

Metallogeny of Folded Belts

The Uralo-Mongolian Belt includes the fold systems of Timan, Urals, Kazakhstan, Tien Shan, Altai, Sayany, Transbaikal area, Yenisey Range, and Taimyr (Fig. 2). This belt is noted for the maximum distribution of geological and ore formations of the early crustal development stages (riftogenic, eugeosynclinal and secondary geosynclinal). Associated with these are world famous deposits (for a recent account in English of some major Soviet ore deposits see Ridge, 1984 – Ed.), including chromite, Cu pyrite and Cu-Fe-Ti-V ores in the Urals; Cu and polymetallic pyrite ores in the Altai region of Central Asia; asbestos in the Urals and Sayany; polymetallic Fe-Mn barite ores of Atasu in Kazakhstan; and skarn-magnetite ores in the Urals and Transurals (Sokolov-Sarbayev, Kachar, Magnitogorsk, Blagodat, Vysokaya). Granitoids of this belt are dominated by early tonalites and granodiorites with Fe and Cu-Mo (Sayak and Kounrad in Kazakhstan, Almalyk in Central Asia, Sorskoye in Sayany), as well as rare-metal skarns with scheelite and molybdenite (Charukh-Dairon and others).

The Mediterranean Belt, which is poorly represented in the U.S.S.R., includes the folded structures of the Carpathians, Crimea, Caucasus, Kopet-Dag and Pamirs, and its metallogenic character is displayed most completely in the Caucasus. A contrasting metal zoning is recorded here, combining very different types of mineralization in a poly cyclic evolutionary pattern characterized by widespread deposits of different periods and stages of crustal development. Located in this belt are early polymetallic pyrite deposits within shaly leptogeosynclines (Filizchai, Kyzyl-Dare); Cu- and polymetallic pyrite deposits of Kafan and Madneuli, and vein barite-polymetallic deposits of the Gagra-Dzhava zone in eugeosynclinal structures. Late orogenic stages are represented by the Mo-Cu porphyries of Kadzharan and Dastakert, the rare-metal skarn of Tyrnyaus (see Figs. 1 and 2 in the preceding article by Smirnov – Ed.), and the epithermal W-Sb-Hg Gornaya Racha deposits.

The Pacific Mobile Belt is well represented in the U.S.S.R. Several types of structures can be distinguished, such as modern outer island arcs (the Kuril-Kamchatka Range), a continental orogenic volcano-plutonic belt (traced from Chukotka to Sikhote-Alin), internal active zones (Transbaikal) and extensive miogeosynclinal areas near junctions with platforms (Yakutia). The metallogeny of these structures also differs markedly. The Kuril Islands, Kamchatka and Koryakia are characterized by Cu and Cr ores associated with basic magmatism and the orogenic volcano-plutonic belt by Au, Ag, Sb, Hg, Pb-Zn and Sn (Omsukchan) or Cu and Mo in those parts of the belt that overlap earlier eugeosynclinal formations. The internal active zones contain rare-metal pegmatites, Sn, Sn-W and greisen (Iultin), fluorite (Voznesenskoye), as well as Au-quartz veins and other deposits. Within the miogeosynclinal zones, sulphide and silicate-cassiterite (Deputatskoye, Ege Khaya), Au-Sb (Sarylakh) and polymetallic deposits occur. In general, the Soviet sector of the Pacific Mobile Belt, as distinct from its counterpart in North America, is characterized by Sn and Au, and weak Cu-Mo mineralization.

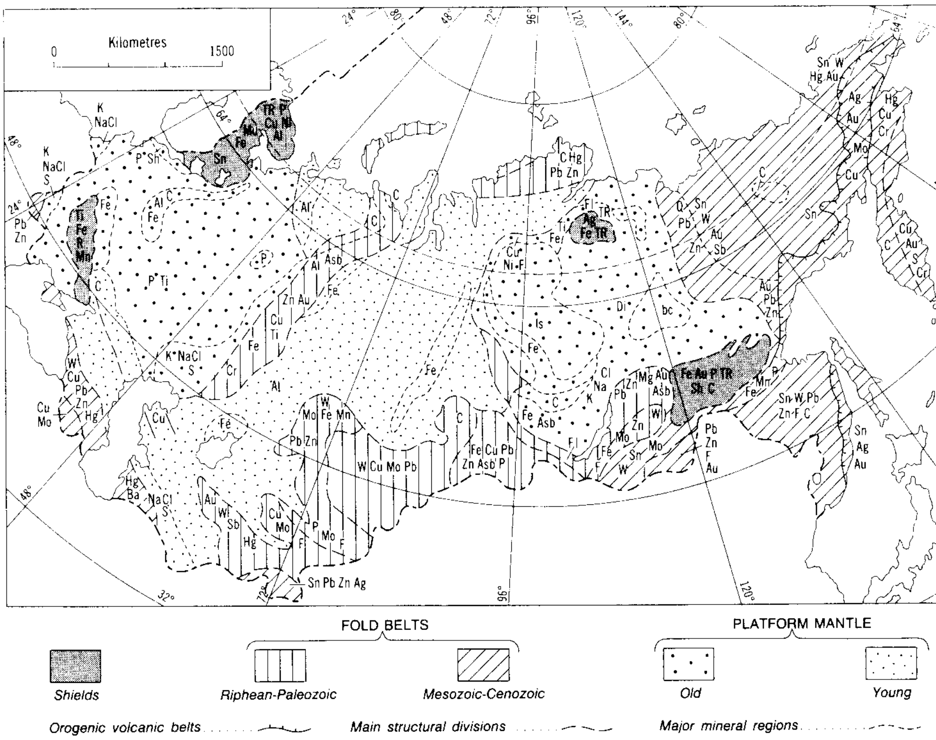

***Figure 3**: Major ore deposits and structures of the U.S.S.R. Young platform mantle overlies older fold belts. Di– diamond, Is– Iceland spar, F– fluorite, Fl– phlogopite, C– coal, Bc– brown coal, Sh– pyroschist, TR– Rare earths; standard symbols elsewhere.*

Metallogeny of Platforms

The East European and Siberian platforms differ appreciably in their evolutionary history and especially in the scale of their magmatism and mineral resources. The mantle of the East European Platform contains oil shale and phosphorite in the Silurian and Ordovician of the Baltic area, Carboniferous bauxites and coals near Moscow and Onega, Devonian and Permian potash and rock salt in the Carpathians and Urals regions, and titanium-magnetite placers in central regions.

The mantle of the Siberian Platform is characterized by endogenetic deposits associated with Devonian and Triassic magmatism. These include the Fe-magnesioferrite skarn deposits of the Angara-Ilim Basin, Cu-Ni sulphide of Norilsk and Talnakh, and diamond and Iceland spar deposits. Among exogenetic deposits are the unique Lena coal basin and the potash deposits of the Nepa Arch in the southern part of the Platform. The major deposits of the younger West Siberian and Scythian-Turan, which have not yet been fully studied, include the oolitic iron ore deposits of Kolpashevo, Ayat and Lisakovsk in the Transurals and western Siberia, the bauxite ores of Turgai, and Ti placers.

Quite different mineral deposits occur in the Precambrian extensions of the Karelian, Kola, and Ukrainian massifs of the East European Platform and the Aldan and Anabar shields of the Siberian Platform. These are characterized by widespread ferruginous quartzites, forming the unique Archean deposits of the Kursk Magnetic Anomaly, Aldan and Karelian-Kola region and the Proterozoic Krivoy Rog deposits. The Soviet part of the Baltic Shield in the Karelian-Kola region

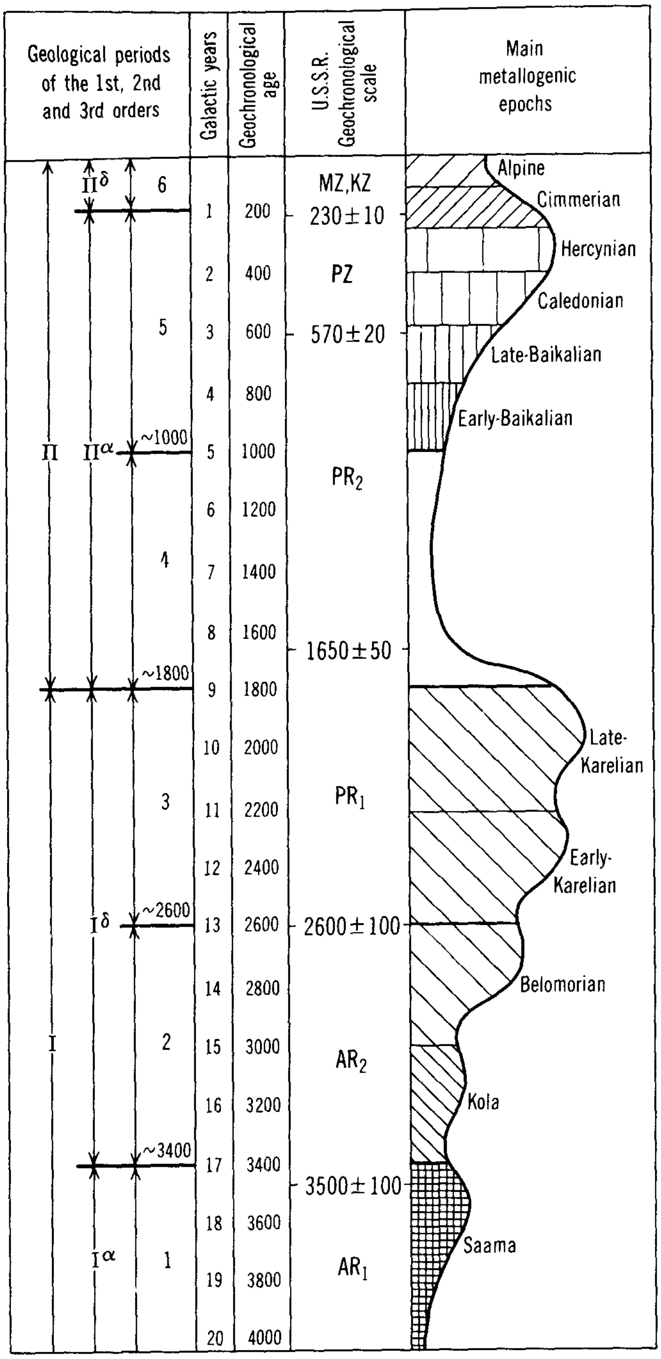

Figure 4: *Metallogenic epochs of the U.S.S.R., showing the standard Soviet time scales.*

contains the Cu-Ni sulphide deposits of Pechenga and Monchegorsk, the unique apatite-nepheline deposits of Khibiny, the highly aluminous Kejvy kyanite schists, the micaceous pegmatites of Chupa and Loukhi, and the large Cu-pyrite deposits of Parandovo and Khautovara.

Within the Ukrainian massif, rare-metal mineralization associated with alkali metasomatism is also widespread, as are metamorphic graphite deposits. The Aldan Shield is the most adequately studied part of the Siberian basement. It is characterized by skarn-magnetite and phlogopite deposits, rare earth complexes in carbonatites, and coals associated with late rift and graben formation.

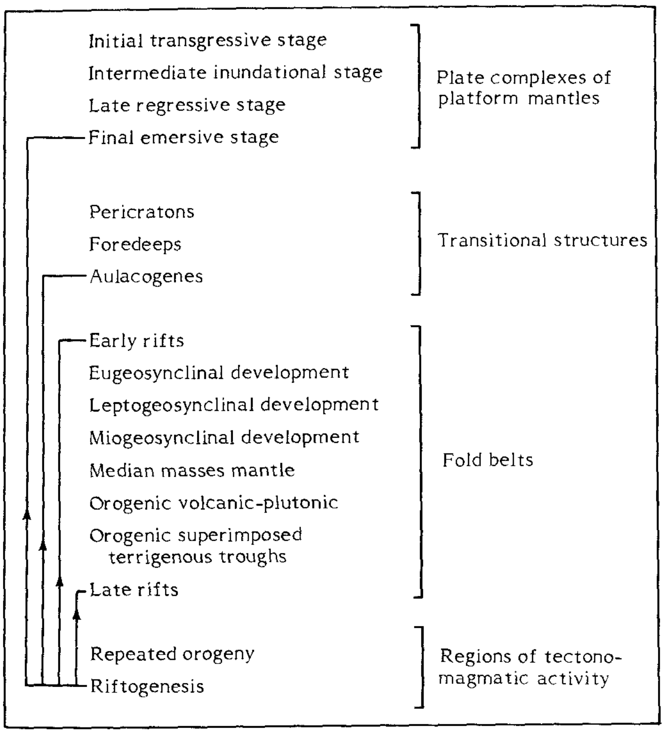

Figure 5: *Types of structural-metallogenic zones.*

Types of Structural-Metallogenic Zones

The basic unit in Soviet metallogenic studies is the structural-metallogenic zone. This combines outcrops of genetically related geological formations and their associated deposits, emplaced at a specific stage in the structural evolution. Each zone may contain formations of different genesis and it may differ from others in its associated mineral resources and distribution patterns. The zones can be thus divided into "stratified" (sedimentary and sedimentary-volcanogenic), "cutting" (intrusive and volcano-intrusive), metamorphic, and weathering (laterite, clay eluvium). In all, 87 types of structural-metallogenic zones have been distinguished in the U.S.S.R. (Rundquist et al, 1980, 1981). These can be grouped into the larger units shown on Figure 5.

Structural-Metallogenic Zones of the Platform Mantles

Exogenetic mineralization in zones of this type can be clearly correlated with the stages of evolution in the platform cover. In the early transgressive stage, as rudaceous material, gray sandstone and clay accumulate, deposits are formed of phosphorite, Mo-V slate (Ordovician, Baltic area), Mn (Oligocene, Ukraine), Ti-Zr placers, and associated red beds and minor siliceous hematite. Zones of the intermediate inundational stage correspond to the transgressive maximum. They include terrigenous and carbonate formations, oil shale (Ordovician Baltic area), fluorite-ratofkite (Carboniferous Moscow syneclise), minor stratiform Pb-Zn and oolitic iron ores.

The late regressive stage zones contain potash salts, boron (Permian, Caspian area) and halite (Carboniferous, Siberian Platform; Devonian, Moscow syneclise; Permian, Caspian area). Of particular significance is the occurrence in these zones of a basalt-dolerite (trap) formation with diverse accessory minerals such as Cu-Ni sulphides, Iceland spar, iron-ore skarns and agate. Traps reflect intervals of rift building and reconstruction and mark the boundary between major metallogenic epochs such as the Caledonian and Hercynian (Devonian, Timan), and the Hercynian and Kimmerian (Triassic Siberian Platform).

Transitional Structural – Metallogenic Zones

Aulacogenes, pericratonic troughs and foredeeps occurring between folded regions and platforms have much in common as regards their metallogeny. They are characterized by stratiform ("telethermal") Pb-Zn deposits in the terrigenous-carbonate formations of Kara Tau (Central Asia) and Sette-Daban (East Siberia), and by rocksalt, potash and sulphur deposits associated with sulphate-carbonate formations of the pre-Carpathian and pre-Uralian zones. In places there are also deposits of cupriferous sandstone (Uralian, Yenisey zones) and minor phosphorites.

These transitional zones with similar metallogeny but different evolutionary history and structure can be grouped as:

- frontal zones-pericratons at early stages and fore-deeps at late stages of mobile belt formation;
- flank zones where fold systems pinch out, such as in the Dnieper-Donets aulacogene where the Urals and Tien Shan terminate, and the pre-Taimyr aulacogene on the extension of the Verkhoyansk fold area;
- transitional zones, developed during a specific period of time.

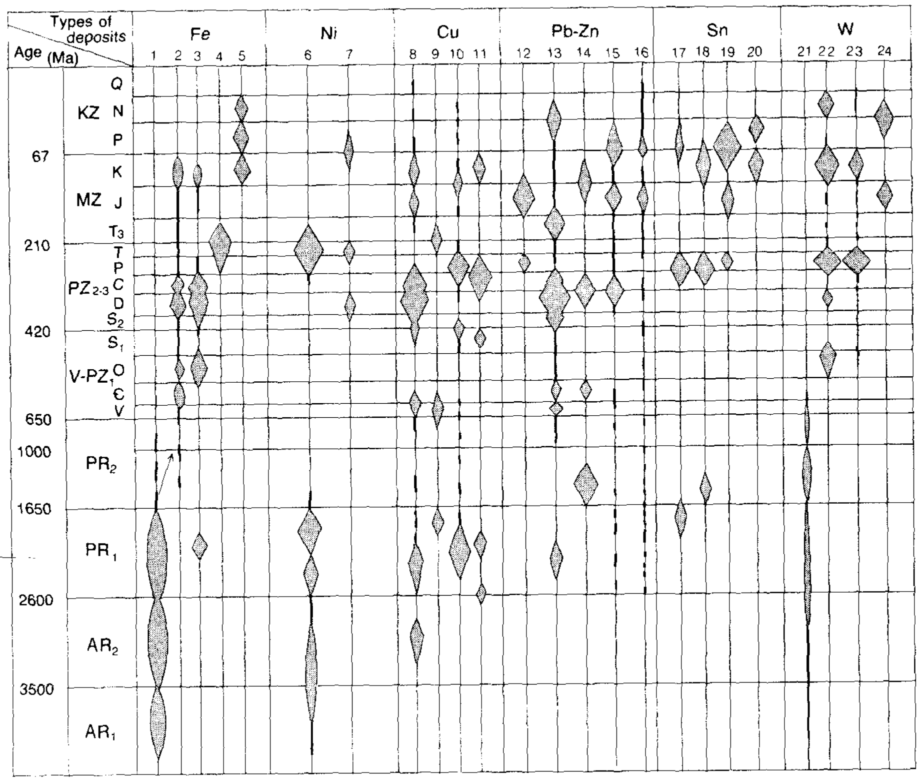

Figure 6: The chronological development of ore deposits of the U.S.S.R.: 1– ferruginous quartzites, 2– siliceous-hematitic iron ore, 3– iron ore skarn, 4– magnesioferritic iron-ore skarn, 5– oolitic iron ore, 6– Cu-Ni sulphides, 7– Co-Ni of weathering crust, 8– Cu-Zn pyrite, 9– epidotic-copper, 10– cupriferous sandstones, 11– porphyry Cu-Mo, 12– Cu-Zn "black slate", 13– Cu-Pb-Zn pyrite, 14– Pb-Zn barite/ siliceous carbonate, 15– Pb-Zn skarn, 16– beresitic Pb-Zn vein, 17– Sn skarn, 18– Sn-W greisen, 19– Sn silicate-sulphide, 20– Sn-bearing rhyolite, 21– W-skarnoid (stratiform), 22– W-Mo skarn, 23– gumbitic W-quartz greisen, 24– argillitic ferberite-stibnite. Width of symbol is proportional to frequency of occurrence.

Fold Belt Zones

Metallogenic zones of this type are highly varied in composition, structural position and metallogeny, the difference being most distinct between eugeosynclinal, leptogeosynclinal and miogeosynclinal zones. Eugeosynclinal zones with mafic, sedimentary and volcanic rocks are characterized by Cu and Cu-Zn pyrite and siliceous hematite deposits (Urals, Northern Caucasus, Tuva). In leptogeosynclines, where slate alternates with tholeiitic basalt, Cu-Pb-Zn and Cu-pyrrhotite deposits are widespread (southern Caucasus, East Kalbinsky zone of Kazakhstan). Fe and Mn ores predominate in the volcanogenic siliceous carbonate associated with stratiform Pb-Zn deposits (Zhairem in Central Kazkhstan), and in siliceous shales associated with phosphorite (the Uda-Kantar zone in Amur).

Zones with developed terrigenous and carbonate formations (miozones) are transitional to aulacogenes and foredeeps, and they are characterized by similar types of mineralization. Stratiform deposits are common, such as barite-Pb-Zn (sometimes with fluorite: Kara-Tau in South Kazakhstan, Sette-Daban), magnesite, sideritic Fe and bauxitic carbonates (western slope of the Urals). In a number of cases these miozones also include typical deposits of base metals and Au in black slate formations (northeastern U.S.S.R.), and Sb-Hg with fluorite (Central Asia, Polar Urals). Zones of late geosynclinal granitoid magmatism contain widespread Fe skarns and scheelite-gold-quartz, Cu-Mo porphyry and polymetallic vein deposits (Turgai, Altai-Sayany).

The mineral deposits of the orogenic zones of the U.S.S.R. are varied. They are associated with subaerial volcanics (Au-Ag, Hg-Sb, S and alunite: northeastern U.S.S.R.), with granitoid intrusions (Sn-W, Cu-Mo, W-Mo-F, Pb-An and Au: Central Kazakhstan, Yakutia, Primorye) and with sedimentary basins (Mn, coal Transcaucasus). Their metallogeny differs according to the composition of their basement rocks: basic magmatics and their metamorphic equivalents occur over mafic basements, and acid magmatics, terrigenous and carbonate rocks and their metamorphic equivalents over salic basements. The former are characterized by Mo-Cu porphyries and the latter by Sn, Ta and Ni deposits. Tungsten, Sb, Hg, Au, Pb and Zn ores are ubiquitous and occur in all types of zones.

Zones of Tectono-Magmatic Activity

Two major types are distinguished here: zones of repeated orogeny and zones of rifting (riftogenesis). The former are accompanied by granitoid magmatism in all regions (Central Asia, Transbaikalia, northeastern U.S.S.R.) and are equivalent in their metallogeny to the orogenic zones of fold belt regions. Among rift zones, three types can be distinguished on the basis of rock composition: differentiated mafic-ultramafic with associated Cu-Ni sulphide and Ti-magnetite deposits (northwest Siberian platform and Kola Peninsula); alkaline-mafic with Fe, Ta, Ni, Al, apatite, fluorite and vermiculite deposits (northwest Transbaikal area, Yakutia); and alkaline salic (foidite) with terrigenous sediments dominated by coal deposits (South Yakutia).

Metallogenic Epochs

For the U.S.S.R. as well as for the other continents, the two most productive metallogenic epochs are the Karelian, (ranging from 2400-1800 Ma) and the Hercynian (the peak of the period 420-200 Ma). These and other metallogenic epochs are shown graphically on Figures 4 and 6. During the Karelian epoch were formed the ferruginous quartzite ores of Krivoy

Rog, micaceous and rare-metal pegmatites in Karelia (Kola Peninsula), the magnetite-phlogopite ores of Aldan, cupriferous sandstone of Udokan, the polymetallic pyrite ores of the Baikal area and the highly aluminous kyanite schist of Kejvy.

The Hercynian metallogenic epoch was marked by the maximum development of Cu and polymetallic deposits (Urals, Altai), stratiform barite and Fe-Mn-barite polymetallics (Kazakhstan), magnetite skarn (Urals, Transuralian area), rare-metal (Mo-W), Cu-Mo porphyry, and many fluorite deposits associated with granitoid magmatism. Sedimentary deposits are widespread: cupriferous sandstone (Dzhazgazgan in Central Kazakhstan, Uralian area), phosphorites (Karelia, Central Asia), bauxites (North Urals Bauxite District) and coals (Karaganda, Kuznetsk Basin).

Between these two most productive metallogenic epochs, there was a period from 1800 to 1000 Ma ago (Early-Middle Riphean) when there was little mineralization. This was a time of pericratons and aulacogenes (Fig. 5), referred to by Smirnov (1982) as the "inter-geosynclinal" period (see preceding paper). There were however a limited number of mainly exogenetic mineral deposts that formed during this period: stratiform siderite deposits (Baikal, Satka), siliceous-hematite shale, stratiform Cu-Pb, W deposits in carbonate and carbon-bearing formations, and the first halogenic deposits, though these are not yet economic.

Of the endogenetic deposits characterizing this period, mention will only be made of skarn and greisen (Sn, W, rare metals) deposits and pegmatites with precious stones and ore minerals (associated with rapakivi granites of Karelia and the Ukraine).

Figure 6 shows the main periods of formation for the major ore deposits of the U.S.S.R. This illustrates how metallogenic and orogenic epochs are used together to divide the geological time scale into a number of "periods" of various ranks (see left-hand column of Fig. 4). The boundary between the two first-rank divisions is placed in the Proterozoic (at 1 800 Ma), and one of the most significant of the third rank is drawn at 1000 Ma (Riphean), following which the role of geosynclines and orogenies gradually increased.

Conclusion

Metallogenic studies in the U.S.S.R. have led to detailed schemes of structural and metallogenic zoning, based on differences in ore deposits. They have also resulted in the distinction of major metallogenic epochs and of stratigraphic "levels" of ore formation. These patterns, together with geological, geophysical and geochemical surveys provide the scientific basis for prospecting in the Soviet Union.

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Ancient Urals — New Problems

by Aleksandr M. Dymkin and V.N. Puchkov

The Ural Mountains have long been regarded as a classical geosynclinal region. However, recent studies on Uralian ophiolites, melanges and deep-fault structures together with seismic profiles and drill-hole data lead to interpretations involving plate tectonic models. In this paper the authors review the overall structure, stratigraphy and evolution of the Urals.

Figure 1: *The valley of the Truba-iu River in the Voykar ophiolite massif of the Polar Urals.*

Introduction: Fixism vs Mobilism

The Ural region (Fig. 2) is one of the oldest mining areas of the world; with very large mineral reserves it is the base of the powerful Soviet industry. Extending north to south for over 2000 km, this range contains folded, magmatic and metamorphic rocks from Archaean to Mesozoic in age. It was in the Urals where Murchison first distinguished the Permian System, and it was here that the stratotype was proposed for the Riphean by N.S. Shatsky. The Urals also provided the material for the fundamental works of A.P. Karpinsky, A.N. Zavaritsky and D.V. Nalivkin. A.V. Peive's concept of deep faults and D.S. Korzhinsky's of metasomatism arose from their work on the Urals, and the Soviet approach to the analysis of formations (N.S. Shatsky and N.P. Kheraskov) began here.

In the last decade or so, two distinct concepts, fixist and mobilist, have been vigorously applied to the Urals. The fixist view in its most complete form was set forth at the beginning of the 1970s by A.A. Pronin (1971) and I.D. Sobolev (1968) among others. According to them a number of cycles (Baikalian, Caledonian, Variscan) can be seen in the evolutional history of the Urals. Each cycle began with the break-up of a stable zone and geosynclinal subsidence, allowing the accumulation of thick sequences of sediments and followed by active volcanism, injection of intrusive rocks and metamorphic processes. Each cycle ended with intense folding, synchronous with movements in other regions and destroying the geosynclinal trough. Temporary stabilization followed until the beginning of a new cycle. The tectonism that caused the formation of geosynclinal zones of subsidence and their annihilation was considered to be the result of vertical movements of crustal blocks separated by subvertical deep faults.

The fixist concept seemed quite secure until the late 1960s when the new ideas of lithospheric plate tectonics began to attract attention throughout the geological world. In this mobilist view, the lithosphere is divided into a number of large plates, which move horizontally relative to one another. Where they diverge in regions of tension along mid-ocean ridges, thin heavy ocean crust is formed. Where they converge in regions of compression, island arcs and volcano-plutonic belts marginal to the continents form, the crust thickens, and light silica-rich material accumulates to build the continents.

Although the plate tectonic concept arose from study of the geology of oceans, it soon influenced ideas on the geology of the ancient folded regions of the continents. Among the first geologists to apply these new ideas were those working on the Urals. An important stage in this work was the creation of a 1:1 000 000 tectonic map published together with an accompanying explanation in 1977 (Peive et al.). This work was carried out by the Geological Institute of the Academy of Sciences of the U.S.S.R., the Institute of Geology and Geochemistry of the Ural Scientific Centre and the Geological Production Association "Uralgeologiya" under the guidance of A.V. Peive and S.N. Ivanov.

Brief Outline of Ural Evolution

Our own view is that at the beginning of the Palaeozoic a continent existed in place of the contemporary Urals. In the Ordovician this continent broke up to form two lithospheric plates moving apart from one another. In the ocean basin that was born between these plates, ophiolites appeared – a stable association of heavy deep-seated rocks depleted in silica (dunites, harzburgites, pyroxenites, gabbroids), a series of diabasic dikes with basaltic lavas, and deep-water sediments (cherts and less commonly limestones). These ophiolites are now best developed on the eastern slope of the Urals within the so-called Zelenokamennaya zone.

In the Silurian there appeared, for the first time within this oceanic depression, extensive calc-alkaline rocks and a variety of shallow and deep-water sediments and tuffs. All these geological formations, including plagiogranites and related rocks, can be readily compared with those in contemporary island arcs. In the Silurian and Devonian, zones of island arc rocks divided the primary oceanic basin into a system of ridges and deep-water troughs, filled with thick sequences of sediments and subordinate volcanics. Throughout this period the light material forming the new continental crust continued to accumulate.

The decisive moment in the development of the continental crust of the eastern Urals was the beginning of strong compressive orogenic processes, which became intensive in middle Carboniferous time, continuing in intervals up to the Triassic. Folding in the Urals was followed by a considerable reduction in the widths of the geosynclinal troughs, by the formation of nappes and huge batholithic granites, and by the thickening of the crust. The result was to unite the colliding lithospheric plates into the uniform platform of Northern Eurasia.

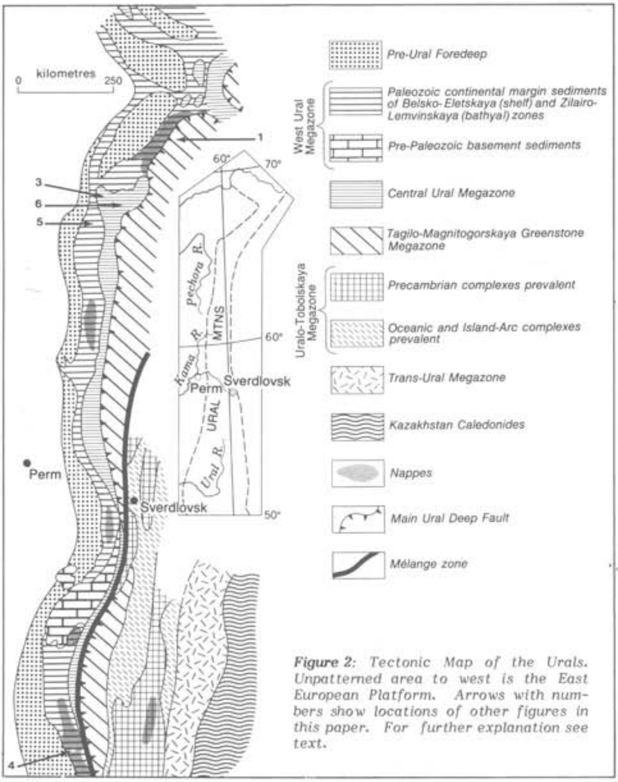

Figure 2: *Tectonic Map of the Urals. Unpatterned area to west is the East European Platform. Arrows with numbers show locations of other figures in this paper. For further explanation see text.*

The Ophiolites of the Eastern Urals

Ophiolitic associations are extraordinarily abundant in the Urals, and one of the central questions now being solved concerns their petrology, structure and genesis – a matter of global importance. A very interesting problem here concerns the inner structure of thick ultrabasic massifs (Fig. 1). According to the view first proposed by S.V. Moskaleva in the 1960s, the large dunite-harzburgite bodies of the Urals such as Syum-Keu, Rai-Iz, Voykar and Kraka represent large masses detached from the mantle and containing relicts of its structure (for recent reviews in English see Savelyev and Savelyeva, 1977, and papers by Ivanov et al., Ruzhentsev and Saniygin, Savelyev and Savelyeva, and Lennykh et al., in Malpas and Talkington, 1979 – Ed.). This concept received much stimulus from the work of A. Nicolas and his colleagues (1973). Studying the structure of these massifs thus reveals something of the stages of development of the Palaeozoic oceanic mantle in the Urals (Savelyeva and Denisova, 1983).

In the popular magmatic-mantle hypothesis, ophiolites are viewed as forming close to the axial part of the mid-ocean ridge in a magma chamber established on a dunite-harzburgite substratum of the mantle. Constant crystallization and differentiation take place as the melt cools. The crystals that appear settle to the bottom to form layers of different composition, mainly dunites, pyroxenites and gabbroids. Diabasic dikes cut the upper part of the gabbroid layer, locally forming continuous complexes of parallel dikes, which testify to stable processes of tension. Further upwards in the section, the dike complex changes into a sequence of basaltic lavas intercalated with deep-water sediments. This hypothesis fits well with plate tectonic concepts of lithospheric platforms, and contributes to comparison of ocean bed formations and to formations of folded continental belts. It also explains the succession of rock formations observed in modern ophiolitic belts.

However, this concept also has its drawbacks. Geophysicists have not found such large magma chambers under modern mid-ocean ridges. It is also rather difficult to estimate the composition of the parent magma, which could have given birth to the layered complex, for there are no analogs to this magma in volcanic rocks of the modern oceans. Ophiolitic sections both in the oceans and on the continents by no means always exhibit the standard succession described above; in particular the dike complex is quite commonly absent. Where present, it usually contains blocks of the underlying rocks, which it had intruded; these older rocks are generally represented by ultrabasics and gabbroids, which were metamorphosed, and deformed and cooled prior to the period of dike intrusion. The rocks of these layered complexes commonly exhibit metamorphic features such as granoblastic texture and stability of composition, insofar as the chemical composition of their minerals is independent of their abundance.

These and other considerations have led to a new hypothesis for the genesis of ophiolites (Yefimov and Puchkov, 1980). Comparison of the composition of the Ural ophiolites with fragments of the relatively deep mantle, which occur as inclusions in alkaline basalts, indicates clearly that the upper mantle contains not only high-magnesium ultrabasics, but also rocks with a chemistry comparable to that of Alpine-type ophiolitic gabbroids, despite the gross differences in the composition of their minerals. Gabbroids cannot however exist at great depths, and their high-pressure equivalents here are garnet pyroxenites and eclogites. These considerations led Yefimov and Puchkov to suggest that ophiolites originate under mid-oceanic ridges from ductile, high-temperature, basic-ultrabasic material rising from deeper portions of the upper mantle, followed by fusion of oceanic basalts.

Undepleted basic-ultrabasic material of the mantle (pyrolite) separates at depths of 20-60 km into basaltic magma and a complex refractory residue composed of dunite, harzburgite, eclogite and garnet peridotite. As this mantle material rises to lower pressure zones, the eclogites and garnet peridotites change into gabbroids, blocks of which, being much lighter than the other mantle rocks, rise to accumulate as the lower layer of the oceanic crust. Meanwhile deeper in the mantle, oceanic basalts originate by the fusion of undepleted mantle material. They rise to the surface to form the volcanic layer, which is then overlapped mainly by deep-sea sediments.

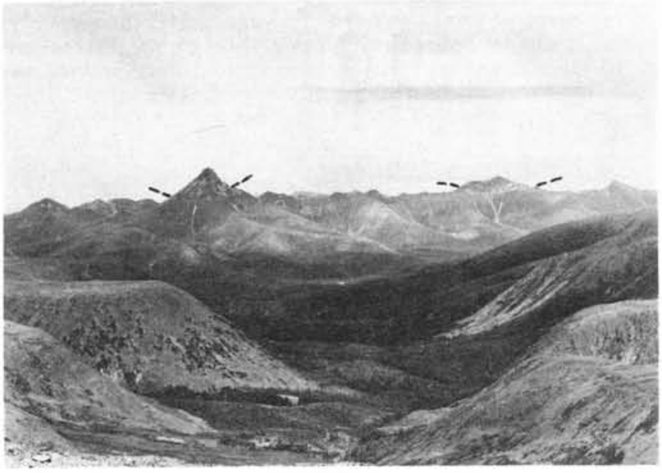

Figure 3: Panoramic view in the northern Urals. Broken line shows unconformity between Riphean and Ordovician. Cambrian rocks are absent here.

This hypothesis is in accordance with the well-known geophysical models that view the convection of magma as the cause of movement of lithospheric platforms. However whether this concept or the mantle-magma hypothesis is correct, only further critical study will decide.

Palaeozoic Sediments of the Western Urals

Recognition of the oceanic nature of the Palaeozoic troughs of the eastern Urals is an important factor in plate tectonic interpretations of this mountain region. The Palaeozoic sediments of the western Urals were considered to be wholly geosynclinal, in contrast to the sediments of the East European platform to the west. These sediments were thought to have undergone Caledonian folding in the Ordovician and/or Devonian to cause the appearance of the Central Ural Uplift, the erosion of which from time to time supplied terrigenous material to the west. However, thorough facies and palaeotectonic analyses show that throughout much of the western slope of the Urals (within the limits of the Belsko-Eletskaya structural-facies zone), shallow water sediments were deposited in the lower and middle Palaeozoic under similar conditions to those existing in the adjacent platform, and that gently sloping platform structures with non-Ural orientation were formed. Not until the end of Palaeozoic time did these rocks undergo intense folding along Uralian trends, and it was at this time that the Central Ural Uplift appeared (Fig. 3, and Puchkov, 1975).

The interpretation of the deep-water Palaeozoic sediments of the western slope of the Urals within the Zilairo-Lemvinskaya zone is of equal importance. These terrigenous sediments consist of interbedded sandstones, siltstones, argillites, limestones, and cherts, ranging in age from Ordovician to Lower Permian, and found in erosional-tectonic remnants throughout the western Urals. Their deep-water character is indicated by the pelagic character of their fossil fauna, their peculiarities of geochemistry and lithological composition, and in particular by the presence of turbidites characteristic of modern continental margins.

Until the recent discovery of conodonts, the extreme paucity of fauna was a principal difficulty in unravelling the geological history of these rocks. Analysis of these organic remains has led to radical changes of the views on stratigraphy of these deposits (Fig. 4). For example, it is now recognized that all the divisions of the Devonian are represented in the Zilairo-Lemvinskaya zone, where previous workers had placed a major erosional hiatus at the base of the Carboniferous sediments, and where only Ordovician, Silurian or Carboniferous rocks were thought to occur

Figure 4: Searching for conodonts in Palaeozoic bathyal cherts.

(Fig. 5). Thus the last arguments in favour of the prolonged development of the Central Ural Uplift disappeared. On the western slope of the Urals, the relicts of a Palaeozoic passive continental margin can clearly be seen as Ordovician-Devonian sediments of neritic and bathyal regions (Puchkov, 1979).

The question of the primary character of the junction between western sediments and the eastern rocks of the palaeo-oceanic region of the Urals has not, however, been solved, for they are now separated by a deep fault zone described below. Nevertheless present-day workers tend to distinguish in the Urals geological assemblages corresponding in composition and lithology to the complexes of modern oceanic basins and island arcs, and to the shelves, slopes and rises of modern passive continental margins. Yet, the width of the Urals does not exceed 300 km, and the Ural geosynclinal trough must have undergone at the end of its development a considerable reduction in lateral dimensions. The evidence for such movements can be found in nappe structures.

Lateral Shortening: Nappes and Island Arcs

As early as the 1930s and 1940s, nappe structures were identified by G.N. Frederix, E.A. Kuznetsov, A.D. Arkangelskiy, K.G. Voinovskiy-Kriger and many others. These interpretations were, however, overshadowed from the early 1940s by fixist concepts of the Ural structure, and it was not until the 1960s that the idea of the wide development of nappes in the Urals was restored as a result of new structural-facies analyses, and geophysical and drill-hole data (e.g. Kamaletdinov, 1974; Ruzhentsev, 1976).

One of the largest nappes, the Malopechorskiy, was identified in the northern Urals; new evidence was presented for the nappe structure of Lemvinskaya zone of the Polar Urals (Fig. 6), and the inner structure of Bardymskaya nappe of the Middle Urals was described (Puchkov, 1979). The latter nappe, first decribed by O.A. Neiman-Permyakova and G.A. Smirnov, is of special interest for its existence was proved by data from five structural holes drilled into the Ordovician-Devonian deep-water, terrigenous to cherty sequences comprising the overthrust sheet and the Devonian shallow sediments of Belsko-Eletskaya zone, which underlie this nappe. The minimum lateral displacement of the Bardymskaya nappe is regarded as about 30 km.

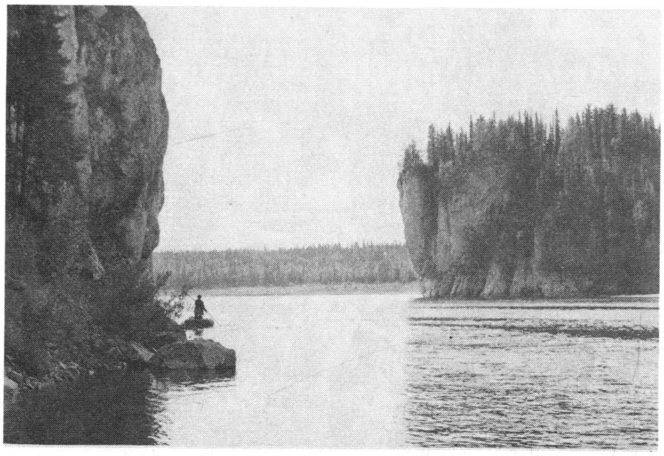

***Figure 5**: The "Middle Gates" of the Schugor River, western slope of the Urals. The cliffs are of Carboniferous limestones which represent the upper part of the section of deformed Palaeozoic shelf sediments. In the background are low outcrops of Lower Permian flyshoid sediments.*

***Figure 6**: Intensely deformed Riphean metamorphics with typically flat-lying schistosity, Khobeis dome, eastern slope of the northern Urals.*

Nevertheless, the nappe tectonics of the Urals and especially its eastern slopes are not yet fully understood. The fundamental question of the width of the Palaeozoic oceanic basin still remains, with some workers comparing it to the width of the Atlantic Ocean, others to the Mediterranean Sea, and some to the Red Sea rift.

The existence of island arcs in the development of the Urals may provide circumstantial evidence of considerable lateral crustal shortening. According to the subduction model, the zones of deep-focus earthquakes, located under the modern island arcs and active continental margins, mark the surfaces on which one lithospheric plate constantly moves under the other, partly remelting and partly being absorbed by the mantle. Strong compression of the Urals in the late Palaeozoic caused the disappearance of the island arcs as such, but there remain thick complexes of calc-alkaline, basaltic, andesitic, dacitic and other magmatic rocks, with relicts of volcanic structures which mark axial volcanic zones of these island arcs. There are also welded tuff and tuff-turbidite sequences with jasperoid horizons which correspond to the slopes of island arcs.

The interpretation of these complexes, their primary lateral distribution, and their relations with the underlying oceanic and overlying flysch sequences is not yet complete because of the lack of stratigraphic data. Recent discoveries of widespread conodonts in cherts will, however, assist in the successful solving of many stratigraphic problems. The correct interpretation of geodynamic history, of course, is not possible without a firm stratigraphic basis.

Paired Metamorphic Belts

The possible existence in the Urals of "twin" or paired metamorphic belts may help to establish indications of subduction zones. These were first established in the Japanese island arc (Miyashiro, 1973) where folded zones of the Pacific Ocean margin commonly contain parallel metamorphic belts of nearly the same geological age but contrasting character. One of these belts usually corresponds to the low or moderate pressures and high temperatures of the amphibolitic facies, and the other to the high pressure and relatively low temperature eclogite and glaucophane-schist facies. Such paired belts are regarded as corresponding to zones of collision between lithospheric plates, the high pressure belt being formed at the front of island arcs close to the sinking cold oceanic platform, and the high temperature belt behind the island arc.

The work of G.A. Keilman, V.I. Lennykh, N.A. Dobretsov, A.I. Russin and others shows that high-pressure metamorphic rocks are centered in a relatively narrow region along the Main Ural Deep Fault zone and to the west of it. High temperature Palaeozoic metamorphics (amphibolite facies) occur only to the east, within the Ural Zelenokamennaya belt and Uralo-Tobolskaya zone. At first sight this situation would seem to represent a typical twin belt of Palaeozoic metamorphism. However the matter is much more complicated, and the Miyashiro scheme does not fit here.

First, the amphibolite metamorphism of the eastern slope of the Urals did not develop everywhere at the same time. In the Zelenokamennaya zone it is mainly middle Palaeozoic, possibly coinciding with the island arc stage of development. However in the Uralo-Tobolskaya zone to the east, late Palaeozoic metamorphism is best represented, corresponding to the time of collision and tectonic piling-up of continental blocks.

Manifestations of eclogite and glaucophane schist metamorphism in the Urals are probably not of the same age and type either. In part, these metamorphic rocks developed at the expense of ophiolitic oceanic substratum, matching the phenomenon of subduction (cf. Miyashiro, 1973). However much of this high-pressure metamorphism has developed on rocks of the continental and intermediate crust within the Central Ural Uplift, regarded as a passive continental margin during the middle Palaeozoic.

One hypothesis, therefore, is that Palaeozoic (and Precambrian) metamorphic rocks of the Urals belong to at least two twin belts of different genesis. The first (middle Palaeozoic) is obviously related to underthrusting of the oceanic plate to the east under the island arc; the other (late Palaeozoic) is associated with the collision of two continental blocks during the final closure of the geosyncline.

The Main Ural Deep Fault

The new interpretations of the geology of the Urals requires a revision of ideas on deep faults, a very popular concept in the U.S.S.R. One of the tectonotypes for these is the Main Ural Deep Fault (MUDF), which separates the western palaeocontinental from the central palaeo-oceanic regions in the Urals.

The MUDF appears to have formed under conditions of tension, bordering the newly formed oceanic crust. Its primary nature has, however, been obscured by later deformation related to the lateral compression of the Uralian geosyncline. It is not surprising therefore that the MUDF is associated with high pressure metamorphism; exposures of blastomylonites of amphibolite and greenschist facies mark its deep-seated portions.

A large part of the extensive Uralian zone of serpentinite mélange is confined to the MUDF zone, where it is represented by gigantic tectonic breccias composed of heterogenous, sometimes exotic, fragments in a ductile serpentinite matrix. As shown on Figure 1, the Sakmaro-Voznesenskaya mélange zone, which extends along the southern segment of the fault, passes northwards into the Serovsko-Maukskaya zone, which is in turn overlapped by Meso-Cenozoic sediments of western Siberia. Together these two zones form one of the world's longest (more than 1200 km), generally unbroken, zone of mélange development, the northern and the southern terminations of which are unknown.

According to recent seismic data, the surfaces bounding the MUDF zone dip to the east at rather high angles (40-60°). However, there is reason to suppose that they flatten out with depth, like the surfaces of many nappes studied by drilling. Considerable overthrusting probably occurred along these surfaces in the Palaeozoic, together with the consumption of a great amount of crust. As a result, extremely varied rocks, originally of far distant facies, have been brought into juxtaposition and whole facies zones obliterated. Similar structures outside the Soviet Union are now generally labelled "suture zones" (e.g. the Himalayan Suture Zone of Gansser, 1980). Thus, the fixist concept of deep faults finds its place in the new tectonic models of the Urals.

Finally, there is the problem of the deep crustal structure of the Urals. There has been much geophysical study of the Urals in the last two decades, geophysical anomalies have been thoroughly investigated and their interpretation attempted. Many seismic studies have been carried out, including several profiles of deep seismic sounding. As a result, the crust beneath the Urals is now considered to be 40-50 km thick and grossly differentiated in its structure. Within the limits of Tagilo-Magnitogorskaya eugeosynclinal zone the crust is thick, heavy, and "simatic," with a reduced "granitic" layer. The granitic layer is however much better developed in the Zapadno-Uralskaya and Uralo-Tobolskaya megazones, the former being characterized by sialic crust, the latter being heavy, heterogeneous and combined with light blocks.

Conclusion

The conclusion that the Uralian crust in the Palaeozoic evolved from oceanic to continental under conditions of compression and tectonic piling-up leads to the supposition that the modern crustal profile may commonly be doubled and tripled in thickness, with old continental blocks locally overlapped by plates of the oceanic crust. However while modelling the deep structure of the Urals, there is still enormous space left for the imagination. Moreover, drilling of the Kola Super-deep well (see Kozlovsky, 1982, – Ed.) has thrown doubt on standard geophysical models of deep crustal structure. Drilling of a new superdeep well (to 15 km) planned for the Central Urals near Krasnouralsk, should give a real geological dimension to the available profiles of deep seismic-refraction.

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The Baikal Rift System

by Nikolai A. Logatchev

Figure 1: The southern flanks of Lake Baikal looking westward across the inlet to the Angara River (foreground right) through which 63 km^3 of water flow out annually.

The Baikal rift of Siberia is a 1800 km-long system of faults and rift valleys associated with a domal uplift. Its central segment is located at the junction between the Sayan-Baikal mobile belt and the Siberian craton in a "weakened" zone from which the rift propagated to the northeast and southwest. The Baikal system is characterized also by basaltic magmatism of a rather monotonous composition. Rifting in East Siberia was an independent phenomenon not connected with the collision between India and Eurasia, but rather the result of local heating and gravitational instability of the lithosphere caused by upwelling of the asthenosphere.

Introduction

The geology and geophysics of the Baikal rift zone were thoroughly studied during the Upper Mantle and the Geodynamics programs (Logatchev and Mohr, 1978). Since then, productive investigations of deep-seated structure and seismicity have been conducted in the 800 km-long zone extending from the northern end of Baikal eastward to the Olekma River. In addition, heat flow and seismo-acoustic measurements have been carried out recently in Lake Baikal. This lake (Fig.1) contains about 23 000 km^3 of fresh water and is the world's deepest (1 620 m) intracontinental water reservoir; its bottom lies 1 165 m below sea level. In 1977, the Canadian-made manned submersible carried out studies in southern Lake Baikal to a depth of 1 410 m (Fig.2).

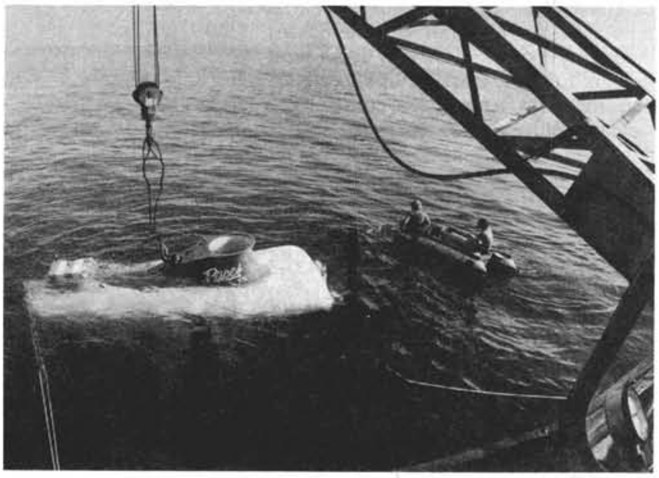

Figure 2: The Pisces manned submersible about to dive in southern Lake Baikal, August 1977.

Morphology and Regional Structure

The Baikal system of rift depressions and faults (Fig. 3) covers a lengthy belt of the southern uplands of East Siberia, extending from northern Mongolia to southern Yakutia. It is confined to the Sayan-Baikal domal uplift, which is the highest part of East Siberia, having been raised to 2 500-3 000 m by Cenozoic movements (Fig.4). The 1 500 m contour line of the Cretaceous-Palaeogene erosion surface in Figure 3 outlines the general shape of this uplift. It consists of two culminations separated in the South Baikal basin by a saddle-like depression to which the delta of the Selenga River, the main tributary of Lake Baikal, is confined.

There is a symmetry in the Baikal regional structure: in the saddle between the two uplift culminations, with their dispersed faults and rifts, the centre of the entire Baikal rift is marked by the South Baikal depression, at 6 000 m the deepest in the whole system. The culminations differ in size, shape and in the arrangement of their faults and depressions. The northeastern culmination is more extensive than the southwestern, and it has a more or less constant orientation in the structural fabric of its Precambrian basement. In the southwestern culmination the strike of the faults and rift valleys changes sharply from latitudinal to meridional, and there is a marked contrast between rift forms and basement structures.

The Baikal rift zone runs close to the edge of the Precambrian Siberian platform. The central segment of the zone occupied by Lake Baikal stretches for about 500 km along the deep-seated marginal suture that separates the cratonic area from the Sayan-Baikal mobile belt, consisting of both Precambrian and Early Palaeozoic fold systems. At both terminations of the South Baikal depression, Cenozoic faults and grabens veer from the craton into the fold belt, indicating less dependence on the basement structural anisotropy.

In the northeast, the Baikal rift system penetrates into the Archean of the Aldan shield where it dies out due to the thickening of the lithosphere at the transition from the fold belt to the craton (Logatchev and Florensov, in Logatchev and Mohr, 1978). The Chara and Tokka depressions (Fig.3) are the last segments of the rift zone located in the craton, and they cross its structural fabric at a right angle. This direction was apparently not suitable for rift propagation, though it coincides with the general strike of the whole zone.

The direction around the Aldan shield along the Stanovik and Dzhugdzhur systems of deep-seated faults is evidently more favourable, for in the Olekma valley region there are small rift-like depressions, and several strong earthquakes (magnitude 6.5 to 7) have occurred there within the last thirty years. Their focal mechanisms are similar to those of rift earthquakes (Misharina, 1967), and the way is open to the east for propagation of the Baikal rift.

Another situation exists in the southwestern culmination of the rift zone. The north-south rift structures of North Mongolia are limited in the south by the east-west Balnai fault (Fig.3), which was rejuvenated as a sinistral strike-slip fault by the strong (magnitude 8.2) earthquake of 1905. This shear zone of deep-seated origin separates two large lithospheric blocks and serves as a barrier preventing the Baikal rift from extending southward. The branching of the Baikal rift in the three depressions of Khubsugul, Darkhat and Busingol also indicates the dispersion of rifting energy throughout a larger volume of the lithosphere than underlying the single Tunka graben. Moreover, at the western termination of the Baikal rift, subhorizontal north-south compression prevails at present, in contrast to the rest of the rift zone where extension across strike dominates (Misharina, 1967; Misharina et al., 1983; and see page 43 this issue of Episodes – Ed.).

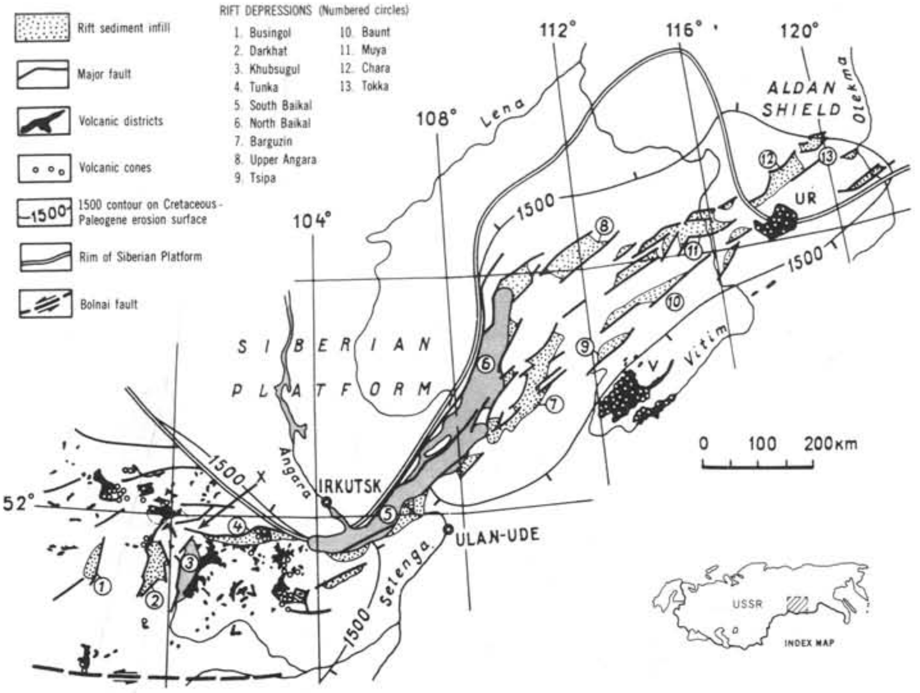

Figure 3: The general regional geological setting of the Baikal rift. V – Vitim plateau, UR – Udokan Range. Lake Baikal shaded.

Rift Valleys and Faults

The Baikal system consists of 13 large individual depressions arranged locally in parallel and separated from each other by transverse or diagonal "cross-pieces" (Fig. 3). The Lake Baikal basin (Figs. 5 and 6) is formed by the two en echelon depressions of South and North Baikal, which are separated by the diagonal uplift of Olkhon Island and the underwater Akademichesky Range. Each of the Lake Baikal depressions is 400 km long and up to 70-75 km wide, whereas other mature depressions in the rift system vary from a few tens to 200 km in length and from 35 to 40 km in width. Alongside the large depressions there are some narrow Pleistocene-Holocene fault trenches ranging in length from a few km to several tens of km.

The thickness of sediments in the basins usually varies from 1 500 to 2 500 m, with the maximum (about 6 000 m) recorded in the South Lake Baikal depression. A borehole 3 000 m deep in the Selenga delta region was stopped in Late Eocene to Early Oligocene sediments. The sedimentary infill of the basins is a mixture of fluvial, proluvial, lacustrine, palustrine, glacial, fluvioglacial and eolian deposits. Lacustrine and fluvial sediments prevail inside the basins, changing to subareal facies in the vicinity of the adjacent mountains.

The rift depressions are bounded on one or both sides by high fault scarps rising 1 500 to 2 000 m above the basin floors. The northern slopes of most depressions are higher and steeper than the southern flanks, and this results in a characteristic structural and morphological asymmetry. The crystalline basement of the depressions is locally cut by small faults, but in general the rifts follow the ductile structures in the basement.

Faults of different trends and ranging in age from Precambrian to Cenozoic play a dominant role in the structure of the rift system. Most of the large faults are normal or oblique-slip, with vertical displacements ranging locally to 3000-4 000 m. The strike-slip faults can be seen on both flanks of the rift zone, and indirect evidence suggests horizontonal displacements of a few km. Focal mechanisms (Misharina et al, 1983) indicate that the central segment of the rift zone (Baikal depression proper) is being formed under the action of a tensional stress field, and the general extension of the crust, including plastic thinning, is estimated by Yu.A. Zorin at 15 to 25 km. Along the rift zone flanks (especially the western ones) the crustal extension is combined with sinistral strike-slip.

The Baikal rift zone is a complex intraplate boundary resulting from the initial divergence of the lithosphere in East Siberia. Nevertheless, it is hard to predict whether the

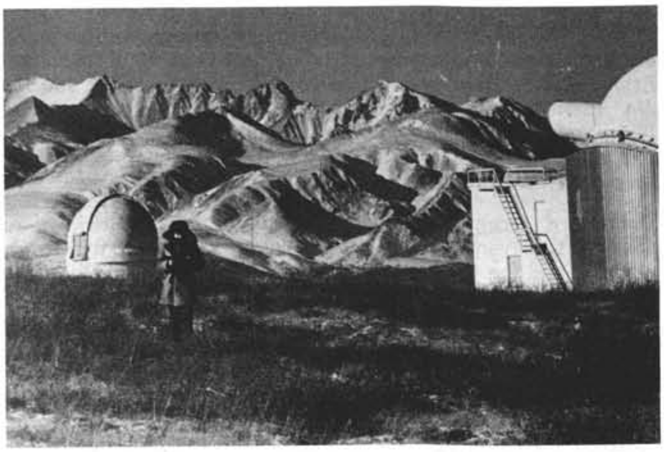

Figure 4: Mountains between the Tunka and Khubsugul depressions with the Munku-Sardyk massif, the highest peak of East Siberia (3 491 m) in the background (X marks location on Fig. 3). In the foreground a solar coronograph and a chromospheric telescope are located on an ancient erosion surface about 2 000 m above sea level.

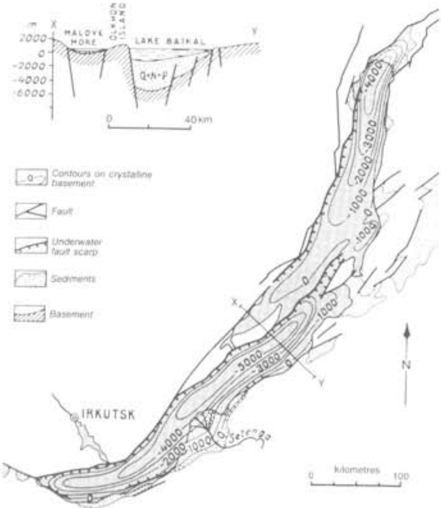

Figure 5: The structure of the Lake Baikal depression, showing a typical cross section. Q+N+P: Quaternary, Neogene and Palaeogene. Shading indicates the extent of the lake.

Figure 6: V.I. Galkins's relief model of the Baikal depression, looking to the NNE. Selenga River delta in right foreground. Vertical scale is 7 times the horizontal.

lithospheric extension will progress to complete crustal disintegration (as in the Red Sea rift), whether the continental lithosphere will be replaced by the oceanic lithosphere, or whether rifting will cease in this continental environment. The Baikal system of rejuvenated ancient faults and newly formed faults reflects elastic destruction of the upper lithosphere. Because of viscosity changes with depth, the lower crust and upper mantle are likely to deform plastically under the action of asthenospheric upwelling and lithospheric necking below the rift valleys.

Volcanism

Volcanism has played a subordinate role in the development of the Baikal rift though there are simple multilayered basalt plateaus and cinder cones. Whereas in the Kenyan and Ethiopian rifts the total volume of volcanics is about 500 000 km^3 (Baker et al., 1972 for a general comparison between the Baikal and Kenyan rifts see Logatchev, Zorin and Rogozhina, 1983a, 1983b – Ed.), in the Baikal rift, which is similar in area, their volume does not exceed 6 000 km^3.

There are three main volcanic areas, from southwest to northeast: Sayan-Khamar-Daban-North Mongolia, the Vitim plateau, and the Udokan Range (Fig. 3). The first field is the most prominent, containing at least 50% of the entire volume of young volcanics. Lava sheets up to 500-600 m thick are widely distributed here, and small cinder cones and dikes are rarer. Stratovolcanoes are absent, indicating the prevalence of fissure eruptions. The lava sheets are usually not confined to rift depressions and bounding faults but are located on the uplifted shoulders of the rift valleys. The Tunka depression is, however, an exception, for basalts are regularly intercalated with sediments and comprise 20% of its 2 500 m-thick infill (Fig. 7). In other depressions, including Lake Baikal, lava covers are absent.

An unexplained paradox is the absence of volcanics from the Lake Baikal depression. The lithosphere below the lake is greatly thinned and extended as compared to other segments of the rift zone (Zorin, 1981). Rare Cenozoic basalt dikes occur in the slopes of the depression, and on the Ushkany Islands, which are a part of the underwater Akademichesky Range, small vents and dikes of biotite, augite and melilite-bearing porphyrites with an age of 52 Ma have been found (Yeskin et al., 1978). These intrusive bodies formed during the initial rifting stage, and may have intruded into the crust prior to the subsidence of the depression. Such a situation is similar to that of the Upper Rhine graben where subvolcanic plugs and dikes (45 to 90 Ma) intruded into the crust long before graben formation in the Middle Eocene (Neugebauer and Temme, 1981).

Unlike the volcanic rocks of the rifts of East Africa and Central Europe, those in the Baikal rift have a rather monotonous composition, mainly alkaline olivine basalts. In rare cases there are continuous variations in chemical composition, from mildly alkaline basalts and trachybasalts to tholeiites. The main reason for the insignificant degree of magmatic differentiation is the long-term existence of melting sources at the same depth within the upper mantle and the ease of melt transfer through fissures to the surface.

The volcanic rocks from the Udokan plateau are, however, markedly differentiated, ranging from mildly alkaline compositions (alkaline olivine basalt-trachyte) to more highly alkaline basanitoid and nepheline mugearite. The Udokan volcanics were evidently connnected with a possible deepening of the upper mantle melting source, due to changes in the tectono-thermal system at its transition from the lithosphere beneath the fold belt to the cooler and thicker lithosphere of the Aldan shield. Yet the Baikal rift volcanics on the whole are differentiated less than volcanics from other zones of Cenozoic continental rifting, such as East Africa, Central Europe, and Western U.S.A., including the Rio Grande rift. Acid differentiates and strongly alkaline rocks with carbonatite are unknown in the Baikal system, and intermediate rocks (trachyte, mugearite, benmoreite) are rare, being found only in the Udokan range.

Basalts from the Baikal volcanic province contain lherzolite and pyroxene nodules whose composition suggests that the uppermost mantle here consists of spinel lherzolite with pyroxenite lenses underlain by garnet lherzolite. The mineral and chemical compositions of the nodules, together with physical and chemical modelling, suggest that the parent melts could have formed through partial melting (5 to 10%) of spinel lherzolite enriched by alumina at a depth of no more than 80 to 100 km. Melt fractionation in the mantle has resulted in formation of large cumulate inclusions of pyroxene, anorthoclase, kaersutite, titanophlogopite, garnet, spinel and titanomagnetite.

The distribution of volcanic rocks shows the independence of volcanicity from rift structure formation in the upper lithosphere. Structural development and magmatism are thus equivalent manifestations of the rifting process, a feature of Cenozoic rifting in East Siberia, which has not yet been properly explained.

A Two-Stage Evolution

The sedimentary infill of the Baikal rift depression can be subdivided into two parts, differing in composition and structure and corresponding to two evolutionary stages. In the lower part of the section are Eocene, Oligocene, Miocene and Lower Pliocene sediments composed of sandstone, siltstone, argillite and clay, with rare beds of brown coal, diatomite and marl mainly close to the periphery of the depression. These lacustrine, palustrine and fluvial sediments accumulated under subtropical (Eocene) to moderately warm (Oligocene, Miocene) climatic conditions, and they lack the coarse-grained marginal facies of a conglomerate or fanglomerate type.

From the Eocene to Miocene, the sedimentary basins were wider than in the Pliocene to Quaternary, because the topographic contrasts were less and the rates of tectonic movements lower than in the latter period. Plateau-like uplifts surrounding the depressions were cut by shallow river valleys. The relative variations in heights of the uplifts ranged from 400 to 500 m to judge from the morphology of the surface buried below Oligocene-Miocene basalts in the Khamar-Daban, East Sayan and Udokan ranges.

The upper strata (Middle Pliocene – Quaternary) differ from the lower ones, for they are coarse-grained sediments most clearly developed at the margins of sedimentary basins, where slightly fragmented sandy-gravel, pebble and boulder deposits prevail. At the margins of the depressions, the upper strata overlie the lower with unconformity and washout, indicating increased tectonic movements during the Middle Pliocene. At that time the boundaries of the depression reached their present position, and contrasts in elevations between neighbouring depressions and uplifts sharply increased. Crustal movements are still taking place at present, as can be seen by repeated levelling surveys and by the seismicity, which is the highest among all other continental rifts.

As to volcanism, the largest volume of basalt was extruded in the early evolutionary stage, and by Pliocene-Quaternary times the volcanic manifestations had decreased. The two-stage rifting is typical not only of the Baikal rift zone, but is also well illustrated in the Upper Rhine graben (Illies, in Ramberg and Neumann, 1978). It is characteristic of rift zones with voluminous volcanicity (East Africa) and is common of Cenozoic rifting in continental environments (Logatchev in Ramberg and Neumann, 1978; Logatchev et al., 1983, 1983b – Ed.).

Deep-Seated Structures and Mechanism of Formation

The velocity of P-waves at the Moho discontinuity is 7.7 km/sec below the Baikal rift zone, as compared to 8.1-8.2 km/sec below the Siberian platform and Transbaikalia (Krylov et al., 1981). Anomalously low velocities in the mantle beneath the rift zone are also indicated by P-wave delays

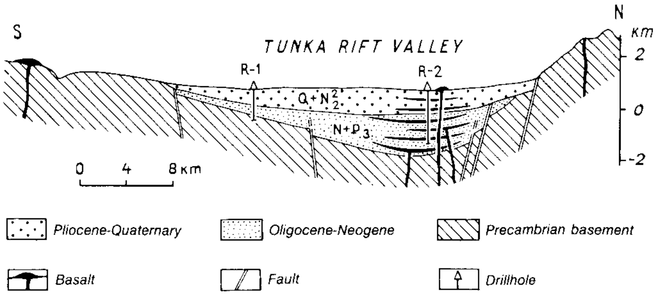

Figure 7: Cross section of the Tunka depression.

from distant earthquakes and explosions. At subvertical emergence of seismic rays, the delays are about one second (Rogozhina and Kozhevnikov, 1979), indicating that the thickness of the layer producing the delay is no less than 150 to 200 km. In other words, there is an upwelling of the asthenosphere reaching the base of the crust here.

The width of the upper part of this upwelling corresponds roughly to that of the domal uplift (200 to 300 km) and exceeds by many times the crustal extension necessary for the formation of the rift depression (15 to 25 km). A straightforward mechanical extension of the lithosphere would not provide the necessary room for such a wide asthenospheric upwelling. Numerical modelling (Zorin, 1981) has indicated the possibility of asthenospheric uprise as a result of separation of lithospheric blocks sinking in and possibly being assimilated by the asthenosphere. The ductile extension of the lithosphere was not important in permitting asthenospheric upwelling, but it was prominent for the formation of the rift depressions.

When the asthenospheric material reached the Moho, its upward movement ceased because its density exceeded that of the crust. Since then (3 to 5 Ma ago), there have been lateral movements in the asthenospheric upwelling, resulting in intense crustal extension, considerable vertical movements along faults and deepening of the rift depressions. Because of the existence of a thick, cold lithosphere to the north and northwest of the rift, a southeastward migration of the asthenospheric material appears to have been most likely (Fig. 8). This situation resulted in an asymmetry in the rift depressions and the distribution of volcanic fields along the southeastern margin of the domal uplift.

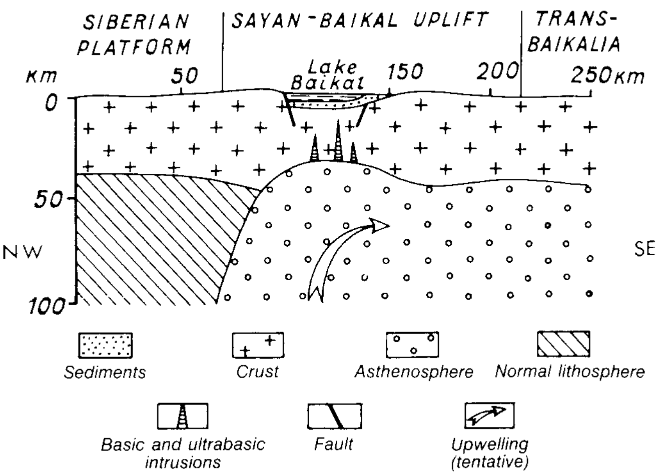

Figure 8: Deep structure of the central segment of the Baikal rift system. Arrow shows tentative direction of migration of asthenospheric material.

Conclusions

The Baikal rift has no direct connections with the world rift system, and the daring prediction of the existence of a spreading centre there that will become an ocean in millions of years is unlikely to prove correct. The restriction of the central segment to the boundary between the craton and the mobile belt indicates favourable conditions both for lithospheric destruction, which results from its earlier geological history, and the earliest beginning of lithospheric extension in the South Baikal depression. Drilling to 3 000 m has reached Early Oligocene or Late Eocene deposits, and beneath this, a complete section of the Eocene probably extending to the Palaeocene is undoubtedly present.

The South Baikal depression is the most ancient part of the entire rift system and the historic centre of the Baikal rift (Logatchev and Florensov, in Logatchev and Mohr, 1978). Later, mainly in the Late Oligocene and Miocene, the rifting propagated in both directions from the South Baikal basin. The flank depressions in North Mongolia and in the region between the Vitim and Olekma Rivers appeared in the Pliocene-Quaternary time. The longitudinal spread of the Baikal rift could not be synchronous and uniform because of the structural anisotropy of the basement and differences in rheological properties of the lithosphere.

In view of the propagation of the Baikal rift from the South Baikal, its symmetric morphology and structure, and the maximum uprise of the asthenosphere to the base of the crust and its possible migration from the craton, a local energy source for rifting appears to exist in the upper mantle. While not ignoring the consequences of the Indo-Eurasian plate collision for the development of inner Asia in the Cenozoic (Molnar and Tapponnier, 1975; Zonenshain and Savostin, 1981), this process does not seem to have been the driving mechanism for the development of the Baikal rift, since this is separated from the Himalaya front by a distance of over 2 500 km and by a system of large stable and mobile tectonic domains.

The entire structural complex of the Baikal rift and the associated volcanism cannot be explained by simple mechanical spreading of the lithosphere and a constrained uprise of the asthenosphere. The main cause of the intraplate rifting in East Siberia was an upwelling and lateral migration of asthenospheric material, resulting in gravitational and heat instability of the lithosphere, the appearance of an arched uplift, rejuvenation of faults, considerable horizontal and vertical movements of crustal blocks and the formation of rift valleys. The Baikal rift is an example of the independent revival of tectonic activity in the Earth's interior, and supports the concept of asthenospheric diapirism as the initial cause of continental rifting.

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Tectonic Layering of the Lithosphere

by Sergey V. Ruzhentsev and Vladimir G. Trifonov

An important and probably global feature of the lithosphere is the existence of large-scale tectonic layering. This results from differential movements and deformation within specific layers, being most pronounced in ancient fold and recent orogenic belts. The authors discuss methods for detecting this tectonic layering, and its role in the formation of regional structures, with examples from the U.S.S.R. and some neighbouring countries.

Introduction

The concept of plate tectonics, which involves the interaction of rigid, lithospheric plates moving over or together with the asthenosphere, has provided explanations for many features of the morphology, distribution and evolution of crustal structures. However, this theory does not seem sufficient. It has been proved, for example, that plates are not at all rigid, but rather suffer deformation and distortion especially along their margins as they move. Within relatively short periods of time (millions to tens of million of years), plate boundaries may display signs of jumping. This phenomenon, first discovered in spreading zones, also occurs in zones of plate convergence and compression such as the Pamirs, the eastern Taurus and Kamchatka, and in zones of reciprocal plate shear such as western North America.

The existence of differential lateral movements of the lithosphere was demonstrated by A.V. Peive (1967). Further elaboration of this concept led to the concept of a tectonically layered lithosphere (Makarov et al., 1974; Knipper and Ruzhentsev, 1977; Peive, 1980, 1982; Peive et al., 1983). This theory holds that layers of the crust and upper mantle do not constitute single thick plates, but move reciprocally and suffer independent and unconnected deformation.

The evidence for the tectonic layering of continental fold belts is provided by overthrusts resulting from décollement and displacement of rock bodies relative to their basement. Décollement could have taken place at different levels within the sedimentary cover, along the contact between the basement and the cover, or even within the basement itself, as shown by allocthonous sections. The presence of isolated allochthons in a major structure is related to a regional décollement at the level of the deepest formations of the allochthon complex. Décollement of the sedimentary cover, first described early this century for the Alps, has been shown to be common in many fold areas. Isolated slabs commonly show evidence of displacement of some tens of kilometers. Overthrusts of the basement are larger and rarer, but their displacement range is measured in hundreds of kilometers.

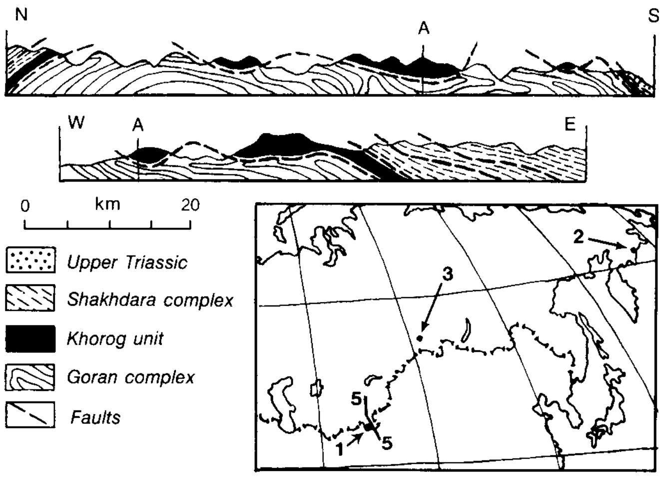

***Figure 1**: Profiles across the southwestern Pamirs, according to A.A. Belov, A.L. Knipper and S.V. Ruzhentsev (in Peive, 1980). Inset shows locations of Figs. 1, 2, 3 and 5.*

The Pamirs

The Central Pamirs contain four nappe complexes each characterized by different rock assemblages: 1) limestones, volcanics and terrigenous Upper Cretaceous-Palaeogene rocks; 2) a predominantly terrigenous Triassic-Lower Cretaceous sequence; 3) a terrigenous-carbonate Cambrian-Permian sequence; and 4) Precambrian gneisses, schists, quartzites and marbles. The first three décollement levels were part of the sedimentary cover, while the fourth was within the basement.

More deep-seated metamorphic rocks have been recorded from the southwestern Pamirs. At the base are plagiogneisses, plagiomigmatites, quartzites and marbles of the Goran complex (Fig. 1). These are overlain by the Shakhdara complex, the lower part of which (the Khorog unit) is composed of hornblende plagiogneisses and plagiomigmatites with numerous boudins and lenses of eclogite-like rocks, acid granulites, metagabbroids and ultrabasites with garnet and spinel. The contact between the Goran and Shakhdara complexes is marked by a thick (several hundred meters) mylonite zone. The plagiogneisses of the Shakdhara complex are covered by Precambrian gneisses and by Palaeozoic and Mesozoic rocks, which have been contact metamorphosed by abundant Mesozoic granites. Further up the section are truncated Phanerozoic deposits displaced independently from the basement. The Goran and Shakhdara contact zone, now curved and tracing the dome of the southwestern Pamirs, is an overthrust that doubles the granite-metamorphic layer of the region. As judged from the composition of the Khorog

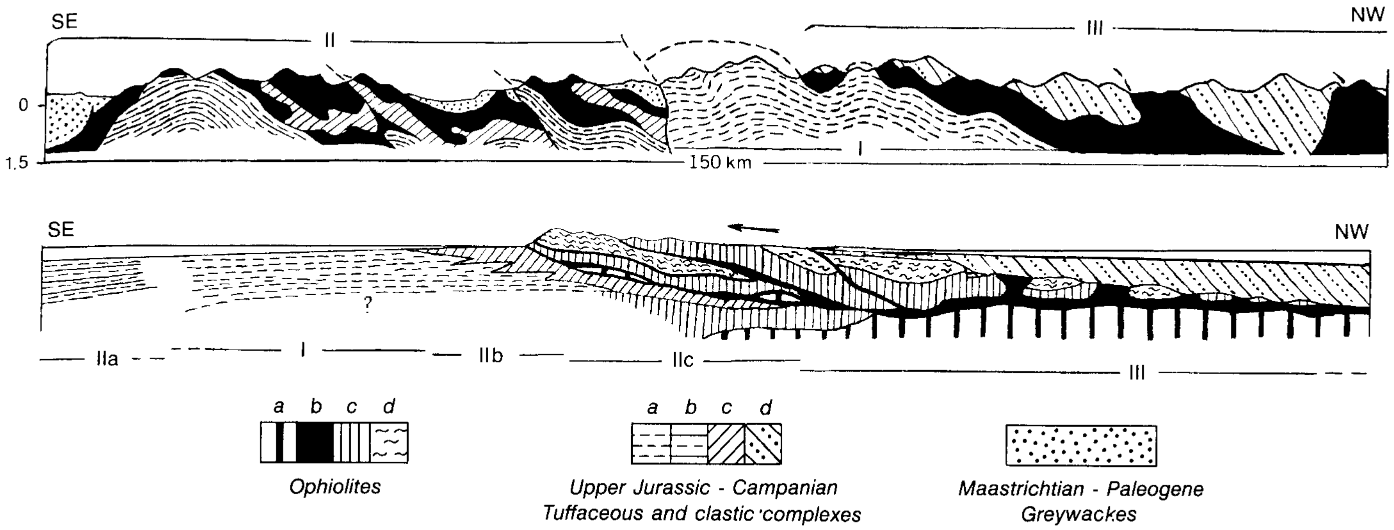

***Figure** 2: Geological section of the eastern Koryak Ridge (above) and a palinspastic profile for the late Campanian early Maastrichtian (below), according to S.V. Ruzhentsev and S.D. Sokolov (in Peive, 1980). Ophiolitic complex: **a** – dunites, harzburgites and lherzolites; **b** – serpentinites and unspecified ophiolites in the upper profile; **c** – layered complex, gabbro, dike complex and plagiogranites; **d** – volcanic-siliceous Carboniferous-Permian sequence. Upper Jurassic-Campanian complexes; **a** – tuffaceous-terrigenous complex (Upper Jurassic-Campanian); **b** – the same with basalts and jasperoid rocks (Campanian); **c** – the same with Upper Jurassic-Campanian olistostrome; **d** – greywackes (Volgian – Upper Cretaceous). Roman numerals indicate tectonic zones.*

unit, the décollement site must have been located within the lower part of the crust and, probably, at its base. Inside the isolated slabs there are gigantic rootless recumbent folds (Peive, 1980).

The process of décollement and crustal motion in the southwestern Pamirs must have lasted a long time, spanning several tectonic epochs. However, most studies have concentrated on the late Cenozoic deformation associated with the northward motion of India relative to the neighbouring parts of the Alpine-Asian orogenic belt. Comparison of the times of the most extensive thrusting and folding in parts of the Pamir-Karakorum region and the ages of offset in different segments of the wrench fault zones, bordering the region to the west and northeast, has proved that the northern front of the moving lithospheric mass migrated repeatedly northward (see Plate Boundary Map on page 43, this issue – Ed.). In the Oligocene it was situated in the Indus zone, the Miocene saw it in the central Pamirs, in the Late Miocene and Pliocene it was to be found near the Karakul thrust of the northern Pamirs, and finally, in the Pleistocene it was located on the southern slope of the Alay valley.

The mechanics of this migration may have worked as follows. As the Indian plate moved northward, a part of the inner zone of the orogenic belt in front of it became involved in extensive folding and nappe deformation. This led to the isolation of the deformed area at its sides by wrench faults, which represent parts of the Chaman-Darvaz-Alay and Pamir Karakorum fault systems, and probably to the décollement of the deformed and faulted crustal masses. As a result, the latter could no longer be seriously deformed, and they joined and moved together with the margin of the plate, while the zone of extensive displacement that marked the front of the moving masses jumped to the north. This process was repeated until the structure in the Karakorum and Pamirs became a series of stacked thrust mega-sheets with a complex inner structure, and structurally isolated from more deep-seated layers of the lithosphere (Trifonov, 1983).

The Urals

Large nappes of the basement of the Urals typically show the following upward sequence of rocks (Peive, 1980; see also Dymkin and Puchkov, this issue of Episodes – Ed.):

- dunites and harzburgites of the mantle,
- pyroxenites, dunites and gabbroids representing a transitional zone between the mantle and crust
- gabbroids partially coverted to amphibolites
- gabbro-diabases, diabases and plagioliparites of a dike complex
- quartz diorites and plagiogranites
- volcanic-sedimentary deposits.

Such ophiolitic allochthons containing dunite-harzburgite rocks demonstrate that, at least in the palaeo-oceans, regional décollement could penetrate the upper mantle.

The Koryak Ridge

The Koryak ridge at the base of the Kamchatka peninsula in the northeastern U.S.S.R. features two stages in nappe formation (Fig. 2), related to the readjustment of the late Palaeozoic structural pattern and the development of a back-spreading frontal-thrust system with pronounced pre-Maastrichtian movements (Peive, 1980). The main spreading of the back trough, together with the exposure of the melanocratic basement, began at the close of the Late Jurassic and continued in the Cretaceous. At the same time, the frontal basin was filled by deposits from the destruction of ophiolitic allochthons moving towards it. In terms of crustal type, structural position and type of sedimentation, the back trough is comparable to newly formed basins of marginal seas. Décollements took place near the Moho discontinuity and also within the crust, dividing it into a series of independently moving slabs.

As shown by the Koryak ridge, décollement of crustal slabs is found not only in areas of compression but also in zones of ocean-floor spreading. The formation and spreading of the oceanic crust was due to the injection of basaltic material along numerous fractures to form dike series. Using examples of ancient oceanic formations in the Urals, Western Sayan and Mongolia, A.S. Perfilyev and N.N. Kheraskov (in Peive, 1980) have shown that dikes and occasionally the magmatic breccias which accompany or replace them saturate the lower gabbroid-ultrabasite part of the crust, though they decrease sharply in the underlying, intensely folded

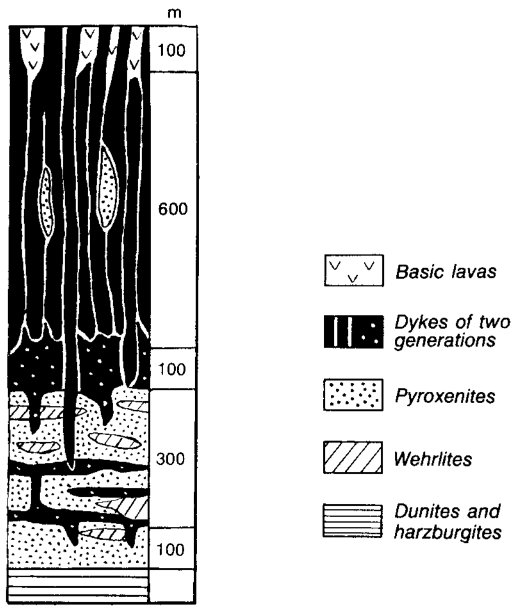

Figure 3: A schematic section through the Kurtushiba ophiolitic complex in the Western Sayan, according to A.S. Perfilyev and N.N. Kheraskov (in Peive, 1980).

dunite-harzburgite layer of the upper mantle (Fig. 3). The ancient crustal spreading appears thus to have taken place in the crust independently of the upper mantle. The bottom of the dike and breccia zone often exhibits sills intruded along the décollement surfaces of the spreading crust and probably formed as a result of heating during sliding.

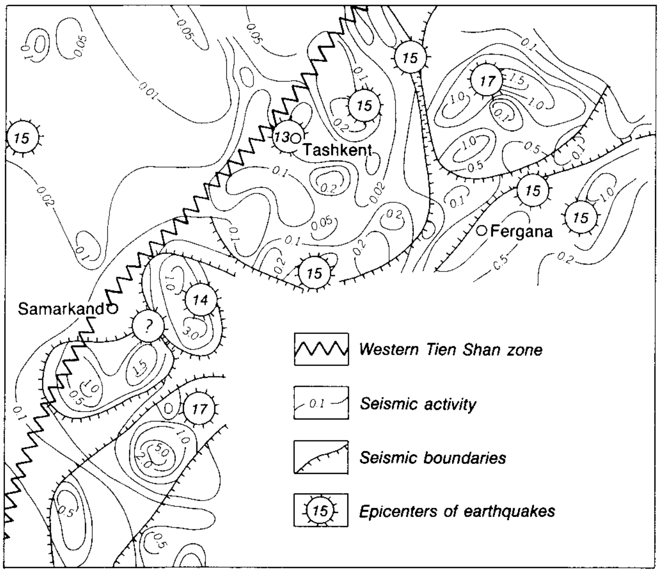

Figure 4: Relation between the Western Tien Shan zone of flexure and faulting and modern seismic activity of Uzbekistan, according to B.B. Tal-Virsky and others (in Peive, 1982). Seismic activity shown as contours of equal energy release according to the Riznichenko method where contour values represent the logarithm of the number of earthquakes with energy class, K = 9.5-10.6, where K = log E-7 and E is the seismic energy of the earthquakes. Numbers in epicenters indicate the energy class, K.

Recent Tectonic Layering

Examples given above are typical of ancient folded belts, where deep-seated zones of décollement and differential lateral movement were subsequently brought to the surface and exposed for study. However, what is important for tectonic theory is whether similar processes exist in modern geological times, when we can reconstruct displacements of the surface on a global scale and for which we have seismic data on movements within the deep-seated lithospheric layers.

There is certainly indirect evidence of recent tectonic layering, which comes from the combined application of geological, structural, geomorphological and geophysical methods (Makarov et al., 1974; Peive, 1980). The neotectonics of orogenic areas show, along with dominant structures such as longitudinal fold-ridges and escarpments, transverse and discordant elements discernible on the surface such as weak flexures, extensive jointing, and the closure of some ridges and valleys. Seismic data on the geometry of focal zones and zones of abnormal propagation and absorbtion of seismic waves make it possible to differentiate modern structures according to the depth of their greatest development.

Satellite imagery also aids greatly the detection and mapping of deep-seated elements discordant to the general surface trends. Such structures are sometimes expressed by neovolcanic and hydrothermally active zones, as well as by hydro- and geochemical anomalies. The comparison has revealed that obscure surface structures can be more pronounced at depth, and that those prominent on the surface can be limited at depth by the sedimentary or granitic-metamorphic layers. Therefore, modern structural patterns in the lithosphere also differ by depth levels, indicating independent neotectonic development of lithospheric layers and their disharmonic movement.

Geological, geomorphological, geophysical and satellite data on the eastern Caucasus demonstrate that the crust here has three structural levels where fault zones and deformation of different morphology and trends have developed simultaneously in modern times. The upper level, occupied chiefly by the sedimentary cover, is dominated by folds and thrusts with the usual Caucasus trend. Below this, at depths of about 20 km, this structural trend is represented only by a seismically active zone of upthrows and thrusts, which is the deeper extension of the southern slope of the Great Caucasus; of importance in this middle level are shorter shear zones with oblique strikes that are poorly reflected in the upper structural level. The density of shallow earthquakes increases along these zones, which are surrounded by regions of abnormal seismic absorption. Associated with these shears are gravity-gradient zones and, to a limited extent, structural elements of the surface of the pre-Jurassic crystalline basement and the Conrad discontinuity. Further downward and reaching the Moho discontinuity, is the continuation of the southern slope of the Great Caucasus, which must become steeper deep in the crust. It concentrates the deepest earthquakes of the region and shows a sharp variation in the thickness of the Earth's crust (from 50 to 60 km in the north to 40 to 45 km in the south).

These signs of structural disharmony may be related to different responses to the general north-south compression of the region. The crustal structures of the Caucasus are crossed by volcanic and related tectonic elements of the Transcaucasian volcanic belt which, according to E.E. Milanovsky, reflect east-west extension and magmatism in the upper mantle portion of the lithosphere. Chains of volcanoes and faults of this belt extend through all the region, suggesting that the structural and dynamic setting of the upper mantle of the Caucasus and Transcaucasus is radically different from that of the crust.

Significant vertical variations have been described in modern structures of the Tien Shan and the adjacent Turanian plate (Makarov et al., 1974; Peive, 1982). At depth, modern folds of the basement are combined into larger structural forms, and transverse and diagonal elements, usually not pronounced in the upper structural level, become more important. An example of these elements is provided by the NE-SW plutonic zone of flexures and faults in the Western Tien Shan (Fig. 4). This corresponds to a significant and extended gravity gradient zone. The crustal thickness increases here from 40 km to the west of the zone to 50 km to the east, and there are also changes in seismic activity, focal mechanisms, and the morphology of the anomalous magnetic field. The Western Tien Shan zone preserves for a considerable distance along strike its anomalous seismic absorption.

Evidence from Seismology

Seismic surveys that detect horizontal focal zones and crustal waveguides provide additional evidence of tectonic layering in the lithosphere. Detailed studies of vertical and tilted focal zones within the continents and on their margins have shown that such zones often have a large-scale beaded structure, wide in one part and narrow in the other or disappearing altogether in other levels of the crust and the upper mantle. The Kuril-Kamchatka focal zone, for example, consists of separate peaks of activity, which are interrupted at depths of approximately 80, 120-160, 220-300 and ?400 km, by horizons of increased absorption of seismic energy (Anon, 1976).

According to Yu.K. Shchukin (in Belousov et al., 1979), this heterogeneity is even more pronounced in the Pamirs-Hindu Kush focal zone (Fig. 5). Here at depths of 40 ± 10 km there is a horizontal zone of hypocenter concentration, which may be a recent manifestation of the demonstratable modern décollement of upper crust structures. This region is underlain by a hypocenter-poor layer above a steeply dipping mantle focal zone. The latter is regarded as a modern deep-seated boundary of the Indian plate, which projects onto the surface somewhere in the Central Pamirs, though the seismic peak in the upper-crust is 150 km farther north. The hypocenters of the upper crust are more common in the south-dipping zone, which, if continued up to the surface, would coincide with the Darvaz-Alay fault zone, the recent boundary of the Indian plate in the upper crustal layer (Trifonov, 1983)

The crust below the Pamirs and Karakorum is up to 70 km thick (Belousov et al., 1979). V.K. Kulagin (in Peive, 1982) has singled out crustal waveguides at depths of 5-18 and 30-43 km. Waveguides have now been detected both inside and at the base of the crust below various active and passive recent structural zones (Fig. 6) such as the Caucasus, the Urals, the Baikal rift zone, Precambrian shields and other continental and oceanic structures (Peive, 1982; Trifonov, 1983). Waveguides are subhorizontal, lenticular zones of low seismic velocity, which may be due to lower effective viscosity and strength of the rocks. Thus, décollements of relatively viscous and solid rock bodies are to be expected along the waveguides in a specific tectonic setting. Such décollements have been proved in some orogenic areas, such as the Pamirs, by the partial coincidence of waveguides and horizontal focal zones. The low effective viscosity of these wave guides may be a result of a seismically induced loss of rock strength (Yu.K. Shchukin in Belousov et al., 1979).

Unevenly distributed hypocenters in vertical and tilted focal zones suggest a vertical, structural and dynamic heterogeneity of more deep-seated lithospheric layers. The existence of such heterogeneity is demonstrated by recent studies of the differences in relative values of shear stress, seismic deformation rates and effective seismic viscosity in different levels of mantle focal zones. This analysis, by F.A. Vostrikov, is based on the interpretation of plots of earthquake recurrence. The mantle focal zone of the Pamirs and Hindu Kush shows two layers with exceptionally low values of

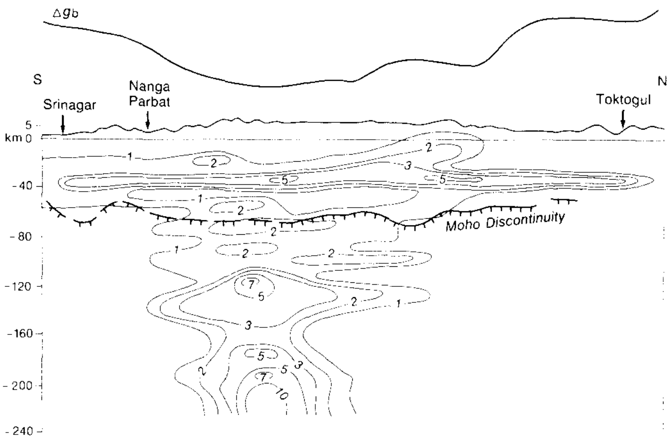

Figure 5: Seismicity of the lithosphere of the Tien Shan and the Pamirs-Himalayas. Shown above is the Bouguer gravity anomaly curve (Belousov et al., 1979). Contours indicate density of concentration of earthquake hypocenters. Horizontal scale approximately 1:9 250 000. Vertical exaggeration = 1.75.

seismic viscosity at depths of 70-100 km and 130-150 km. The acting stress is also low in these layers, perhaps as a result of higher plastic deformation. Rates of seismic deformation (rupturing) decrease in the lower and in part of the upper low viscosity layers and increase at depths of some 70 km.

A.V. Nikolayev and I.A. Sanina (1982) have analysed differences in the travel times of seismic waves of local deep-focus earthquakes detected by Central Asian stations. This has led to the discovery of broad lateral and vertical varia-

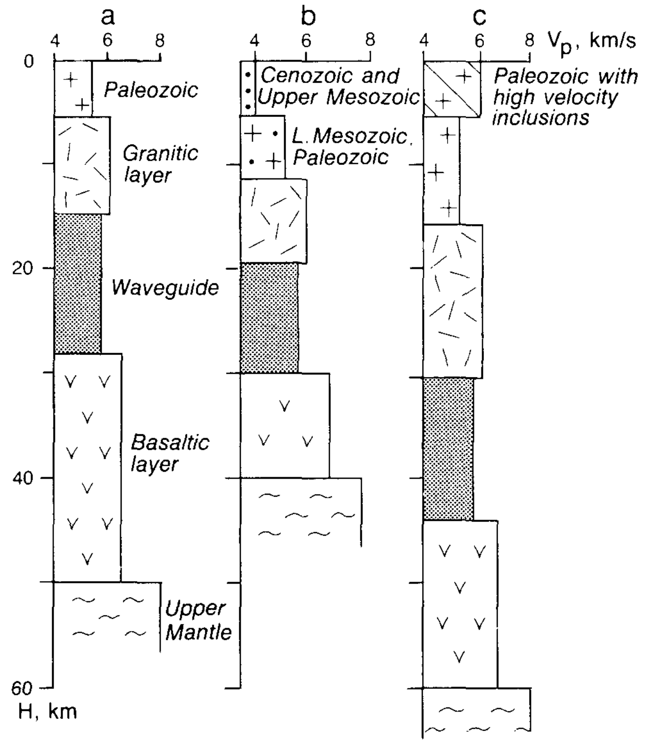

Figure 6: Averaged crustal velocity sections for (a) the Southern Tien Shan, (b) the Tadjik basin and (c) the Pamirs according to V.K. Kulagin (in Peive, 1982).

tions in seismic rates in the upper mantle of the Afghan-Tadjik basin and the Pamirs at depths of up to 300 km. In contrast to the northern parts of this region, where the distribution of seismicity is in agreement with a layered model, in the vicinity of the Pamirs-Hindu Kush focal zone and southward there is a more complex distribution of seismic rates. This may reflect differential movements of mantle rock bodies no less complex than those in the crust.

Discussion

Thus, abundant data indicate that in ancient and modern orogenic belts, rock bodies of the crust and upper mantle interact not as rigid plates with lithospheric thicknesses, but rather as a complex of relatively thin rigid slabs and blocks separated by zones of high-gradient lateral movements (asthenolayers and asthenolenses). Similar signs of structural and dynamic layering in the lithosphere have also been discovered in rift systems and shear belts. However, the disharmony between different layers of the lithosphere is not absolute. Certain links between them are preserved and permit deep-seated neotectonic structures to be reflected in the topography and deformation of the surface, where they can be identified from space images.

Whether or not tectonic layering extends across the boundaries of geologically active regions cannot be determined as yet. However, as outlined above, one possible approach to this problem is to determine rates of lateral movements of different slabs of the same plate relative to those in adjacent ones. For example, the average convergence rate for India and Eurasia, according to Quaternary fault displacement and fold deformation in the area of their interaction, is 3-5 cm per year (Trifonov, 1983). However, analyses of oceanic anomalies indicate that the rate of the motion of the Indian Ocean floor relative to the Eurasian plate reaches 5-6 cm per year. It is possible, therefore, that the upper mantle and thin oceanic crust of the Indian Ocean are converging with Eurasia more rapidly than the Indian continental crust.

These and other considerations lead to the conclusion that differential movements of lithospheric slabs along asthenolayers and asthenolenses are global, though distributed unevenly from region to region. It is not these differential movements that are important in controlling regional structures but rather the change in their relative rates, which results either in piling-up of rocks or in spreading and injection of plutonic differentiates. It is such regions that are interpreted as active and in which tectonic layering is most pronounced.

The concept of tectonic layering provides a new approach to many problems of tectonics. For example, it is hardly possible to explain the structural consequences of Indian and Eurasian convergence as mere subduction. Instead there is a piling-up of rock here due to differential movements and independent deformation at different levels in the lithosphere. The shortening is complemented by squeezing-out of rock masses away from areas where lithospheric slabs are most compressed.

This model of tectonic layering contributes also to our understanding of isostatic compensation. We should take into account possible fractional melting in asthenolayers if we want to explain regional granitoid magmatism and formation of contrasting volcanic complexes. Irregular layering in the lithosphere and differences in rates of motion and deformation of the slabs could have led to their destruction and mixing, accompanied by chemical change, fractional melting and gravitational differentiation. This mechanism should also be taken into account in metallogenic and hydrocarbon studies, for allochthonous granitic-metamorphic masses may conceal undiscovered oil and gas fields. Analyses of the recent activity of some crustal zones of lateral sliding, especially where areas of different structural trend make contact, also open up new prospects for the prediction of seismic risk.

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Geological Education in the U.S.S.R.

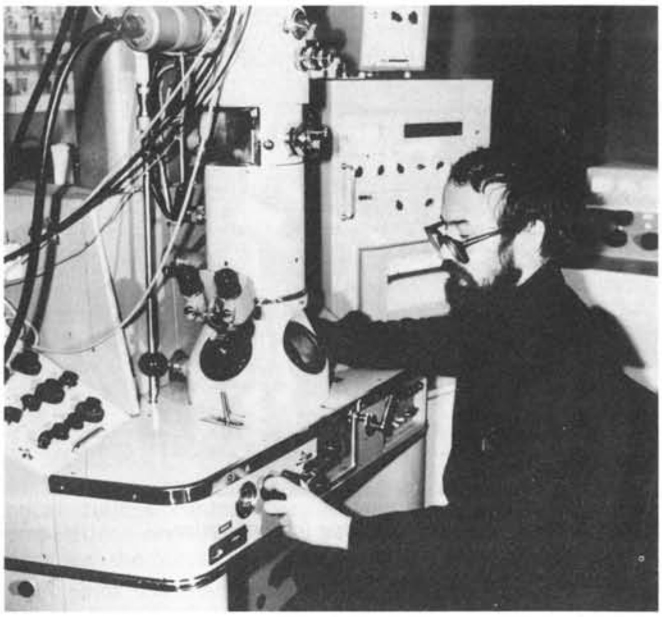

Figure 1: Using the electron microscope.

by D.P. Lobanov and E.D. Yershov

This article outlines the overall organization and course structure of geological education in the Soviet Union. There are now nearly 200 000 geologists and technicians with first or higher degrees from technical schools, higher technical institutes and universities. To illustrate the latter two, the authors review the syllabuses for geological studies at Moscow State University and the Moscow Geological Prospecting Institute. (Certain explanatory sections have been added by the Editor based on information from the U.S.S.R. National Committee of Geologists).

Historical Background

Geological education in the U.S.S.R. began in the 18th century with the opening of mining schools in the Urals. These schools taught Russian grammar, mineralogy, geognosy, mining and mine surveying. In the middle of the nineteenth century, a special mining school was founded in Ekaterinburg (now Sverdlovsk) to train specialists for mineral production. In 1755, Moscow University and in 1773, the Mining College in Petersburg (Leningrad) were established for the teaching of geological and mining subjects. Lectures on geological subjects were delivered in the Medical Faculty and later (1804) in the Faculty of Physics and Mathematics (Vorobjov et al., 1980).

The study of geology and mining was based on the fundamental work of the great scientist M. Lomonossov and on the practical techniques of many talented Russian miners and engineers. By the early 20th century, there were in many Russian cities a variety of institutions offering geological courses, many with their own individual teaching systems. After the October 1917 Revolution, all citizens of the U.S.S.R. were given the right to higher education, and since then the volume and quality of geological education has greatly increased. Each of the fifteen Soviet republics now trains its own geologists.

Structure of Soviet Geological Education

Geological education in the U.S.S.R is carried out at universities, higher technical institutes and special technical schools. There are direct (full-time) studies, evening studies and tuition by correspondence.

There are now more than 90 000 geological technicians in the U.S.S.R. In general, these are graduates of three to four year courses at "special schools" (secondary technical institutions), of which there are over 40 in the U.S.S.R., graduating together some 5 000 students each year. Some may later advance to "colleges" (universities and higher technical institutes), where the average course lasts five years. College graduates are called Geologists or Engineers in Geology, and they now number approximately 100 000. There are today more than 50 colleges, which graduate a total of some 6 000 students each year. Soviet universities teach a range of subjects, including the natural sciences, whereas the higher technical institutes generally concentrate on one discipline. One example of the latter is the Moscow Institute ("I. Goubkine") for Oil and Gas Industry, one of nine such institutes where engineers specializing in the geology of and exploration and drilling for oil and gas are trained.

Candidates are roughly equivalent to Ph.D. graduates, having published several papers in a coherent field of study. The category of Doctor is higher than that of Candidate, and scientists with this title must have produced a number of significant works (e.g. monographs) in one field or, perhaps, pioneered a new one. An approximate equivalent here might

Figure 2: Moscow State University.

Figure 3: Practical field training in geophysics.

Figure 4: Studying crystal structure at MSU.

be the D.Sc. of British universities. There are some 7000 Candidates and Doctors now in the U.S.S.R., and about 300 new ones are added each year.

Most graduates from the special schools enter industry, while many from universities go on to research positions (Fig. 1). As a rule one to two years before graduation, all students know the place of their future job. After their final exams, they are given official assignments to work in accordance with their specialization. The best graduates, of course, have a wider choice of positions.

The Central Committee of the Communist Party and the Council of Ministers, govern the work of the universities and higher institutes through instructions and recommendations from the Ministry of Higher Education, which confirms and renews teaching programs every five or six years. Some leading colleges may, however, have their own syllabuses, which are monitored by the Ministries of Higher Education and Geology.

Every Soviet geologist is expected to be familiar with both theory and practice, to enrich his knowledge, to widen his social-political outlook and to supervise workers and technicians. Education at all Soviet colleges and universities is free of charge. Advanced students get a State allowance, and there are also scholarships from the Ministries of Higher Education and Geology, the Academy of Sciences and the Central Committee of the Young Communist League.

Course Structure

The average five year course at Soviet universities runs for some 4500-5000 hours. Students have up to 36 classes (normally 45 minutes) each week (excluding physical education) in the first to third years, and up to 30 hours a week in the fourth and fifth years. Independent research, library work and assignments total 2700 to 3000 hours.

Classes in engineering subjects make up over 1200 hours, and in geological topics more than 2000 hours, or for the more specialized courses, 3000 hours. Geological courses include historical and regional geology, Quaternary deposits, lithology, palaeontology, geomorphology, structural geology, geotectonics, mapping, mineralogy, petrography, crystallography, geochemistry, ore deposits, prospecting (geological, geophysical and geochemical) hydrogeology, geological engineering and environmental geology.

Socio-political subjects make up 12% of the total course work and include topics such as the history of the Soviet Communist Party (120 hrs in the first year), Marxist-Leninist philosphy (90 hrs in the second and third years) and political economy (140 hrs in the fourth year). Students may also attend elective courses on Marxist-Leninist ethics and aesthetics, and scientific atheism.

Foreign language studies (English, German, French or Spanish) include 800 hours of compulsory classes, 330-340 of optional classes and 250 hours of independent work. There are 530 hours devoted to physical education, for it is considered very important that geologists should be familiar with matters of health and hygiene.

Much attention is also paid to physics, mathematics, chemistry and engineering. For example, students learn probability theory, mathematical statistics, and the principles of mathematical logic and cybernetics applied to geological problems.

Moscow State University

The Geological Faculty of the Moscow State University, "M. Lomonossov", is a leader in Soviet geological education (Fig. 2). The MSU Geological Faculty trains specialists in five areas: geological surveying, prospecting for oil and gas, geophysical prospecting, geochemical prospecting, and hydrogeology and geological engineering.

Students of geological surveying have three main choices of specialization: mapping and the search for useful minerals, geology and mineral exploration, and palaeontology. The first group concentrates on the study of the structure and development of the crust, modern geological processes and geomorphology. The second group focuses on the distribution of minerals in the crust, exploration methods, and the composition and structure of deposits. Palaeontology specialists also take lectures on biological subjects.

Students who select oil and gas prospecting are trained in the detection and evaluation of oil, gas and coal deposits, including the application of geochemistry to this field. The geophysical option includes gravity, magnetic, seismic, and electrical methods of prospecting, and geophysical engineering (Fig. 3). Those graduating from this stream are employed in scientific research institutes, or in mineral prospecting. They may also do research in such applied fields as engineering construction, hydrogeology and marine geophysics.

In the geochemical stream, students specialize in petrography, mineralogy, crystallography or geochemistry. Petrographers study the geology, structure, metallogeny and physical properties of magmatic and metamorphic rocks, and they also do experimental research in technical petrography. Mineralogy students concentrate on the conditions of formation of minerals, their physical and chemical properties, and the composition of ore deposits. These students also do laboratory research on synthetic minerals. Crystallography specialists study the structure and the chemical composition of crystals and minerals (Fig. 4), with the focus on the properties that make them useful in industry. The geochemists study the geochemical processes in the crust, methods of separation and analysis of ores and minerals, the determination of their absolute age, and geochemical prospecting. They also do laboratory, experimental and industrial research.

Hydrogeology and geological engineering students specialize also in geocryology and soils. Hydrogeologists are trained in the search for potable, medicinal and industrial groundwaters, and after graduation they may be involved in hydrotechnical work (e.g. dams and reservoirs), land drainage and reclamation, water supply, or the control of mine waters. Specialists in geological engineering and soils study rocks as the base for construction, and geotechnical work. Those concentrating on geocryology must learn methods of researching frozen grounds, and the process and structures of permafrost and seasonally frozen grounds.

In training geologists for all specialties, practical training is of great importance. MSU students, for example, acquire practical training in the field parties of the Ministry of Geology and the Academy of Sciences.

Moscow Geological Prospecting Institute

A good example of a higher technical institute for geological training is MGPI – the Moscow Geological Prospecting Institute, "S. Ordjonikidze". This is the only college in the U.S.S.R. specializing in rare, non-ferrous and radioactive metal deposits. Candidates and Doctors of Science comprise 78% of its staff (Lobanov, 1979).

There are seven directions of study at MGPI of which three are on similar topics to those at MSU decribed above. In contrast to the university students, those at MGPI receive wide practical training as engineers in prospecting methods, mining technology, and the economics and management of geological exploration. Upon graduation, they receive the degrees of "Geological (Geophysical, Hydrogeological) Engineer" or "Mining Economist."

Geological surveying at MGPI has four directions: geological surveying and prospecting for (1) all types of solid rocks, (2) rare and radioactive elements, (3) semi-precious stones, and (4) the applied mineralogy of diamonds and semi-precious, precious and industrial "stones."

MGPI students in geophysical prospecting specialize in methods for rare and radioactive elements, structural geophysics, mining geophysics, or the geophysics of drill holes. All students have lectures on exploration geophysics, petrophysics, nuclear geophysics, the recording and interpretation of geophysical data, and on gravity, magnetic, electrical, and radiometric surveys.

The third area in common with MSU is hydrogeology, but MGPI students concentrate more on prospecting for and evaluation of underground waters, and on geotechnical aspects. Under the title of technology and techniques of prospecting, MGPI trains mining engineers in the technology of drilling and rock openings. Practical training takes place on modern drill-rigs in the MGPI laboratories, which approximate industrial drill equipment and conditions of production drilling. Students learn to construct mathematic models of drill processes and to use computers for the analysis and optimization of drilling.

MGPI students may select mine economics and management. In addition to geological and technical subjects, they study the theory and practice of geological and economic valuation of deposits. They also have lectures on management, psychology and sociology. After graduation they are employed on geological expeditions, and in mines, offices of economics and so forth. There are also specialties at MGPI in the technology and complete mechanization of underground mining and the exploitation and mechanization of placers.

MGPI students gain practical training (for which they earn a salary) in the field expeditions and institutes of the Ministry of Geology. They may, for example, learn at first hand problems of super-deep drilling on the Kola Peninsula (see Kozlovsky, 1982 – Ed.), they may work on data from the Soviet automatic space stations on Venus, or they may gain practical experience in big mines and quarries.

Good contacts between MGPI and the Academy of Sciences allow students to master the newest methods of remote sensing, laser and telemetric systems, neutron activation analysis, the use magneto-hydrodynamic generators in prospecting, and much more.

Other Aspects

Soviet colleges require that their students engage in independent research. During their courses, students devote 250 hours to their own work, in addition to presenting papers at annual college conferences. Many take part in student competitions organized each year by the Academy of Sciences and the Ministry of Geology. The best works may be published and awarded cash prizes, medals or certificates.

Finally it should be mentioned that many geological institutions have clubs for school children to introduce them to the profession. They may receive in this way theoretical and practical training in some of the most interesting geological regions of our country. There are also geological excursions, which take place during school holidays (see cover photograph). These youngsters are a good source for future geologists, and they learn also to love nature and to protect it for future generations.

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Prof. **D.P. Lobanov** has been the Chancellor of MGPI since 1964. He is a specialist in the geotechnology of rare and radioactive elements, and has authored works on the construction of mining equipment, and prospecting methods for deposits with complicated structure. His scientific research is reflected in more than 200 publications and 60 patents.

Prof. **E.D. Yershov** is the Dean of the Geological Faculty at MSU. His main research is on the field of geocryology, and he has been an active participant in developing the main principles of cryolithogenesis, and the thermodynamics, physics, chemistry and mechanics of frozen rocks. He is a member of the National Councils for Geological Engineering and Geocryology of the Academy of Sciences.

NEWS REPORTS

New International Effort on Mineral Deposit Modelling

There has been considerable success in recent years in modelling mineral deposits in response to the need to appraise national resources and to formulate guidelines for rational land use. Many tens of millions of dollars have been spent in industrialized countries on this process, and a significant body of expertise and knowledge has now been accumulated.

Ore deposits form according to certain physical and chemical processes, and they have many features in common, which allow them to be grouped into genetic models and geological settings. Mineral deposit modelling is, thus, the theoretical or empirical process of systematically arranging all known information on deposits of a distinctive type so as to define and describe their essential attributes.

The critical first stage is to recognize similar features so that groupings are possible. As information on size and quality of the deposits becomes available, grade/tonnage models can be developed, and when genetic processes are recognized, quantitative process models can be formulated. Geologists are now well on the way to understanding deposit types such as placer gold, evaporites or laterites, but information is much less complete for porphyry deposits, sedimentary manganese or podiform chromite. And for other deposit types, our understanding has not progressed beyond the descriptive stage. Much effort is thus needed in order to improve our knowledge of economically important mineral deposit types.

Not all countries have examples of every geological setting or ore-deposit model. Moreover, known models must be modified if they are to be applied successfully in regions where the climatic and physiographic conditions that influence exploration are markedly different from those in developed countries.

Third World nations also need to discover and develop their mineral raw materials, but before this can be done they need to gauge their resource base in order to undertake realistic socioeconomic, environmental and land-use planning. However, most developing countries cannot do this, given their existing level of educational and technical development. It seems natural, therefore, to develop a program under which mineral-deposit modelling techniques can be applied effectively in developing countries.

Against this background, a small group of specialists met in Paris in January 1984, to draft recommendations for a proposed program to be sponsored by IUGS and Unesco. This will advance geoscientific knowledge and expertise in mineral-deposit modelling for use in exploration, assessment and development of resources. It will also facilitate the transfer of this knowledge and expertise to developing countries, and assist in training and educating geoscientists from Third World regions so that they can carry out the necessary exploration and resource assessment in their home countries.

The program will begin with the compilation and publication of information on existing models, including brief summaries of the major attributes of mineral deposits, the identification of the various models, and the definition of tectonostratigraphic domains in selected study areas so as to identify the appropriate mineral-deposit types. This will be followed by the development of short courses for presentation to developing countries. There will also be field excursions conducted in order to identify reference types for later study. Later, there will be field studies and research programs to develop and modify deposit models appropriate to the specific terranes of developing countries. Discussions are now underway in order to refine these proposals. Additional information on this program may be obtained from Dr. **R. Sinding-Larsen**, (Dept. of Geology, Norwegian Institute of Technology, Hogskoleringen 6, 7034 Trondheim, Norway)

GARS : A New Remote Sensing Program

The need to improve international collaboration on the geologic applications of remote sensing was demonstrated clearly by IGCP 143, now completed. This project brought together geologists and other scientists in an exchange of information about remote sensing missions, data uses, processing techniques and acquisition of Landsat multispectral scanner data. IGCP 143 has now been succeeded by a new thrust, a program on the Geologic Applications of Remote Sensing (GARS), supported by IUGS and Unesco. This development is timely because of the new types of data now becoming available, for example from the Landsat Thematic Mapper and from airborne sensors. These data, combined with interests in exploration geology, offer new research directions in geological remote sensing. The stage has also been reached whereby informal international cooperation can progress to actual experiments at selected test sites.

Against this background, participants at an IUGS seminar on remote sensing held at Orléans, France, February 2-4, 1984, identified three key elements for the GARS program. These are the discrimination of lithological characteristics of rocks and sediments by remote sensors, improving the recognition of geomorphological/structural/tectonic signatures in remote sensing, and the use of botanical indicators (such as plant stress) in recognizing underlying rocks and deposits. The first GARS activity will be carried out in the Kibaran belt of East and Central Africa. A second project is proposed for Latin America (1985 or 1986), to test remote sensing methods in areas of dense vegetation.

P. Teleki
Reston, U.S.A.

Preparing for the Congress

The Official Medal of the 27th International Geological Congress.

The preparations for the 27th International Geological Congress to be held this August in Moscow were reviewed recently by Dr. **Ye.A. Kozlovsky**, President of the Organizing Committee. In a recent report to IUGS, Dr. Kozlovsky stated that the Soviet Government has made the Academy of Sciences and the Ministry of Geology responsible for preparing and conducting the Congress. This is the third one to be held in the U.S.S.R., the first being the 7th IGC in Petersburg in 1897 and the second, the 17th IGC in Moscow 1937.

The Congress will provide an opportunity for foreign participants to become acquainted with recent progress in theoretical, experimental and field geology in the Soviet Union and with new developments in geophysical, drilling, mining and analytical equipment. This will also be an opportunity for Soviet geologists to benefit from the ideas and methods of their foreign colleagues, and the hope is that there will be creative and constructive discussions that will help to advance the geosciences.

The opening and closing ceremonies for the Congress will be held on August 4 and 14 in the Kremlin Palace of Congresses. Technical sessions will be held at Moscow University in the Lenin Hills and at the International Trade Centre ("Sovincentr"). Some 6 000 delegates are expected to attend the Congress, and as of January 15, 1984, abstracts had been received from 5 768 participants in 84 countries. The largest number of foreign abstracts had come from the U.S.A. (352), People's Republic of China (315), India (155), France (152), Czechoslovakia (98), with 91 from each of Bulgaria, Poland, Canada and the Federal Republic of Germany.

The Third Circular was scheduled to be sent out to registrants in March, 1984. This outlines the requirements for presenting papers, procedures and closing dates for registration, the dates for the main Congress events, a list of scientific excursions, and regulations for obtaining vouchers through Intourist. More than 90 international organizations will be holding scientific and business meetings during the Congress. Among these will be many sessions of IGCP and ILP as well as the quadrennial meeting of the IUGS Council, which will elect a new Executive Committee for the Union.

There will be two plenary sessions of the Congress. The first on August 5 is entitled "Contemporary Problems in Geology," and the second on August 14 will be concerned with problems of environmental protection. In all, some 2 500 papers will be presented at 22 sections, 47 inter-sectional symposia and 6 colloquia. In addition there will be 10 special symposia held under the International Lithosphere Program. It is expected that the colloquium on the "Geology of the U.S.S.R." will attract particular interest, since it will feature reviews prepared by leading scientists from the Academy of Sciences and various universities.

GEOEXPO 84 will be held from August 3 to 12 in the "Krasnay Presnya" Exhibition Centre located near Sovincentr. This will contain displays of equipment for drilling, mining and beneficiation, geophysical surveys, groundwater surveys and engineering geology, surveying, air photography and photogrammetry, marine geology, and laboratory analysis. There also will be an exhibition of more than 53 maps and 1 000 books published between 1980 and 1984 in the Soviet Union. Applications to participate in GEOEXPO 84 are still arriving in Moscow.

Congress participants will be offered a wide variety of scientific excursions to various regions of the Soviet Union, as well as to Hungary and Czechoslovakia. Many of the points to be discussed during the technical sessions will be illustrated during these field excursions. The **A** excursions will run prior to August 4, **B** excursions will run on August 11 and 12, and **C** excursions will begin after August 14. A total of 204 scientific leaders have been appointed for the excursions, most of them coming from the Academy of Sciences and Ministry of Geology. Working languages for all excursions will be Russian and English, and there will be guidebooks available in both languages.

At the request of a number of international organizations, special trips are being arranged by the Ministry of Geology to the Crimea (to illustrate problems of environmental protection), to the Zheltye Vody uranium mine, the Krivoy Rog iron mine, and to the Kola super-deep hole. Particular interest has been shown by early registrants in excursions to the Caucasus, Ukraine, Kola Peninsula, Aldan region, Central Asia and East Siberia. All excursions start in Moscow, and the complete program of the Congress including the **A** and **C** excursions will last 35-39 days. Excursions will be serviced by Intourist in the U.S.S.R., by Malev Air Tour in Hungary and by Chedok Czechoslovakia.

Congress participants will be given the opportunity to visit leading research institutions, universities and scientific museums in Moscow and other parts of the Soviet Union. Details of these visits will be available at registration.

A large social program has been planned including the opening and closing ceremonies of the Congress, a gala concert, a reception and three local excursions of the choice of each participant. There will be visits to places of interest in and around Moscow, as well as to the old Russian towns of Zagorsk, Suzdal and Rostov the Great, and there will be concerts of old Russian choral music in Moscow cathedrals. The Ladies Committee is arranging visits to the House of People's Friendship, the Exhibition of U.S.S.R Economic Achievements, "Mosfilm" Studio, the Stud Farm near Moscow, the ALL-Union fashion house, and the Museum of "Decorative Stones."

A press center will be provided in Sovincentr, with offices and appropriate technical facilities. Journalists arriving at the Congress will begin to receive their accreditations on July 20. Press bulletins and press releases will be issued daily to cover all major events of the scientific program.

Further details on timing of the Congress and its events can be found at the end of the Coming Events section of this issue of Episodes.

Stratigraphic Commission Setting Many Standards

Logo of the International Commission on Stratigraphy

The International Commission of Stratigraphy reports a number of interesting and important developments in international stratigraphical affairs in 1983. Many of these were encouraged and developed under the chairmanship of the late **Anders Martinsson**, and it is a tribute to his organization that since his death it has been possible to continue the programs that he initiated almost without interruption. New officers will be elected at the Commission meeting during the 27th IGC in Moscow, and a very full scientific program is being planned for the Congress.

According to Secretary General **Michael Bassett**, the most significant feature of 1983 was the accelerated progress by many subcommissions and working groups towards the establishment of stratigraphic boundaries and subdivisions of a standard stratigraphical scale. Formal proposals will be made at Moscow for the definition of boundaries or chronostratigraphic intervals for the Precambrian, the Precambrian-Cambrian, the Ordovician-Silurian, the Silurian, the Devonian, the Devonian-Carboniferous, the Cretaceous, the Palaeogene and the Pliocene-Pleistocene. Almost all other bodies have adopted some informal working agreements for their respective intervals, and it is not unrealistic to expect that by 1988 there may be international agreement on a complete standard global chronostratigraphy.

The Working Group on the Precambrian-Cambrian boundary is now in the process of voting on stratotype candidates in the U.S.S.R. (see article by Rozanov in this issue of Episodes), China and elsewhere. The group for the Cambrian-Ordovician boundary decided to place the base of the Ordovician at or near the base of the Tremadoc Series, but the final choice of a specific horizon has not yet been made. The Silurian Subcommission agreed informally to use the name Llandovery for the first series of the Silurian System, that there should be three stages within this series, and that the boundary stratotypes for the bases of the second and third of these should be at specified localities within the Llandovery district of Wales. There was also a clear choice of the name Přídolí for the fourth series of the Silurian and for defining its base at the bottom of the Monograptus parultimus biozone in the Pozary section in the Barrandian district of Czechoslovakia.

The Subcommission on the Devonian voted in favour of setting the Frasnian-Famennian boundary level at the base of the Middle triangularis Conodont Zone, close to the historic Frasnian-Famennian boundary. Members of the Carboniferous Subcommission voted on three recommendations for fixing globally the biostratigraphic position of the mid-Carboniferous boundary. This approximates to the boundary between the Mississippian and the Pennsylvanian of North America and to that between the Lower and Middle Carboniferous of the U.S.S.R. The Subcommission in 1983 issued the first volume of "The Carboniferous of the World" as IUGS Publication No. 16.

The Subcommission on the Triassic had as its main task in 1983 the publication of a new magazine "Albertiana." This is a bulletin for announcements and general information as well as a platform for scientific discussion in all fields of research in the Triassic. Albertiana is named after F.A. von de Alberti on the 150th anniversary of the establishment of the Triassic System. The Subcommission on the Paleogene (spelled thus on the Subcommission stationery) is in favour of maintaining Paleogene and Neogene as systems or periods, with the break in the Tertiary at the Eocene-Oligocene boundary. There is, however, no agreement on whether the Quaternary should be a Period like the Neogene and the Palaeogene or an Epoch included in the Neogene. The Neogene Subcommission agreed that the terms Palaeogene and the Neogene should be retained, but recommended that the Palaeogene be spelled thus! The Subcommission proposes to include the Pleistocene as part of the Neogene and to set the boundary between the Palaeogene and Neogene coincident with that between the Oligocene and Miocene. The terms Tertiary and Quaternary would be abandoned except as informal terms.

The Subcommission on Stratigraphic Classification continues its work in preparing a revised version of the International Stratigraphic Guide. Much attention was focused in 1983 on the classification and nomenclature of igneous rocks, unconformity-bounded units, seismic stratigraphy, and the preparation of a glossary of stratigraphical terms.

from ICS 1983 Annual Report

Geotraverses Help to Unravel African Geology

There were a number of important activities in 1983 under the Unesco major regional project "Geology for Development," which focuses on Africa. Geotraverses were run across the Precambrian of several countries. A workshop on the Kibaran System held in Burundi last October led to the establishment, for the first time, of a tentative correlation for the Kibaran between a number of African countries.

Data collected during the 1982 geotraverse in the Copper Belt region of Zambia show that the change in grade of metamorphism, from low in the NW to medium grade in the SE, is directly related to the deformation of the Lufilian and Irumide orogenic belts. The Copper Belt is now seen to form part of a major Pan-African thrust belt with transport direction to the ENE. The basement Irumide rocks were tightly folded and thrusted toward the north prior to the Lufilian deformation, and it is easy to separate the effects of these two orogenic disturbances. The southern boundary of the Lufilian arc is a major shear zone in the form of a lateral thrust ramp.

In the north the Irumide structures form a major northward-verging thrust and fold zone, considerably thickening the succession and in places forming kyanite-bearing assemblages. In the central part of the Irumide belt, structures are upright, but in the south they form a series of southward-verging thrusts, isoclinal folds and recumbent shears. Overall the regional structure represents a major crustal "pop-up" similar to that described across the western Himalaya. No ophiolites have been found, such as might indicate crustal collision. Copper mineralization in aplites and amphibolites within the Nkushi gneiss complex is thought to have been derived from basic and ultrabasic rocks during regional metamorphism and deformation.

Analysis of the results of the 1982 geotraverse across the Ubendian belt of western Tanzania has shown that the NW-SE structural trend that characterizes the Ubendian belt is younger than 1900 Ma. A detailed geochemical reconnaissance of the Sangu-Ikola carbonatite, which covers an area of some 14^2 km, has turned up some rather interesting results. The P_2O_5 content in residual soils over some parts of the carbonatite ranges between 8 and 15%, the maximum values correlating roughly with the highest values of apatite in the underlying rocks (5-7% P_2O_5). It appears that the residual soils could themselves be regarded as potential ore deposits.

Wide homogeneous zones have been found that are of sufficiently good quality to be used in the cement industry. CaO values of carbonatitic material in these zones are between 48 and 50%, with MgO values less than 2-3%, P_2O_5 generally below 1% and Fe_2O_3 less than 3.3%. Possible reserves have been calculated at between 8-10 million tons per metre of depth. A close look at the rare earth content of the residual soils shows there is good correlation in the soils between P_2O_5 and Sr. The fact that the P_2O_5 reflects an enrichment of phosphate in the underlying rocks suggests that strontium could be used as a pathfinder in the search for phosphate enrichments. A good correlation has also been found between Ce, La and Y in an approximate ratio of 10:5:2. Thus, only one of these three elements needs to be analysed in order to estimate the other two.

In Burundi, geological work by local and Belgian geologists, under the Unesco major project, has focussed on determining the major structural trends of the Kibaran Belt here, and on defining its tectonic and magmatic evolution. New age determinations using Rb-Sr and U-Pb methods indicate that the granite magmatism occurred between 1 350 and 1 150 Ma ago. An alkaline-syenite with associated carbonatite was emplaced about 700 Ma. Geochemical studies on mafic magmatics of the Burundian of the western part of the country show that these have a tholeiitic affinity, and that these rocks may have formed in a continental rift zone.

Geotraverses by west African geologists were undertaken in 1983 in Upper Volta and Togo focussing on the metallogeny of the various Precambrian formations in this part of West Africa. Upper Volta offers an excellent example of Lower and Middle Precambrian, essentially granitoid volcanoclastic and metasedimentary terranes. Contrary to the volcano-sedimentary Birrimian of Upper Volta, which is mineralized, the mainly granitoid Birrimian of Togo is sterile.

Work by Somali and Italian geologists also began in 1983 on the basement of northern Somalia, representing the first new work on this region in the 30 years since the regional surveys by British geologists. The main focus here is on lithostratigraphic classification and metamorphic evolution. Four rock complexes have been recognized, but it is not yet clear whether these were orginally linked together and, therefore, represent stratigraphic assemblages, or whether they are only structural complexes.

Studies of the tectonic and magmatic evolution of the Precambrian of western Zaire also began in 1983 with the aim of correlating the Precambrian of lower Zaire with corresponding rocks in Angola, Cameroun, Gabon, and the Central African Republic. The multi-disciplinary team is composed of geologists from Zaire and Congo, together with consultants from the U.K. and Belgium.

Plans are now being made for geotraverses in the southern part of the Sudan aimed at correlating the Precambrian geology here with that of the adjoining regions of northern Uganda. Some work was also begun in 1983 on the Precambrian of Kenya, involving geologists from the University of Nairobi and the Kenya Department of Mines and Geology. A proposal has also been submitted for a geotraverse across the Kibaran belt of southwest Uganda, which contains a wide variety of economic mineral deposits.

From Geology for Development Newsletter, December, 1983

IUGS - Progress on Many Fronts

Figure 1: The IUGS President (E. Seibold), Treasurer (J.A. Reinemund), and Secretary General (C. Weber) against a background of Tertiary sands near Blois, France.

Considerable progress was made over the past year in many scientific activities sponsored by IUGS. New programs initiated in remote sensing and mineral deposit modelling are reported elsewhere in this issue, as are recent developments in the IGCP, which is sponsored jointly by IUGS and Unesco and in the IUGS Commission on Stratigraphy. The wide spectrum of IUGS activities was reviewed in February by the Executive Committee at its 26th meeting held in Blois in the Loire Valley of France.

The Chairman of the Advisory Board for Research Development (ABRD), **W.W. Hutchison**, reviewed the many projects receiving support from the Board. Under the general title of "Metallogenesis of Latin America," a final report on a study of Bolivian tin deposits stated that a geochemical profile through the lower Palaeozoic sequence of the Cordillera Real in Bolivia had detected no sedimentary tin or boron anomalies. A new geochemical investigation of Miocene-Pliocene tin deposits in rhyolitic centres of Bolivia is now underway funded by the U.S.A. and Bolivia. This study will later be extended to similar rocks in southern Peru, northern Chile and northwestern Argentina. A planning meeting was also held in 1983 to discuss a potential study of the metallogeny of Caribbean mafic and ultramafic rocks, and a project proposal was expected in the near future.

The ABRD supported discussions in 1983 on a planned research project on the tin-tungsten granites of Southeast Asia and the Western Pacific. The outcome is a new IGCP Project (220) to investigate the correlation and resource evaluation of these important economic bodies

The first phase of a worldwide program to compile, evaluate and interpret information on the geology and resources of sedimentary basins was established in 1983. Now underway are the compilation and publication of six map sheets at 1:2 000 000 of the hydrocarbon resources of Southeast Asia. This will be coordinated by the Circum-Pacific Map Project, with the cooperation of CCOP, ASCOP, IOC, and CGMW. A pilot study has also begun of the offshore areas of Sarawak, Sabah, Brunei and Kalimantan.

Another important thrust is on urban geology in Southeast Asia. A planning meeting is now being held in Kuala Lumpur, under the cosponsorship of IUGS, Unesco, AGID and the Geological Society of Malaysia, to launch specific research proposals on the application of geology to the planning and development of urban centres in the region. Linked to this program will be an international symposium on urban geology scheduled for Hong Kong in 1985.

The ABRD is also supporting an international workshop on geochemical exploration in tropical rain forests, sponsored by AGID and AEG, now being planned for Manaus, Brazil, later this year. The aim will be to recommend directions for long term research on this important topic.

The latest developments in the application of computer technology to the managment and interpretation of geological data were reviewed in a November 1983, symposium in Buenos Aires, Argentina. Sponsored by the ABRD and various Latin American organizations, this meeting outlined a regional program dedicated in alternate years to energy and to mineral resources. Planning is now underway for the first symposium on energy resources to be held in early 1985 in Lima. This project is being coordinated by COGEODATA with support from Unesco.

The ABRD also supported in early 1984, the IUGS seminar on remote sensing, reported elsewhere in this issue. Papers presented at the 1982 seminar and workshop on petroleum resource assessment in Hawaii have now been edited and will be published in the very near future as part of the IUGS publication series. A 70 page, illustrated guide and legend for the paleogeographic map series on the Neogene of the Pannonian Basin was published last year. Manuscript maps for the Neogene of Bulgaria, Czechoslovakia, Hungary, Romania, Poland, Italy and the F.R.G. were submitted and plans for publication are now well underway. The ABRD also provided financial support in 1983 to IGCP projects 27 (Caledonide Orogen), 41 (Neogene-Quaternary Boundary), 120 (Magmatic Evolution of the Andes), 156 (Phosphorites), and 200 (Sea Level Correlation and Applications).

The IUGS Executive Committee reviewed many items of a more administrative nature. Concerning the payment of annual dues by national members of IUGS, note was taken of a number of countries that were not up-to-date with their dues payment, some not having paid for five years. Those in arrears would not normally be able to vote at the IUGS Council Meeting to be held at the time of the Moscow Congress. Approval in principle was given to the creation of a new category of associate members, and an appropriate amendment to the statutes will be proposed at the Moscow Council. Two new member countries, Algeria and Belize, will be approved at that time.

The Executive Committee was impressed with the achievements in its first year of full operation of CIFEG, the Paris-based International Centre for Training and Exchanges in the Geosciences. CIFEG was encouraged to broaden the international representation on its board, but an application for affiliation to IUGS was regarded as premature.

Linn Hoover, Editor for the IUGS New Publication Series, was appointed a member of the Advisory Board on Publications, and **G.N. Rassam**, the new Chairman of the IUGS Commission on Geological Documentation. The Executive Committee expressed its pleasure at the increase in Episodes' subscriptions in 1983, and acknowledged with gratitude the support of the Geological Survey of Canada. A Standing Committee on Remote Sensing was created under the chairmanship of **Paul Teleki** to maintain links with the new GARS program.

In reviewing developments concerning the forthcoming International Geological Congress (see "Preparing for the Congress" elsewhere in this issue), the Executive Committee expressed its wish that a special Congress publication be dedicated to the memory of **Anders Martinsson**, the late Chairman of the International Commission on Stratigraphy. It noted that visas to participants from countries without diplomatic relations with the U.S.S.R. would be arranged via Paris for South Africa and Israel, and via Tokyo for South Korea. IUGS is assisting in making arrangements for air tickets of participants from developing countries who are being invited by the Congress Organizing Committee. **Brigitte Sangnier**, who worked extremely hard with her late husband, **Paul Sangnier**, to organize the 26th Congress in Paris, was appointed Acting Secretary General for the Moscow Congress.

The Executive Committee noted that an invitation to hold the 28th International Geological Congress in Washington, D.C. in July 1989, would be presented by U.S.A. delegates at Moscow. This timing, rather than 1988, was being proposed so as not to interfere with plans already long underway for the Decade of North American Geology celebrations in 1988.

NEWS IN BRIEF

PERIODICITY OF EXTINCTION

Virtually all species of animal and plants that have ever lived are now extinct, for there are some 200000 extinctions known from the fossil record. Strong evidence that many of these are short lived events of special stress has been presented recently by **D.M. Raup** and **J.J. Sepkoski, Jr.** (Proceedings of the National Academy of Science, February 1984).

Using rigorous statistics and time-series analyses, they tested the record of disappearance of some 3500 families of marine animals over the past 250 Ma (Late Permian to Recent). Using the Harland time-scale, a 26-million year cycle of extinctions can be recognized, in which two of the events coincide with those previously linked with meteorite impacts at the end of the Cretaceous and in the Late Eocene. For the Palaeozoic, however, no evidence of periodicity has been found that can survive the statistical tests used here for the later period.

Sepkoski and Raup favour extraterrestrial causes for this periodicity, because they do not believe purely biological or earthbound physical cycles of fixed length and measured on a time scale of tens of millions of years could operate. One possibility is that an increase in comet flux could occur as the Solar System passes through the spiral arms of the Milky Way, but much more information will be needed in order to rule out the possibility that there may be other periodic phenomena to which the biological extinction record is sensitive.

There are profound implications in this finding for evolutionary biology. It seems that the evolutionary system is not "alone," but is partly dependent upon external influences more profound than the local environmental changes normally considered. Moreover, when the biosphere is forced through such narrow "bottlenecks," recovery from these events is usually accompanied by fundamental changes in biotic composition, without which the general course of macroevolution might have been very different.

ARTIFICIAL COAL

Investigators at the Argonne National Laboratory (U.S.A.) have recently synthesized coal from natural materials as part of their program to characterize coal chemically and to document the geological processes of its formation (Chemical and Engineering News, November 21, 1983). One of the geological processes thought to be involved in the formation of coal deposits, the biogenetic alteration of plant material followed by its metamorphism to coal, is disputed by the new results. In the artificial coalification experiments, lignin was converted directly to lignite by a process catalyzed by natural clays. The geological analog would be the slight alteration of wood with the loss of hydrocarbons, followed by the formation of coal macromolecules at relatively low temperatures (150-200°). If lignins and other similar materials do survive sedimentary diagenetic processes they might, therefore, be converted directly to coal molecules in relatively short times (months) by naturally catalyzed reactions.

DWINDLING WORLD OIL RESERVES

The known world reserves of economical recoverable petroleum have been estimated recently at approximately 723 billion barrels of conventional crude oil (BBO). In a recent U.S.G.S. Open File Report (83-728, 1983), **C.D. Masters**, **D. Root** and **W.D. Dietzman** estimate that there is a 5% probability that as much as 1417 BBO and a 90% probability that at least 321 BBO will be found, 550 BBO being the most likely amount for future discovery. These estimates do not take into consideration such alternatives as heavy oils, bitumen and oil shales, for these are not regarded as likely economic fuel sources in the near future.

The authors point out that the new reserves of oil discovered each year declined from about 38 BBO in the early 1960s to about 10-12 BBO at present. Thus, at the current rate of production and discovery the total of 723 BBO present reserves plus 550 BBO of future potential would be enough to last only for about another half century. The decrease in discovery rate is evident outside the U.S., Canada and the Communist block where each wildcat well drilled in search of a new field discovered an average of about 23 million barrels of oil in the early 1950s, but only 10 million barrels in the recent past. The U.S.G.S. estimate of 550 BBO as the most likely amount to be discovered compares with another recent estimate by **M. Halbouty** and **J. Moody** of 987 BBO yet to be discovered, this being the most likely value in their range of 280-2415 BBO.

EDIACARAN ALIENS

A radical new interpretation of the late Precambrian Ediacaran fauna was recently offered by **A. Seilacher** to the Geological Society of America (Indianapolis, November 1983). These relatively diverse, soft-bodied, shallow water organisms found first in Australia and now in South Africa, England, U.S.S.R. and Newfoundland have been traditionally linked with jellyfish, certain corals or with worms. Many workers have suggested that they were evolutionary precursors to the Cambrian explosion in species diversity and number. Unlike other soft-bodied organisms, which are generally preserved as flattened impressions in soft fine sediments, the Ediacaran fossils are typically found in coarse sandy sediments, their flexible cuticular hydroskeletons resisting microbiological degradation. This type of fossilization is rare after the beginning of the Cambrian. Seilacher suggests that their flattened quilted shapes with their large ratio of surface area to volume developed for the external exchange of metabolites, an idea consistent with the absence of a mouth in some of the metre-long Ediacaran "worms."

In distinction to modern organisms with their systems of internal tubes (vascular networks, lungs, digestive tracks etc.), the Ediacaran fauna may represent a widespread but failed biological experiment, the first major extinction and one that removed a form of life alien to all those that followed.

GEOLOGICAL COOPERATION IN HISPANIOLA

Government geologists from Haiti and the Dominican Republic have recently established a series of annual meetings to discuss scientific problems of mutual concern to these neighbouring countries. Participants visit mineral exploration projects in both countries, some of which are being carried out with UN support. The 1984 meeting will focus on the Mt. Organize-Terre Rouge gold district in Haiti and the Restauración copper project on the Dominican side. Later this year another meeting will be held on stratigraphic correlation between the two countries and will involve university researchers from U.S., France and Guadeloupe.

International cooperation has also received a boost from a recent U.S.-Dominican Republic agreement for a five year mapping and geochemical project aimed at compiling a geological map of the country and identifying targets for mineral exploration. One phase of this program is a survey of offshore minerals, especially gold and other heavy minerals. Japanese and West German geologists are also involved in mapping and mineral evaluation in the Republic and are assisting in the creation of a geological survey department. In the long run the aim of Haitian and Dominican geologists is to complete a geological map of Hispaniola.

YANGTZE RIVER SEDIMENTS

The common terms *deposition, accumulation, accretion*, and *sedimentation* are generally used interchangeably. However, as **B.A. McKee, C.A. Nittrouer** and **D.J. DeMaster** point out in Geology (November 1983) "most natural environments are dynamic, and a particle undergoes many episodes of emplacement on and removal from the seabed before it is permanently incorporated into the stratigraphic record." Temporary emplacement in the seabed and temporal differences separating these processes are thus important considerations in stratigraphy and sedimentology. Radiochemical techniques using ^{234}Th and ^{210}Pb are now being applied in modern sedimentary environments to allow the distinction between deposition ("temporary emplacement of particles on the seabed"), sediment accumulation ("the sum of particle deposition and removal over a longer time scale"), accretion ("positive accumulation" when deposition is greater than removal), and sedimentation ("overall process of particle transport to, emplacement on, removal from and preservation in the seabed"). Measurements by the authors on the continental shelf near the mouth of the Yangtze River indicate short-term deposition rates of about 4.4 cm per month, whereas accumulation rates integrated over a century are only about 5.4 cm per year. The difference between these rates represents the sediment eroded and transported southward to distant parts of the dispersal system of the Chinese shelf.

NUCLEAR WASTE FOR CHINA

A letter of intent has been signed by China and West Germany under which the People's Republic expresses its willingness to accept spent nuclear fuel from the whole of western Europe for disposal in the Gobi desert. If the letter ever becomes a contract, West German companies will act as agents on behalf of other European nuclear companies to collect and transport radioactive waste to China for final disposal. It is interesting to note that although China joined the International Atomic Energy Agency in January 1984, accepting the principle of IAEA inspections, it has not yet signed the nuclear non-proliferation treaty.

IGS TO BGS

The Institute of Geological Sciences (U.K.) recently changed its name to the **British Geological Survey**, coincident with a restructuring of the organization at its new base in Keyworth near Nottingham. The new name will give a clearer impression to foreign agencies of the parallels between the B.G.S. and other national geological surveys like the U.S.G.S. and the Geological Survey of Canada. There will not, however, be any narrowing of the research base of the B.G.S., and its traditional roles will continue. These include the continous reappraisal of the geology of the landmass and continental shelf of the U.K., the maintenance of a comprehensive national geological data base, and the assistance in the planning and execution of overseas geological and mineral resource activities under Britain's technical aid programs.

DECLINING ORE GRADES?

The general belief that the grade of ores mined must decline over time is based on the assumption that higher grades are found and exploited first. In Canada, it has been argued that the best deposits have now been mined out and that gradual depletion of nonrenewable resources has forced the industry toward mining lower and lower grades and, thus, less profitable deposits. **H.L. Martin** and **L.S. Jen** speaking at a recent IIASA seminar in Laxenburg, Austria, argue that this is clearly a misconception.

Between 1939 and 1979, and forecasting to 1989, they show that in Canada the average mined grades of Ni, Zn, non-porphyry Cu and Au ores were remarkably steady over this period of time. The average grade of Au mined did drop some 20% in the 1970s as the price shot up to levels where mining of lower grades became profitable, but it is expected that new gold mines will probably raise the average grade back again to its historic level by the end of this decade.

There have been declines since 1939 in the average grades of Pb, Ag, porphyry Cu and Mo ores. However, in the case of Pb the decreasing grade reflects the predominance of the giant Sullivan Mine, which had an unusually rich start among a small number of Pb producers. No further decline in the average grade of Pb ore mined is expected in this decade. The decline in Ag from 1939 mirrors a sharp change from many small-grade operations to the production of Ag as a co-product from large Cu-Zn-Ag mines.

As for Cu, the increase in ore production since 1960 is largely accounted for by the shift to new, large and profitable porphyry operations, and not as the result of depletion of higher grade ores. Porphyry Cu mined in Canada does show a decline in average grade over time, but this trend seems to be related to the growth and scale of such mining operations, and lower grades are being mined without a deterioration in financial returns.

Martin and Jen conclude that the record of 50 years of mining shows that the question of "when will we run out of good ores" may be for Canada safely set aside until some time in the next century or even the one after that.

PHANEROZOIC CRUSTAL GROWTH

The continental crust has grown throughout the Phanerozoic at a rate of about 1.65 km^3 per year, according to new estimates by **A. Reyman** and **G. Schubert** (Tectonics, February 1984). Data from 17 magmatic arcs and hot spots indicate that approximately 0.6 km^3 of crustal material is being lost by subduction each year, resulting in a net annual growth rate of 1 km^3. This rate satisfies the constant freeboard constraint because of the cooling of the earth and the gradual deepening of the ocean basins. Growth rates during the Archaean, however, must have been 3-4 times this rate, and the evolution of Archean and some younger terranes such as the Arabian-Nubian shield may have involved large hot spot-type additions to the crust.

A SUCCESSOR FOR GLOMAR CHALLENGER

A replacement vessel to the Glomar Challenger, which travelled the seas for 15 years drilling more than 1 000 holes for DSDP, has now been selected. It is the Sedco/BP 471, owned jointly by Sedco, an American firm, and British Petroleum. The ship has a computerized control system, is substantially larger (16600 tonnes) than its predecessor, and will be able to accomodate earth scientists and drill on site for 90 days at a stretch. The ship's drilling equipment can penetrate 3 km into the sea-bed in water depths as great as 1.8 km. Safeguards can be added to the drilling system to counter against blow-outs.

The Sedco/BP 471 will spend its first year moving northward from the Gulf of Mexico to the Blake/Bahamas area of the Atlantic, and possibly farther north to drill in the Labrador Sea, on the mid-Atlantic ridge, and in the Norwegian Sea. The next stop may be the Mediterranean, followed in the second year by a move into the southern hemisphere. By 1986/87 the ship should be drilling in the Weddell Sea off Antarctica.

IRIDIUM AT KILAUEA

Surprisingly high concentrations of Ir have been found in dust plumes from the January 1983 eruption of Kilauea. According to **W.H. Zoller**, **J.R. Parrington** and **J.M.P. Kotra** (Science, December 9, 1983), the Ir/Al ratio in airborne particles is 17 000 times higher than in normal Hawaiian basalt. This enrichment may be associated with high fluorine contents of volcanic gases being released as IrF_6. Selenium, As and Sb also have enhanced concentrations in both the Kilauea dust and the Cretaceous-Tertiary boundary layer, supporting the concept that volcanism may have been involved in producing the later. The volume of the 1983 Kilauea eruption was, of course, far too small to have global effects, but the authors suggest that if volcanism was involved in the K-T boundary events, the source may have been similar to that for the Deccan flood basalts.

ORIGIN OF NEW SPECIES

It has been traditionally assumed that environments which support rich and complex groups of species, for example the tropics as compared to higher latitudes and off-shore as against near-shore communities in the marine realm, would be the site of major evolutionary innovations. Such new species are the foundations of distinctly different adaptations or architectural forms, the beginnings of new genera, families or even higher taxonomic groups. Rich evolutionary potential in rich species diversity appears a very reasonable assumption, but recent work by **D. Jablonski J.J. Sepkoski Jr.**, **D.J. Bottjer**, and **P.M. Sheehan** (Science, December 9, 1983) indicates that it is likely to be wrong.

Nearshore environments contain fewer species, each with lower speciation and lower extinction rates, than species in offshore communities. Individual nearshore species are therefore older than those further out on the continental shelf. However, Jablonski and his colleagues have found evidence that nearshore species, which individually may have substantial geological longevity, represent the most recently evolved forms of life, while offshore species represent the longest established life forms. Thus, a traverse across the seabed from the edge of the continental shelf to the shoreline is like a trip through time from the oldest to the newest evolutionary inventions.

The authors have found this general pattern in the fossil record of the Cambrian-Ordovician interval and also for the Late Cretaceous, implying a continuous process of territorial expansion of the newest evolved forms from the nearshore communities down and across the continent shelf.

The reasons why new species generate preferentially nearshore are not clear. One possibility is that evolutionary novelties are equally likely in speciation events, but that the greater extinction resistance of nearshore species permits new innovations here to persist long enough to diversify. A second possibility is that ecological constraints in certain environments enhance the likelihood of large evolutionary jumps during speciation events.

VENUSIAN VOLCANOES

Recent studies in the U.S.A. suggest that Venus may be experiencing huge volcanic eruptions every 5 to 10 years, with smaller scale volcanism taking place continuously. **L.W. Esposito** has detected a huge injection of sulphur dioxide into the Venusian atmosphere that took place just a few months prior to the Pioneer Venus space probe in December 1978. Even at the time of that encounter levels of sulphur dioxide were still 50 times higher than normal (at 100 ppb), and they have been declining steadily ever since. According to Esposito (in Science, March 9, 1984), eruptions that caused such high levels of sulphur dioxide were ten times larger than the El Chichon eruption, and powerful enough to push sulphur 70 km into an atmosphere that is 100 times more dense than that of earth. A similar appearance of the planet in the late 1950s implies that there may have been injection of sulphur dioxide due to episodic volcanism.

A new high resolution (≃ 2 km) radar image of Beta Regio (see review by McGill in Episodes, 1983/4) reveals details of the Venusian structure which seem to confirm earlier suggestions that this region consists of a rift system and associated volcanism. **D.B. Campbell**, **J.W. Head**, **J.K. Harmon** and **A.A. Hind**, at the 15th Lunar and Planetary Science Conference held recently in Houston, Texas, reported numerous long, linear features running roughly parallel to the north-south trending trough in Beta Regio discovered by the Pioneer Venus orbiter. They interpret this trough as being an indication of extensive faulting, and new radar reflectivity data suggest that there is a major volcano (Theia Mons) situated on the western boundary fault of this rift system. Theia Mons shows an extremely close correlation of topography with major brightness variation, and there are lobate flow-line structures extending radially down-slope from the central area.

It may be that Venus cannot dissipate its internal heat in the way that earth does, since it has no ocean spreading regions where the crust is opened up and liquid magma can pour through. If so, the waterless planet may be forced to concentrate the release of its heat in areas such as Beta Regio.

MINOAN HOMOGENITES

New findings in the eastern Mediterranean of a huge muddy deposit ("homogenite") of middle Holocene age are reported in the February 1984 issue of Marine Geology. Earlier studies by **M.B. Cita** and **K.A. Kastens** indicated a link to the Bronze Age (Minoan) eruption of Santorini, and the new works support the concept that this homogenite is the result of a tsunami-induced gravity flow related to the collapse of the Santorini caldera some 3 500 years ago. New localities on the Messina Abyssal Plain and the deformation front of the Mediterranean Ridge are described for this bed of homogenized, non-bioturbated mud, with a sharp basal contact and a bottom layer of foraminifera sand with normal grading. According to **W. Heike** this layer covers an area of at least 1 100 km^2 and, assuming a minimum thickness of 10 m, comprises a volume of 11 km^3.

More recent sedimentary masses related to submarine slumping in the eastern Korinthiakos Gulf in Greece are reported by **C. Perissoratis**, **D. Mitropoulos** and **I. Angelopoulos**. One slump mass, covering an area of some 16 km^2 at a water depth of 100-250 m, was triggered by earthquake activity in the region between February 24 and March 4, 1981.

These examples of seismically induced deposits add to the growing "catastrophist" record of sediment deposited by sudden events ("tempestites"-storm deposits in fluvial, deltaic and litoral shelf environments), turbidites, "seismites" (beds with post-consolidational, soft-sediment deformation structures), and even "unifites" (muds deposited from low density gravity flows).

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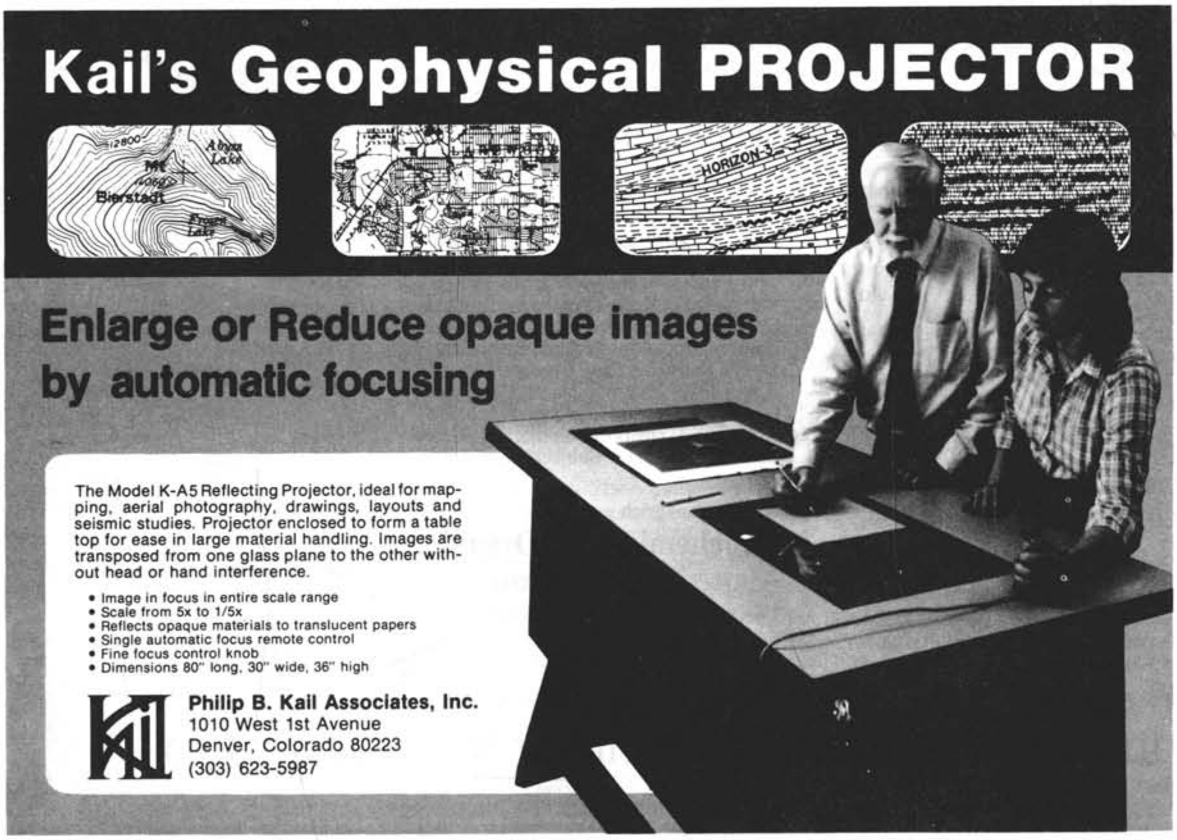

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CONFERENCE REPORTS

Biochronology and Quantitative Stratigraphy

Halifax, Canada, October 11-14, 1983 and
Kharagpur, India, December 12-17, 1983

IGCP 148 has been concerned with the development and application of new quantitative stratigraphic techniques and algorithms which "think" along stratigraphic lines of reasoning. Theoretical and practical testing of such methods to develop biozonations include seriation, ranking and scaling, unitary associations, multivariate clustering and lateral tracing. Data sets developed and analyzed by these methods, commonly include microfossil distribution in deep-sea drilling and commercial boreholes.

In 1983, the final year of its existence, IGCP 148 was concerned with developing numerical time scales to quantify geological processes, one goal in stratigraphic correlation being isochron contouring. This research involves calibration and linkage of fossil and other unique geological events to a common chronostratigraphic scale and stretching of this to create a geological time scale measured in million year (Ma) units. In the absence of direct radiometric estimates for many stratigraphic boundaries, geological and statistical techniques have been developed to allow reliable estimates to be made of the numerical age of stage boundaries, especially for the Mesozoic and Cenozoic. Senior oil company geologists now stress the practical importance of these techniques developed in IGCP 148.

The Halifax conference on "Biochronology and Stratigraphic Correlation" was attended by over 100. It began with a contribution by W. Riedel on rating and scoring the widely varying quality of palaeontologic information used to make zonations and correlations. The art of doing this and of comparing events that score equal points based on different characteristics, needs to be further developed. After all, the input is what largely determines the results, or as L. Edwards put it, "any method will work with superior data." The two methods now used to construct range charts by stretching the true range between the lowest and highest observed relative positions, and by averaging the range (taking into account all the relative highest and lowest occurrences observed) may yield the same answer. This is especially so when more sections are added to the standard, and when care is taken to separate consistent from isolated first and last occurrences.

Normality testing of individual sequences of events relative to the RASC (Ranking and Scaling) standard, as a means to improve zonations and correlations, was demonstrated by F. Gradstein and F. Thomas. G. Williams found that the use of RASC for subsurface palynology zonations, provided a good estimate of the spacing of the taxon events over the successive zones. The clear and concise presentations by S. Mohan and S. Nederbragt showed the value of combining simple palaeontologic and stratigraphic data by using sedimentation and subsidence rate functions. Mohan showed that tectonic forces may have controlled the main subsidence of the Bombay High.

A key theme was the manner in which time scales from Triassic through Cenozoic are made, and their properties for quantitative geology. E.T. Tozer staunchly defended the use of classical ammonite stratigraphy to erect detailed intercontinental zonations. In his view, the history of ammonites is one punctuated by disasters or other discontinuities, which acted in the same way in widely different localities. In this sense the classical ammonite zones represent chronozones of supra-regional significance.

G. Westermann used the standard ammonite zonation to subdivide Jurassic time. As clearly outlined by J. Van Couvering, the use of equal duration of zones is only one of several approaches to measuring time over the chronostratigraphic scale. More direct, but also more difficult to use for older events due to larger absolute errors, is the radiometric dating of ash beds and plutons injected close to stage boundaries. A variant method tries to link radiometrics and bio- or magnetostratigraphic events. In several Cretaceous and Tertiary land and ocean sections, magnetic reversals have now been tied to biostratigraphic events and to radiometric dates, as demonstrated by J. Hazel. The powerful, indirect technique outlined by D. Kent and F. Gradstein uses the assumption of constancy of seafloor spreading over 10 Ma or more to stretch the marine magnetic reversal record.

F. Agterberg presented a new method to estimate the age of chronostratigraphic boundaries, using a maximum likelihood

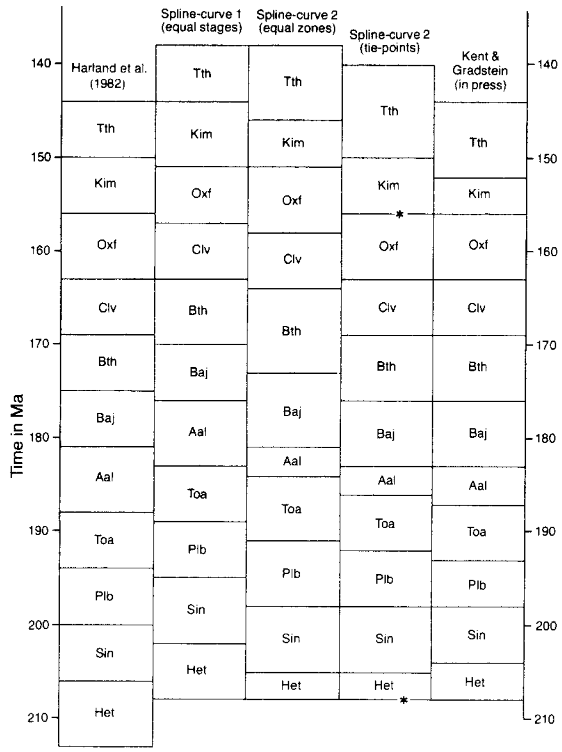


Figure 1: Comparison of spline-curve ages with other recent age estimates for the Jurassic. See text for explanation.

function to interpolate all radiometric ages relevant to a stage boundary. When the likely ages of a number of chronostratigraphic boundaries have been estimated, the geological time scale can be further interpolated using cubic spline smoothing functions.

Figure 1 shows the Jurassic time scale, as presented by different authors, using slightly different methods. To the left is the 1982 scale advocated by Harland and his colleagues using the equal duration of stages concept. Key ages or tiepoints are outside the scale shown in column 1. Columns 2 and 3 are spline curve interpolations using equal stage and equal zone duration between the base of the Hettangian (208 Ma) and Jurassic/Cretaceous boundary (138 Ma). If the key age of 156 Ma for Oxfordian/Kimmeridgian boundary is used, the scale of column 4 is generated. This is close to the multiple scale in column 5. Given that there are absolute errors in Jurassic radiometric dates of 5-10 Ma, the different scales are remarkably close.

Shortly after the Halifax conference, the 7th international meeting of IGCP 148 was held at the Indian Institute of Technology, Kharagpur, with as many as 180 scientists attending. Among papers of note was one by B.K. Ghose and B.C. Jaiprakash that analysed palaeontologic time series based on abundance data of foraminifers, which came from DSDP core sites located in the middle of the Indian Ocean at about 10°S. Depth plots of total abundance of planktonic forams display an abundance peak at a depth of about 5.7 meters, indicating warmer water in this region 0.4-0.6 Ma ago. Other peaks were observed and cyclical patterns established by performing harmonic analysis of time series for individual species, notably *Orbulina universa*. Different locations of peaks in the power spectra were used to estimate local differences in rates of sedimentation.

In a session on quantitative lithostratigraphy, A. Mukherjea, M. Mohan, N. Vashist and V. Raiverman proposed time-stratigraphic classification by the quantitative analysis of contemporaneous and post-depositional sedimentological processes. Irreversible processes like progressive dissolution of complex mineral suites, compaction and lithification can provide a stratigraphic clock for marking geologic time on an ordinal scale. Examples were given from the Cenozoic sequences of the Himalayan foothills and the Indo-Gangetic plains. Automatic computer plots were displayed for percentages of heavy mineral asemblages arranged according to their order of stability. Systematic changes in the mineral suites from the oldest to the youngest aided in sediment classification and stratigraphic correlation.

W. Schwarzacher considered possible causes of complex cycles in carbonate sequences. Limestone-marl sequences frequently contain cycles consisting of between 5-7 marl-limestone couplets. The thickness of such a group of beds is of the order of 1-3 meters. Power spectra show that the pattern of these cycles is remarkably similar in sequences ranging in age from the Carboniferous to the Pliocene. Schwarzacher tentatively suggested that the basic 1-meter cycle may be related to the 100 000 year periodicity of the Milankovitch cycle, because no other mechanism capable of producing such a persistent pattern seems to exist.

The 4th International Short Course on Quantitative Stratigraphic Correlation, which followed the Kharagpur conference, covered many quantitative methods in biostratigraphy. The participants were provided with a copy of "New Concepts and Methods of Stratigraphy," which also constitutes the first draft of a guidebook to be published by Unesco in 1985.

*From reports by **F.P. Agterberg**, Ottawa, Canada and **F.M. Gradstein** and **M. Williamson**, Dartmouth, Canada*

Groundwater Development in the Third World

London, U.K., October 11, 1983

The International Drinking Water Supply and Sanitation Decade has focussed the attention of governments and financial donors on meeting the Decade targets of providing potable water and adequate sanitation facilities for all by 1990. However, although these issues have received much attention from both engineers and economists, an estimated 1 500 million people still do not have access to these basic needs. This one day conference was aimed at reviewing the level of groundwater development in the Third World and suggesting ways of meeting the Decade targets.

The first contribution was from S.M. Niaz of the World Bank (Washington, D.C.), who provided the link between the financial and technical facets of groundwater development. He outlined the Bank's cycle of project identification, preparation, negotiation, implementation, completion and evaluation, pointing out that in general World Bank schemes use only proven technology, although a limited amount of new technology may be included on a trial basis.

J.W. Lloyd (University of Birmingham, U.K.) discussed the difficulties of groundwater assessment in the volcanic-sedimentary environment of Central Java. Lithological inhomogeneity, does not allow easy aquifer delineation and also makes the construction of dams to retain the high rainfall difficult. Only major dewatering schemes can substantially add to the groundwater resources of the area and then only after careful long-term planning.

The problems of locating groundwater resources in African basement complex were outlined by L. Clark (Water Research Centre, U.K.) and M.J. Jones (International Geotechnical Engineers, U.K.). Clark suggested that as the groundwater occurs in the upper, weathered zone of these rocks, there are no regional aquifers and the groundwater reservoir is, therefore, structurally controlled. However, Jones had a distinctly different view, considering the weathered zone to be hydrogeologically very uniform. The outcome of this controversy will determine whether or not traditional hydrogeological techniques are suitable for locating groundwater resources in such regions.

The progressive development of well design in Pakistan was described by R.F. Stoner (MacDonald & Partners, U.K.), and

W. Moffatt (Loughborough University of Technology, U.K.) discussed the hydrogeology and optimum design of wells for the coastal aquifer of North Yemen.

The final contribution was from E.P. Wright (British Geological Survey, U.K.) on the role of the hydrogeologist in the provision of water supplies for rural African communities. Dr. Wright maintained that, contrary to recent thought, considerable attention needs to be given to the design and construction of rural groundwater schemes. A further significant issue discussed was the need for hydrogeologists and water engineers to be more aware of the social and institutional difficulties that could arise in an African culture as a result of their work.

Further details of this meeting may be obtained from the Geological Society of London, Burlington House, Piccadilly, London W1V 0JU, U.K.

K.M. Baxter
Medmenham, U.K.

10th Caribbean Geological Conference

Cartagena, Colombia, August 14-20, 1983

Coordinated by INGEOMINAS, the Colombian Instituto Nacional de Investigaciones Geológico-Mineras, this meeting was attended by some 250 geologists from the Caribbean community and beyond. The three themes: tectonics and structure, statigraphy and marine geology, and petrology and geochemistry attracted 120 papers.

The first theme included discussions of new tectonic models currently proposed for Caribbean geology. For example, R. Alonso-Harris (Puerto Rico), E.A. Krieg, and A. Meyerhoff (U.S.A.) showed that the Puerto Rico Trench exhibits evidences of a post-early Pliocene graben origin rather than one associated with a subduction zone. In contrast D. Elston and R. Krushensky (U.S.A.) argued that palaeomagnetic data indicate that Puerto Rico was an exotic terrane, which had originated at about the latitude of Ecuador and Peru in the Cretaceous.

Among the papers of note on stratigraphy and marine geology, was one by F. Maurrasse, (U.S.A.) presenting new biostratigraphic information on the Eocene-Oligocene boundary in Barbados, and another by R.D. Liska (Trinidad) on the equivalence of Bolli's Globorotalia menardii zone with the Globorotalia acostaensis zone in Trinidad. All the discussions confirmed once more that the Caribbean is very complex and still far from being fully understood.

During the conference, the 4th Regional IGCP Meeting was held to review progress on 21 projects with activities in Latin America. Another session dealt with the coordination of activities under the IUGS-sponsored project on the metallogeny of mafic and ultramafic rocks of the Circum-Caribbean region. The Council of Directors of Latin American Geological Services also discussed ways of encouraging geological research in the region through cooperation among the various national geological surveys. Representatives from Venezuela, Nicaragua, Dominican Republic, El Salvador, Mexico, Costa Rica, Barbados, Cuba, Guatemala and Colombia attended this meeting together with observers from Argentina, United States, Ecuador, and Trinidad and Tobago.

Barbados was designated as the site for the next Caribbean Geological Conference to be held in 1986. INGEOMINAS agreed to provide a temporary secretariat in Bogota for the conferences in order to improve the coordination of future activities.

From report by H. Duque-Caro,
Bogota, Colombia

Rocks for Buildings

Nairobi, November 15-19, 1983

A regional workshop on use of rocks for building materials was held recently in association with a major symposium on appropriate materials for low cost housing. The workshop, which took place within the framework of the Unesco project Geology for Development, aimed at informing African geologists on the exploration, evaluation and exploitation techniques for rocks as the basis for building and construction materials. Rocks, in this sense, include not only building stone but also clays, sands, and pozzolanas.

In his opening address the Commissioner of Mines and Geology for Kenya, Mr. C.Y.O. Owayo, pointed out the relative neglect of industrial minerals in construction despite the potentially great advantages of exploiting local deposits for local markets and end uses, often substituting for more expensive imported materials. To correct this situation, however, demands a greater awareness on the part of geologists of the role and uses of stone, clays and limestones, as well as an appreciation of their properties and methods of processing.

Country papers from Botswana, Ethiopia, Kenya, Nigeria, Tanzania and Uganda reviewed briefly the geology of each country's construction and building material resources, together with a brief run-down on status of the extraction and processing industries based on these minerals. Specific case studies examined marble quarrying in Nigeria, and a small open glass-sand mining operation in Malawi. A local company near Nairobi showed the participants a range of mineral products and processing operations based on limestone and marble, dimension stone, gypsum, kaolin and feldspar.

A series of presentations related to low cost cementing materials (other than Portland cement) dealt with natural and artificial pozzolanas, laterite and gypsum. Lime production using small vertical shaft kilns was also reviewed, particularly from the point of view of selection and assessment of suitable raw materials and testing of the final product for a variety of end uses. There were also presentations on industrial clays for the metallurgical manufacturing and processing industries, and clays for structural ceramics, such as bricks, tiles and aggregates.

The workshop concluded that there should be a continuing regional program of workshops and field courses dealing with the practical aspects of industrial and construction minerals. Information on techniques of resource assessment and evaluation, mineral processing and industrial applications should be shared regionally, and there should be access established to international sources of related information. Regional cooperation on these issues, the workshop concluded, would benefit from the appointment of a full-time coordinator. National mineral development policies should help to bridge the gap between resources and their industrial utilization by providing relevant services and an environment in which small mining and mineral-based business can flourish.

Figure 1: *Pyroclastic volcanics being quarried for building stone, near Nairobi.*

Further information on the Nairobi workshop and on activities related to small mining in eastern Africa may be obtained from F.R. Almond, Intermediate Technology Industrial Services, Myson House, Railway Terrace, Rugby CV21 3HT, U.K.

From ITIS press release

IGCP: Annual Review and Financial Constraints

Paris, February 6-17, 1984

Like many other organizations Unesco now faces serious funding problems. These were very much in the minds of the Scientific Committee and Board of the International Geological Correlation Programme, which met recently in Paris. As E. Seibold, President of IUGS, pointed out, the IGCP is one of the strongest components of the "S" in Unesco's acronym. The financial support provided by IGCP was always understood to provide seed money for its projects. But "half a seed will not sprout," so that any further reductions in the overall budget of Unesco should not be applied linearly across all its programs.

R.W.R. Rutland, Chairman of the Scientific Committee, emphasized that the current level of funding available to IGCP (planned at close to $300 000 US for 1984) was below the reasonable level of credibility, even for the present level of activity. It was a critical constraint on increasing the involvement of less-developed countries in IGCP. Board members also pointed out that the funds available to IGCP have become less and less adequate to meet even the modest needs of individual projects. The present funding hardly justifies the time and effort by project leaders, national committees or by Board and Scientific Committee members. A substantial increase of funds to at least three times the present level, would be needed if international cooperation in high priority projects is to be adequately stimulated.

The financial problems must not be allowed to become even more acute in the event that the total funds for Unesco are cut, for example by the planned withdrawal of the United States. The IGCP is widely regarded as one of the more successful scientific programs in Unesco, and its Earth Sciences Division should be in a strong position to argue for maintaining present funding levels even if the overall budget is cut.

The Secretary of IGCP, E. von Braun, reported that three major publications were issued in 1983 by the secretariat; Geological Correlation No. 11, the Second Interim Report (1978 to 1982), and the second volume of the IGCP Catalogue. The latter is an indexed bibliography of some 10 000 titles produced by IGCP projects! Of 50 ongoing projects in 1983, 40 had requested and received grants to hold annual meetings. Eight projects were scheduled for termination in 1983, and 14 proposals for new projects were received. There are now 81 established national committees of which 32 had submitted reports on their activities in 1983. Two regional meetings took place in 1983, one in Bangkok that resulted in the proposal for two new regional projects, and one in Sri Lanka.

The Board decided to admit seven new projects to the IGCP:

- 211– Late Palaeozoic of South America (Project leaders:

A.J. Amos and S. Archangelsky, Argentina);

- 215– Proterozoic Fold Belts (R. Caby, France);
- 216– Global Biological Events in Earth history (O.H. Walliser, F.R.G.);
- 217– Proterozoic Geochemistry (K.C. Condie, U.S.A.);
- 218– Quaternary Processes and Events in SE Asia (N. Thiramongkol, Thailand);
- 219– Comparative Lacustrine Sedimentology through Space and time (K. Kelts, Switzerland);
- 220– Tin and Tungsten Granites in SE Asia and the Western Pacific (S. Suensilpong, Thailand and T. Nozawa, Japan).

This brings the number of ongoing IGCP projects in 1984 to 48 and those "on extended term" to nine.

Experience shows that successful IGCP projects tend to share certain characteritics. They focus clearly on specific scientific problems and do not suffer from a diffusion of ideas and opinions. They identify timely problems that are amenable to advances, and the potential for advancement was apparent before the project began. They provide a vehicle through which field, laboratory and theoretical studies are brought together. Successful projects have provided a base on which future studies can proceed, emphasizing the education and training aspects. They are also distinguished by the high quality of their leadership. Good leaders are not only knowledgeable and active scientists who are widely respected, highly productive and intellectually agressive, but they are also prepared to devote a good deal of time, effort and thought to the success of the project. The final characteristic is that successful projects have typically closely interwoven the "basic" and "applied" aspects of their projects.

The Board repeated its concern at the lack of projects involving geophysics and the marine geosciences. There was a continuing problem in getting substantial geophysical input into IGCP projects, though care must obviously be taken that there is no overlap with ongoing ILP projects. The Board also considered other gaps, which are largely interdisciplinary and relate to the interaction between geology and biology, meteorology (climatology), hydrology, and hazard prediction and mitigation. The first three of these subjects could well be included in the planned ICSU project on the biosphere and geosphere (see Episodes, 1983/4, p. 29-30).

- from IGCP documents

First International Conference on Palaeoceanography

Zürich, Switzerland, July 19-21, 1983

In the early days of the earth-science revolution, marine geologists were either geophysicists or micropalaeontologists. They had all the fun, interpreting magnetic anomalies and dating the sediments above the ocean crust, and they were the heroes who upheld the seafloor spreading theory. Sedimentologists then had the thankless task of describing hundreds and hundreds of meters of pelagic oozes, which looked all alike – a routine that could be done by any high school graduate.

Micropalaeontologists used to get together in international meetings called Planktonic Conferences, held every three years. The first was instrumental in straightening out the zonation of planktonic foraminiferas, and the second the zonation of nannoplanktons. At the third conference, in Kiel (1974), there was a shift in emphasis, and many micropalaeontologists turned to isotope geochemistry. Analyses of the oxygen isotopes of foraminiferas yielded palaeo-temperatures, though few seemed to understand what the carbon isotopes meant.

No more planktonic conferences have been held since then. Biostratigraphical zonation still had its problems, but the first flush of excitement was over. Palaeoceanography was developing as a new earth-science discipline, though few thought of themselves as palaeoceanographers.

The idea of a meeting to compare notes and exchange ideas was first discussed, with the idea of calling it the Fourth Planktonic Conference. However, on the advice of Bill Haq it became the First International Conference on Palaeoceanography. This was held last year under the sponsorship of the Geological Institute of the Swiss Federal Institute of Technology, the IUGS Commission on Marine Geology, and by ICL Working Group 7.

During the three day meeting, the latest results and ideas were presented on such general themes as ocean circulation, palaeoclimates, ecology, sea-level changes and sedimentological processes. There were also workshops on biostratigraphy, numerical ages, and stable isotopes. The conference ended with a three-day field trip to the Southern Alps, during which discussions were held on the evolution of the southern continental margin of the Tethys Ocean and the impact of oceanography on the Mesozoic Tethyan sediments.

Sedimentologists, geochemists and micropalaeontologists, many of them shipboard friends on Glomar Challenger during the DSDP, joined efforts at the Conference to present the results of this newest interdisciplinary field of research. Analytical techniques have now advanced so far that a few foraminiferal tests can be used to provide a meaningful signal. Numerical ages of biostratigraphic zones were worked out, with correlative accuracies down to 10^5 years. Detailed records of surface, intermediate, and bottom temperatures were compiled, many of the data points spanning time intervals of 10^4 years or shorter. The history of surface and bottom circulations of the world's oceans was unravelled, and the interplay between tectonics, ocean circulation and climate, and their influence on biologic productivities were examined.

Bill Berggren and his colleagues at Woods Hole Institution of Oceanography were given the task of organizing the Second International Conference on Palaeoceanography to be held there, September 8-12, 1986. The themes for meeting will include ocean palaeochemistry, flux rates and mass balance, evolution and the marine record, deep-water palaeocirculation and biotic response, marine geochronology, Palaeozoic-Mesozoic oceans, Cenozoic oceans, eustastic sea-level changes, Late Neogene climates and polar seas. Information on this second conference can be obtained from Dr. W.A. Berggren, WHOI, Woods Hole, MA 02543, U.S.A.

K.J. Hsü and J.A. McKenzie
Zürich, Switzerland

BOOK REVIEWS

GEODYNAMICS OF THE EASTERN PACIFIC REGION, CARIBBEAN AND SCOTIA ARCS

S.J. Ramón Cabré (ed.)

Geodynamics Series, vol. 9 (1983), American Geophysical Union, Washington, 280 pages, $24.00

This book bears the same name as the second of the ten Working Groups of the International Geodynamics Project, the predecessor of the International Lithosphere Program. It is a summary volume that brings together part of the work carried out during the ten-year lifespan of the Project. Aside from short introductory statements by C.L. Drake, A.L. Hales and the Editor, the book consists of 14 chapters ranging in length from 3 to 34 pages and dealing with specific areas from the Juan de Fuca plate in the north to the Scotia Arc in the south. The title of the volume is somewhat misleading as it implies a heavy or even exclusive emphasis on marine environments, whereas in fact, more than half the pages deal with on-land geology. Here one is struck by how far our knowledge of the geology and tectonics of Central and South America (a fertile realm for arm-wavers!) lags behind that of the offshore geology and geophysics.

The objective of the book is only partly achieved. Some chapters are concise, up-to-date summaries useful to specialist and generalist alike. Outstanding are contributions on the Juan de Fuca plate by R.P. Riddihough and six co-authors, on the Nazca plate and Andean forearc by L.D. Kulm, J. Dymond and K.F. Scheidegger, and on the Scotia Arc Region by P.F. Barker and I.W.D. Dalziel. Two other chapters offer new slants on the old problems of the Peru-North Chile segment of the Nazca-South American subduction zone (L. Ocola) and the kinematics of the South American subduction zone (based on "long-route" plate reconstructions by R.H. Pilger, Jr.). The remaining nine chapters range from reviews of material more cogently published elsewhere, to unflattering potpourris. Four of these have no abstracts, and the chapter on Caribbean geodynamic investigations is without a map to guide the hapless reader through one of the stickiest geographical labyrinths in the world.

The book is printed from camera-ready copy and reflects the worst abuses of this process. Articles by authors whose native language is English and who presumably had in-house proofreaders fared well, though the number of typographical errors still exceeds the norm for typeset print. Other authors who struggled with an alien tongue and lacked access to editorial help had less satisfactory results. Ten to twenty typographic errors per page, repeated paragraphs, dropped lines and the like combine to befuddle the reader.

Although the book includes more than 1 300 references (distributed very unequally, from only 16 to a staggering 563 per chapter), only four of the 14 chapters include citations more recent than 1979. Much of the current published work on the area between the Mendocino Fracture Zone and the Chile Rise has been missed.

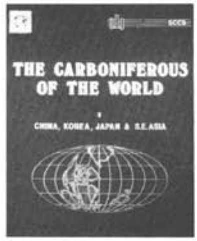
In summary, the three chapters cited earlier (about one third of the book) are carefully executed studies, concisely reported. The remaining chapters range downward from these standards, and poor editing mars much of the book. Better summaries of some of these areas can be found in Geological Society of America Memoir 154: "Nazca Plate: Crustal Formation and Andean Convergence" (1981), and "Geodynamic investigations Venezuela" (1981) published by the Ministerio de Energía y Minas, Caracas.

Tomas Feininger
Ottawa, Canada

THE CARBONIFEROUS OF THE WORLD: VOLUME 1 CHINA, KOREA, JAPAN & S.E. ASIA

R.H. Wagner, C.F. Winkler Prins and L.F. Granados (eds.)

IUGS Publication No. 16, 243p., 3 tables., 55 figures, 27 plates, $20.00 (US). (Available from the EPISODES Secretariat).



The synthesis of knowledge concerning any geological period is a major undertaking, and the IUGS Subcommission on the Carboniferous and the Spanish National Subcommission on Stratigraphy must be commended for undertaking this projected four volume series. The approach is not all-inclusive but restricted to "stratigraphic and palaeogeographic information." Some readers might expect, or wish for, more information concerning economic geology, palaeotectonics and even palaeogeography than is given.

This first volume presents an up-to-date review of Eastern and Southeastern Asia, providing this reader with a much clearer picture of the Carboniferous stratigraphy and fauna of an area not well known to most American geologists. The volume is timely in that it precedes the convening of the XI International Congress of Carboniferous Stratigraphy and Geology, which will be held in China in 1987.

The discussion on China by Yang Shigpu and others is much the longest, as might be expected from the large number of isolated exposures scattered throughout the country. A division into five regions is used, based upon differences in sedimentation and biota: South China, North China, Northwest China, Tibet-West Yunnan, and Tianshan-Hinggan. Ten different authors discuss Lower, Middle and Upper Carboniferous stratigraphy, fauna and boundary relationships, with a consistency of style throughout. The numerous maps and figures showing correlations, biozones, and faunal and floral distributions make it relatively easy to follow the discussion geographically, although somewhat more difficult in a stratigraphic sense. The main focus in the past ten years seems to have been on mapping, faunal and floral studies, and development of zonation, to judge by the figures and the extensive reference list.

The more significant faunal and floral elements are illustrated in 21 plates, but, except for the Lower Carboniferous, little is said concerning palaeogeography and biogeography. Non-Chinese geologists usually set the Carboniferous Permian boundary between the Triticites Zone and the Pseudoswagerina Zone. However, the authors in this book include both the Pseudoswagerina Zone and the Robustoschwagerina schellwieni Zone in the Carboniferous.

Book Reviews ...

The chapter on Korea by Chang Hi Cheong is very short (5 pages). Only Middle Carboniferous strata have been identified on this portion of the Sino-Korean platform, whereas both Middle and Upper Carboniferous are exposed in the North China region. Exposures are also present in seven coal fields in South Korea and three in North Korea. A short tectonic history is given, and correlation is based on fusulinids, although no faunal illustrations are given.

The Japanese Carboniferous (M. Minato) appears to have been studied in more detail than the other areas included in this volume. The extensive use here of fusulinids and conodonts has produced a detailed zonation. The most complete Lower Carboniferous sequence is found in Kitakami Mountains of northeast Japan, whereas a nearly complete section from the upper portion of the Lower Carboniferous through the Upper Carboniferous is present in the Fukuji area of southwest Japan. Major facies relationships of the Middle and Upper Carboniferous are discussed, and there is a short discussion on magmatism, palaeolatitudes and palaeogeography. Major faunal elements are illustrated on three plates.

Southeast Asia, consisting of four tectonic blocks that accreted during post-Carboniferous time, presents difficult correlation problems as a result of quite different depositional histories. These are designated as the West Malaya, East Malaya, Indochina and South China blocks, and the relationship of Gondwana as a source area at the western margin of the West Malaya Block is noted. The author (I. Metcalfe) has successfully synthesized the information from the various regions through brief discussions, faunal lists, zonal charts and stratigraphic correlations. Conodonts, the smaller foraminifers and brachiopods appear useful in correlation for the Lower Carboniferous. Whereas the base of the Lower Carboniferous is either unconformable or a nonsequence, the Upper Carboniferous boundary is transitional through a limestone sequence and is drawn at the base of the Pseudoswagerina Zone. Three plates of representative fusulinids, corals, brachiopods, and conodonts are included.

The reader is distracted by misspellings (especially in major titles such as "Introducction" on page 11), words omitted from sentences, and inconsistent punctuation, primarily with abbreviated words. The major problem concerns the orientation of the figures and their legends in the chapter on Southeast Asia, where the legends for Figures 7 and 8 are reversed. The list of editors and contributors and their addresses is useful though two are omitted; the name of one non-contributor is added and two are misspelled. The volume is otherwise quite readable, and I look forward to the remaining volumes of this useful Carboniferous reference.

R.D. Hoare
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THE SHELFBREAK: CRITICAL INTERFACE ON CONTINENTAL MARGINS

D.J. Stanley and G.T. Moore (eds.)

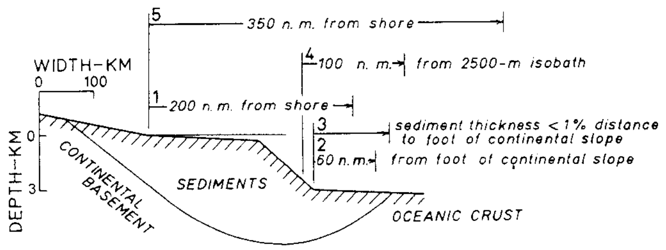
SEPM Special Publication No. 33, 1983, Tulsa, Oklahoma, U.S.A., 467p, $20.00 (U.S.)

The shelfbreak is a feature of first order importance on continental margins, stretching for more than 300 000 km around the world's landmass, plateaus and islands. It marks the boundary between the continental shelf and slope, major structural and physiographic provinces, which can be defined by changes in water mass regimes, depositional processes, sediment facies and faunal distributions, as well as by structure and bathymetry. It has also recently taken on significant economic and political dimensions.

Although students of modern oceans and sediments had recognised the significance of the shelfbreak, it has received surprisingly little attention, and much less so in the ancient rock record. The publication of the proceedings of an SEPM research symposium held in 1981 on the topic in San Francisco is, therefore, very timely in reviewing what we know of the geology of the shelfbreak and in posing major questions for future research.

There are 28 contributions from a mainly North American authorship, covering a wide range of aspects, regions and ages of shelfbreak geology. These have been grouped into eight sections dealing with: morphology and sea-level change, structural and stratigraphic framework, sedimentation and deltaic influence, carbonate margins, processes and sediment dynamics, sedimentary responses to processes, distribution of faunal and organic matter, and economic prospects and legal aspects. Some papers are an overview or partial reviews of a particular topic, including shelfbreak physiography (J-R. Vanney and D.J. Stanley), prograding shelfbreak types on passive margins (D. Mougenot, G. Boillot and J-P. Rehault), ancient carbonate shelf-slope breaks (N.P. James and E.W. Mountjoy), factors that influence sediment transport (H.A. Karl, P.R. Carlson and D.A. Cacchione), and infaunal-sediment relationships (N.J. Blake and L.J. Doyle). Others are more specific contributions presenting new results and concepts on canyon evolution on the middle Atlantic slope (J.A. Farre, B.A. McGregor, W.B.F. Ryan and J.M. Robb), shelf-edge sediment instability off the Mississippi Delta (J.M. Coleman, D.B. Prior and J.F. Lindsay), and modern sediment dynamics off Nova Scotia (P.R. Hill and A.J. Bowen).

However, whether more broadly or narrowly defined, most of the contributions present a new perspective on the data by focussing on the shelfbreak. D.J. Stanley has been writing for some years now about the mudline, but his paper in this volume (with S.K. Addy and E.W. Behrens) takes that concept a step further by discussing the shoaling or deepening of the mudline in terms of the controlling influences on sediment distribution. L.J. Pietrafesa assesses much of what has been learned by physical oceanographers about circulation, fronts and mixing between water masses with regard to how these processes might affect shelfbreak sedimentation. Several contributions dealing with seismic reflection profiles highlight the seismic facies characteristic of shelfedge deposits (e.g. M.E. Field, P.R. Carlson and R.K. Hall) and their interpretation with respect to sea-level changes (W.C. Pitman III and X. Golovchenko). These are, of course, not new concepts to those involved in geophysical interpretation, but they do serve to emphasise the critical nature of the shelfbreak.



USE 1, 2, OR 3– WHICHEVER REACHES FARTHEST OCEANWARD; BUT NOT FARTHER THAN EITHER 4 OR 5.

Legal definition of outer limit of "continental shelf." Reproduced with permission from paper by Ross and Emery in this book.

One might be tempted to criticise the book on its broad coverage and its partial solutions, or on what has been left out and unanswered. But, as the editors themselves admit, "knowledge of the shelfbreak remains rudimentary and it would be pretentious to assert that we have progressed much beyond a preliminary understanding of this environment." Not all the papers are of an equally high standard or interest and some appear to force the theme onto data that are not really appropriate. There is certainly more emphasis on the modern than on the ancient, but then the shelfbreak does not necessarily have a very great potential for preservation. The book, however, does provide a focus to disparate data and a starting point for the systematic multidisciplinary studies that will be needed to answer the questions that have been posed. It is interesting to see that lawyers have matched the geological complexity of the shelfbreak with their legal definition of the outer limit of the continental shelf!

Overall, this is another good volume in the SEPM Special Publication series, with the normal high standard of presentation and reasonable costs. It certainly should not be missed by geology libraries as a useful and topical research publication, and I would recommend it to individuals working in this general field.

Dorrik A.V. Stow
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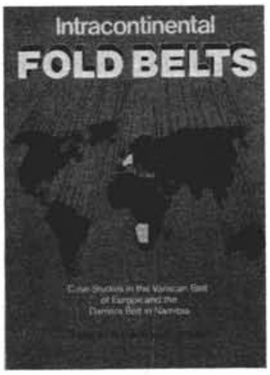
INTRACONTINENTAL FOLD BELTS: Case Studies in the Variscan Belt of Europe and the Damara Belt in Namibia

H. Martin and F.W. Eder (eds.)

Springer Verlag, Berlin, Heidelberg, New York, 1983, 945p., \$52.00 (U.S.)



This useful reference volume represents the results of a major research program carried out by a multidisciplinary group at Göttingen University, between 1969 and 1980. Under the chairmanship of Henno Martin, and with financing from the Deutsche Forschungsgemeinschaft, a group of over 40 contributors studied stratigraphy, sedimentation, structure, metamorphism, geochronology and geophysics of the Variscan belt of Europe and the Damara belts of southwestern Africa.

The choice of orogens was guided by the considerable experience of the Göttingen group in the Variscan, and by H. Martin's intimate knowledge of the Damara. The aim was also to compare a lower Palaeozoic belt with an upper Proterozoic one. Judging from the number of papers (19 on the Variscan, 21 on the Damaran) the two belts are given equal treatment. However, many papers on the Variscan concern themselves with much smaller areas and more detailed problems than those on the Damara. More emphasis is put on stratigraphy and sedimentology of the Variscan, whereas discussions of metamorphism and geochronology of the Damaran are more common. On the whole, however, the papers indicate faithfully which disciplines are progressing more rapidly in both regions, and it should not be surprising to see more emphasis placed on geochronology in a Proterozoic belt.

In discussing numerous aspects of the two belts, how successful is the book in achieving a comparison between them? Is the rather broad title of "Intracontinental Fold Belts" justified? Besides a wealth of details, a first brief general comparison by Martin and H.-J. Behr lists the similarities, differences and characteristics of both belts. Both evolved from a thinned, rifted continental crust through a subsidence phase into a compression phase. Ophiolites are missing. Tectonic nappes are more abundant than previously realized. The evolution of ideas on the Damara belt is summarized in a masterful critical review by Martin. It is regrettable that no such summary exists for the Variscan, for readers not familiar with the latter will need some time and effort to build a mental picture of its evolution.

A group of important papers discusses subfluence (A-subduction) and crustal thickening, processes that have broad applications to other intracontinental belts. There are, for instance, papers by Behr on intracrustal and sub-crustal thrust-tectonics, by P. Giese, J. Jödicke, C. Prodehl, and K. Weber on modelling crustal thickening by stacking, and by Weber and Behr on a geodynamic interpretation of the mid-European Variscides.

The volume is characterized by an abundance of new data and a minimum of "arm-waving." As it represents work by the Göttingen school, it does not pretend to be a summary of all available information or opinions. It would have been wonderful, for instance, to find here discussions of the Damaran by British, South African and Namibian geologists, who have been quite active in recent years.

The volume is generally well presented, and illustrations are uniformly good. Typographical errors are still too numerous for my taste, and on some pages imperfect printing makes P's out of B's and F's out of E's, which is rather disconcerting. Some papers lack an abstract. In view of the fact that some authors collaborated on five or more papers, bibliographical lists are quite repetitive. It would have been simpler to make one list for papers on the Variscan belt and another for the Damaran.

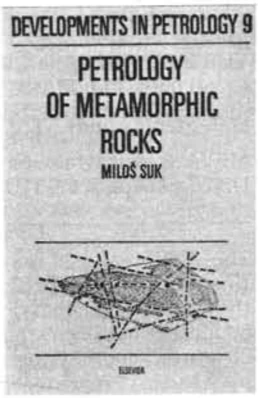
For earth scientists working in the Variscan and in the Damaran belts, this volume is a must. Others seriously interested in the "comparative anatomy" of mountain belts will find in it important contributions to this topic and abundant useful data for comparison with yet other orogenic belts.

A.J. Baer
Ottawa, Canada

PETROLOGY OF METAMORPHIC ROCKS

Milos Suk

Elsevier, Amsterdam, New York, 1983, 320p, \$68.00 (U.S.)/Dfl 160.



According to the author, his book "summarizes the opinions on the formation of metamorphic rocks and their genetic system as they have developed in Central Europe from the confrontation of classical works with the modern theories of the Soviet and American scientists." The book is of interest because it provides a summary of recent work and recent ideas from geoscientists in Czechoslovakia, as well as of relevant literature from the Soviet Union and other parts of Eastern Europe. There are 43 pages of references, of which the most recent are from 1979, although there are citations to some papers in press in 1982. References to

Soviet literature are given in English translation and in Russian.

In his introduction, Suk discusses the concepts of isograds, metamorphic zones and metamorphic facies in a fairly conventional manner. He reviews the Al_2SiO_5 polymorphs with an emphasis on the experimental and thermodynamic uncertainties, though some of his assertions, such as the stability of individual polymorphs is controlled by bulk composition, would not be supported by some Western petrologists. Suk also discusses petrogenetic grids, though without a clear statement of the source of data. The presentation of α-β transitions in SiO_2 polymorphs appear to be of little use in the construction of a petrogenetic grid.

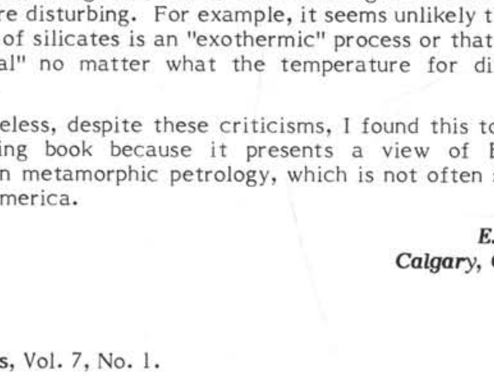
Coverage of the "conditions of metamorphism," is quite different from that in many Western textbooks. For example there is a systematic discussion of the chemistry of individual metamorphic minerals as a function of metamorphic grade and bulk composition, which is not commonly considered under the heading of conditions of metamorphism. Moreover, Suk states that minerals such as kyanite and cordierite form independent of directed pressure, yet he later states that higher density minerals form in zones affected by stress.

Suk discusses chemical changes produced by metamorphism under the headings of chemically conservative metamorphism; metasomatism, and ultrametamorphism. The treatment of the latter two topics makes little use of modern physical geochemistry.

The longest chapter in the book covers the genetic classification of metamorphic rocks based upon petrographical properties, types and grades of metamorphism, and especially on parent rocks. The discussion of mineral assemblages in different parent rocks and changes in bulk composition accompanying metamorphism covers a wide range of geological areas, but lacks a unifying thread. Of particular interest, however, is a review of the metamorphism of organic substances.

The final chapter is a 5-page summary of the role of metamorphic rocks in the evolution of the earth's crust. This section is so brief that it adds little to the book.

The list of errata that accompanies the book unfortunately covers only a fraction of the errors. There are, for example, a number of references cited that are not in the list at the end of the book, and typographic errors and spelling mistakes are far too numerous, even for a first edition. There are also



some misleading statements and downright factual errors which are disturbing. For example, it seems unlikely that the melting of silicates is an "exothermic" process or that PO_2 is "identical" no matter what the temperature for different buffers.

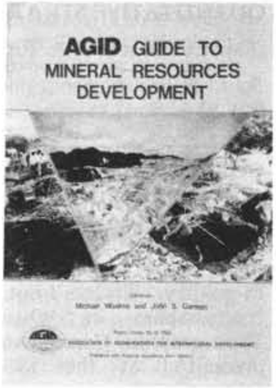
Nevertheless, despite these criticisms, I found this to be an interesting book because it presents a view of Eastern European metamorphic petrology, which is not often seen in North America.

E. Ghent
Calgary, Canada

AGID GUIDE TO MINERAL RESOURCES DEVELOPMENT

Michael Woakes and John S. Carman (eds.)

Association of Geoscientists for International Development, Bangkok, Thailand. Report 10, 504p., 1983, $25.00 (U.S.)



The need for geoscientists in developing countries to guide mineral resources development is evident, given the lack of an integrated geoscientific, engineering and administrative infrastructure, the absence of a mining tradition in many of these countries, and the fast turnover of qualified personnel.

This book is a valuable reference work aimed at such countries. It contains readily applicable information on technical aspects of mineral exploration, remote sensing from space, airborne and ground geophysical methods, geochemistry, sampling techniques, and other practical topics. Managerial and technical facets of small-scale mining and processing are discussed in depth, as are placer mining, open-pit and underground mining, and heap leaching for gold. Requirements for capital and manpower are also reviewed.

Most of the contributions were apparently written in the second half of the 1970s, but prices for exploration services, capital and exploration costs have been updated to 1982. From a technical point of view, this guide is rather complete. It deals with raw materials such as stone for building construction, laterite, ores and mineral resources for fertilizers and soil enrichment. Unfortunately the treatment of subjects that have undergone the most dynamic development of late, such as remote sensing and mining and investment codes, is somewhat out of date. Mention should also be made of the poor binding of a volume that is supposed to be a travelling companion for the earth scientist.

Managerial aspects of mineral resources development that are touched upon include the structure of geological surveys, data acquisition and retrieval, and policy matters, such as mine evaluation, pricing and marketing. Arrangements for training of manpower for small mines are suggested, drawing on the experience of a training institution in a developed country. Unfortunately, traditional earth-science training at the university level in developing countries is not covered, and such problems as the staffing of these institutions with explorationists and experts in mining and beneficiation are left aside.

The editors intended the book to be used, among others, by policy makers in the developing countries. These are rarely geoscientists, and it would have been useful to have included a discussion of the integration of the educational, scientific, technical, legal and financial aspects with the local and global economic and political forces that are the final determinants for development. The need to address policy makers is clear, because mineral production in these countries during the last two decades has been unsatisfactory, despite the considerable efforts made by geoscience institutions, strengthened by international and bilateral assistance, to provide the basic technical ingredients for mineral resources development.

I recommmend this book as a unique source of information for those directly involved with mineral resources of developing countries. It will, undoubtedly, prove very useful as well to policy makers at the national and provincial level in industrialized countries.

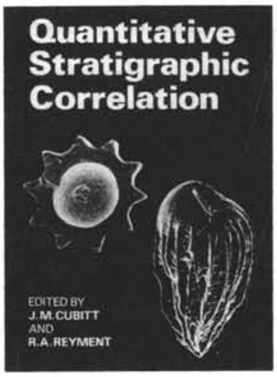
E.H. Dahlberg
St. Paul, Minnesota, U.S.A.

Book Reviews ...

QUANTITATIVE STRATIGRAPHIC CORRELATION

J.M. Cubitt and R.A. Reyment, (eds.)

John Wiley & Sons, Inc., New York, U.S.A., 1982, 298p., $54.95 U.S.



Geological literature is cluttered with book-length symposium volumes that are more often than not a mixed-bag of papers lacking coherence and varying widely in quality. While all but a few of the papers in "Quantitative Stratigraphic Correlation" were presented at the 1980 IGCP Project 148 symposium in Paris, the volume is an exception to the rule on both counts.

The short first part of the book on formalized stratigraphy and correlation includes a brief argument by B.R. Shaw for restricting the definition of "correlation" to relations between formal stratigraphic units, thus relegating event stratigraphy to mere "matching." This is followed by a paper by R. Carimati, A. Marini and R.G. Potenza, which provides a mathematical (set-theory) analysis of relations among stratigraphic units, and one by I. Dienes presentating his approach to formalized stratigraphy. The third part of the book, on lithostratigraphy is also very short, containing only an account by W. Schwarzacher of a time-periodic model used to describe sedimentation of a limestone-shale series and one by C.M. Griffiths of a segmentation algorithm for borehole data.

High quality papers on biostratigraphy (part two) make up most of the volume and cover, with very little overlap, a wide variety of quantitative and other new innovative approaches. A reader new to the field would do well to start with the short introduction to quantitative biostratigraphy by L.E. Edwards, though I differ with her on some points. For instance, I do not believe that probabilistic approaches to correlation attempt (or should attempt) to "discover the peaks on the probability curves." Like other methods discussed in the volume, probabilistic approaches are designed to work out the succession of first and last occurrences in time. Further, ranking probabilistic methods requires the assumption of spatial homogeneity only as part of a null hypothesis or an estimate of a confidence limit. Nonetheless, her paper provides a nice introduction to topics covered in the book.

Various contributions describe important new approaches to the use of fossils in time correlation, including paired-comparison ranking methods (also called probabilistic methods) pioneered by W.W. Hay, and scaling methods, which attempt to resolve the temporal distance between events as well as their rank order (F.M. Gradstein and F.P. Agterberg). A paper by E. Davaud deals with the identification of unitary associations (cliques of species), which succeed one another in time with no overlap. Other important methods are presented in the contribution by J.C. Brower and W.A. Burroughs on seriation of fossil samples as a way to estimate their relative ages (a technique very popular amongst archaeologists). M.E. Hohn describes the use of principal components to develop composite standards, and briefly covers the use of multivariate statistics to delineate assemblage zones. S.A. and M.T. Millendorf deal with the lateral tracing of biostratigraphic units.

Other papers on biostratigraphy cover a variety of topics, such as the use of correspondence analysis in inferring the depositional environments of biotic associations (I. Cojan and H. Bremner-Teil), modeling the relationship between two variables that have been measured at various depths down a stratigraphic column (A.D. Gordon); the relationship of changes in the abundance of planktonic foraminifera species to climatic fluctuations (B.K. Ghose), and correlations between boreholes using log data and morphologic variations of foraminifera species (R. Reyment).

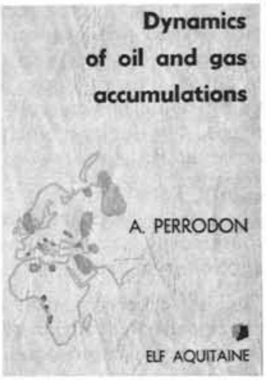
I recommend buying the book, for it provides a nice introduction to the important and rapidly expanding field of quantitative and non-standard approaches to correlation, and especially to the use of fossils in time correlation. Only in-depth treatments of the Shaw method of defining a composite standard, of tests of significance and confidence intervals and of measures of reliability are lacking.

C.W. Harper, Jr,
Norman, Oklahoma

DYNAMICS OF OIL AND GAS ACCUMULATIONS

Alain Perrodon

Elf-Aquitaine Memoir 5, France, 1983, 368p., 220 Figs., 5 Tables, 4 Plates, 240FF.



With rare exceptions, those magnificent petroleum geology courses taught by major oil companies are not made available to the public. Alain Perrodon's manual-style text on the dynamics of oil and gas accumulations is therefore both unusual and extremely welcome. Perrodon was formerly head of Elf-Aquitaine's Geology Division, and this book bears the stamp of a company introductory course aimed at newly hired earth scientists.

The author has distilled material from several earlier manuscripts, and compiled an overview that is thorough, scientific, scholarly and perceptive. The French text has been translated sensitively without sacrificing Perrodon's style or burying the European philosophy and history of enquiry that have spawned many of the approaches described here. Terms like "intumescence" remain, reminding us that sounds and processes can be combined less aridly than by the descriptive term "diapiric uplift." The illustrations are clear and have English captions. Text errors are few and metric units are used throughout.

All the major targets are hit and woven into a text that logically explores the exciting intellectual adventure of hydrocarbon exploration. To Perrodon, sedimentary basins are "crucibles in which hydrocarbons are produced from organic matter," and he begins by analyzing the various types of basins, their evolution and the thermo-chemical consequences of burial within them. This section is followed by a discussion of the nature of hydrocarbons, their diagenesis and their primary migration.

Once the hydrocarbons have graduated as oil and gas and are upwardly mobile, Perrodon turns his attention to the positions where they may come to rest. Common types of reservoirs and seals are described, followed by the opportunities for relocation provided by secondary migration, alteration and seepage prior to final entrapment. Since this is the exploration target, trap and pool geometries are described at length, using examples from all over the world. Perrodon then discusses the types of geological conspiracies required to create "petroleum provinces."

In the latter part of the book we are led through all the oil-rich basins of the world in a 73 page chapter humbly entitled "The Main Petroleum Provinces." To my knowledge, this is the most complete compilation of its kind in print, and an invaluable introduction for explorationists. The final apéritif contains some general thoughts on petroleum exploration, including the sad perceptions that exploration success is progressively declining and that, after an initial flurry of discoveries in a basin, the exploration yield generally decreases with increasing effort.

Clearly, Perrodon has hit all the targets, although, since his book is an introductory overview, he has obviously not scored top marks everywhere. The section on organic geochemistry could be updated, especially with respect to source rock deposition. Thermal controls of hydrocarbon generation and basin modelling also deserve more comprehensive discussion. One could add other items, such as modern reservoir analysis, but many of these areas are doubtless well covered in other Elf-Aquitaine course manuals, which one hopes may also be made available before too long. This text is the overture; the complete opera has several acts. Alain Perrodon's book is a composition that should not be ignored.

J.S. Bell
Dartmouth, Canada

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EFFECTIVE USE OF EARTHQUAKE DATA. U.S. National Academy Press, 1983, 51p., (P) price not listed. **(11)**

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Pond, Stephen and Pickard, George L. **INTRODUCTORY DYNAMICAL OCEANOGRAPHY,** 2nd ed. Pergamon Press, 1983, 329p. $12.50/ 6.95. **(7)**

Procter, R.M., Taylor, G.C. and Wade, J.A. **OIL AND NATURAL GAS RESOURCES OF CANADA 1983.** Geological Survey of Canada Paper 83-31, 1983, 59p., $4 (Canada); $4.80 (elsewhere). Available from the Canadian Government Publishing Centre, Supply and Services Canada, Ottawa, Canada K1A 0S9.

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PROCEEDINGS OF SYMPOSIA

Bhandari, L.L. et al. (eds.) **PETROLIFEROUS BASINS OF INDIA,** in Petroleum Asia Journal. Co-sponsored by IUGS. K.D. Malaviya Institute of Petroleum Exploration, 1983, 189p., $50/Rs. 200. Available from Petroleum Asia Journal, Himachal Times Building 57-B, Rajpur Road, Dehra Dun, U.P. India.

Evenson, Edward B., Schlüchter, Ch., and Rabassa, Jorge (eds.) **TILLS AND RELATED DEPOSITS.** Proceedings of INQUA Symposia held 1981, U.S.A. and 1982, Argentina. Balkema, 1983, 464p., $45/ 27. **(3)**

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Lehman, John P. (ed.) **HAZARDOUS WASTE DISPOSAL.** Proceedings of a Symposium held October 1981, Washington, D.C. Plenum, 1983, 396p., $49.50. **(8)**

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Popoff, Michel and Tiercelin, Jean-Jacques (eds.) **ANCIENT RIFTS AND TROUGHS.** Proceedings of a Symposium held 1982, Marseilles. Bulletin of Exploration and Production Research, Elf-Aquitaine Petroleum Company, 1983, v.7, no.1, 448p., $25 (volume); $15 (abstracts). In French with English abstracts. Available from Michel Popoff, Laboratoire de Géologie Dynamique, Faculté des Sciences et Techniques de Saint-Jérome, F-13397 Marseille 13, France.

REGIONAL WORKSHOP ON THE GEO-SCIENCE EDUCATIONAL INSTITUTES IN NATIONAL RESOURCES DEVELOPMENT IN AFRICA. Proceedings of CIFEG, AGID, Unesco Workshop held December 1982, Nairobi, Kenya. CIFEG, 1983, 59p., price not listed. Available from CIFEG, 103 rue de Lille, 75007 Paris, France.

STRUCTURE AND DYNAMICS OF TRANSITION ZONES. Abstracts of International Symposium held December 1983, Sochi, U.S.S.R. Moscow, 1983, 238p. Available on a book-exchange basis from the Soviet Geophysical Committee. In Russian and English. **(9)**

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ATLAS OF AUSTRALIAN RESOURCES, 3 maps: (1) Coal resources 1981; (2) Energy resources 1981; (3) Surface rock types. Division of National Mapping, 1982, scale: 1:10 000 000, prices not listed. Available from Map Sales, Box 31, Belconnen, A.C.T. 2616, Australia.

CLIMATOLOGICAL ATLAS OF THE WORLD OCEAN. NOAA Professional Paper 13, $11. Available from Superintendent of Documents, U.S. Government Printing Office, Washington, DC 20402, U.S.A.

GEOLOGICAL MAP OF SWAZILAND. Directorate of Overseas Surveys (Great Britain), 1982, scale: 1:250 000, price not listed. Available from Geological Survey and Mines Department, Box 9, Mbabane, Swaziland; or E. Stanford Ltd., 12/14 Long Acre, London WC2E 9LP, U.K.

Ishihara, Takemi. **FREE AIR GRAVITY ANOMALY MAP OF THE CENTRAL PACIFIC.** Marine Geology Map Series 19. Geological Survey of Japan, 1982, scale: 1:2 000 000, price not listed. Available from Geological Survey of Japan, 1-3 Higashi 1-chome, Yatabe-machi, Tsukuba-gun, Ibaraki-ken, 305 Japan.

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May 6 - 8, 1984
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May 7 - 11, 1984
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May 8 - 10, 1984
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GEOLOGICAL ASSOCIATION OF CANADA, MINERALOGICAL ASSOCIATION OF CANADA (Joint Annual Meeting), London, Ontario, Canada. (N.D. MacRae, Department of Geology, University of Western Ontario, London, Ont., Canada N6A 5B7)

May 14 - 17, 1984
DRAINAGE BASIN EROSION AND SEDIMENTATION (Conference), University of Newcastle, N.S.W. Australia. Sponsored by IAHS. (Dr. R.J. Loughran, Department of Geography, University of Newcastle, N.S.W. 2308, Australia)

May 14 - 18, 1984
AMERICAN GEOPHYSICAL UNION (Spring Meeting), Cincinnati, Ohio, U.S.A. (Meetings, AGU, 2000 Florida Avenue NW, Washington, DC 20009, U.S.A.)

May 14 - 18, 1984
GEOMECHANICS (4th Australia-New Zealand Conference), Perth, Western Australia. (The Conference Manager, 4th A.N.Z. Geomechanics Conference, The Institution of Engineers, Australia, 11 National Circuit, Barton, ACT 2600, Australia)

May 15 - 19, 1984
THRUSTING AND DEFORMATION (International Conference), Toulouse, France. Field trips. Languages: English and French. (J. Deramond, Laboratoire de géologie-pétrologie, Université Paul Sabatier, 38 rue des 36 Ponts, 31078 Toulouse Cédex, France)

May 17 - 18, 1984
PROSPECTING IN AREAS OF GLACIATED TERRAIN, Glasgow, Scotland. (Conference Office, IMM, 44 Portland Place, London W1N 4BR, U.K.)

May 20 - 23, 1984
AAPG and SEPM (Joint Annual Meeting), San Antonio, Texas, U.S.A. (AAPG, Box 979, Tulsa, OK 74101, U.S.A.)

May 20 - 23, 1984
INDUSTRIAL MINERALS (6th International Congress), Toronto, Canada. (B.M. Coope - Editor, Industrial Minerals, 45/46 Lower Marsh, London SE1, U.K.)

May 20 - 25, 1984
▲ **OBSERVATION OF THE CONTINENTAL CRUST THROUGH DRILLING** (International Symposium), Tarrytown, N.Y., U.S.A. Co-sponsored by ICL. (Margaret Swan, Lamont-Doherty Geological Observatory, Palisades, NY 10964, U.S.A.)

May 21 - 23, 1984
▲ **AGGREGATES** (International Symposium), Nice, France. Sponsored by IAEG. Languages: English and French. (M. Louis Primel, LCPC, 58 boulevard Lefébvre, 75732 Paris Cedex 15, France)

May 21 - 23, 1984
CLIMATE: PRESENT, PAST, AND FUTURE (Symposium), New York, N.Y., U.S.A. Sponsored by Columbia University in honour of Rhodes W. Fairbridge. (John E. Sanders, Department of Geology, Columbia University, 606 West 120th Street, New York, NY 10027, U.S.A.)

May 21 - 23, 1984
▲ **GROUNDWATER RESOURCE UTILIZATION AND CONTAMINANT HYDROGEOLOGY** (International Symposium), Montreal, Quebec, Canada. Sponsored by Canadian National Chapter of IAH and CWWA. Languages: English and French. (Mr. H. Sommelet, Geomines Ltd., 1010 Sherbrooke St. W., Suite 2202, Montreal, Quebec, Canada H3A 2R7)

May 28 - June 2, 1984
IRRIGATION AND DRAINAGE (International Congress), Fort Collins, Colorado, U.S.A. (U.S. Committee on Irrigation, Drainage & Flood Control, P.O. Box 15326, Denver, CO 80215, U.S.A.)

May 30 - June 3, 1984
● **THE RHENISH MASSIF** (International Workshop-Meeting), Boppard/Rhein, Germany. Language: English. (Dr. Reinhard Greiling, Inst. für Geowissenschaften, Johannes Gutenberg Universität, Saarstrasse 21, D-6500 Mainz 1, F.R.G)

June 3 - 7, 1984
● **TUNNELLING 84** (Symposium) Caracas, Venezuela. (Secretario General, ITA Tuneles 1984, Apdo 68265, Caracas 1062 A, Venezuela)

June 4 - 6, 1984
MATHEMATICAL MODELLING OF SEDIMENT TRANSPORT AND MORPHOLOGY (Euromech Colloquium), The Netherlands. (Prof. H.H. Fernholz, Hermann-Föttinger-Institut für Thermo- u Fluiddynamik, Technische Universität Berlin, Strasse des 17 Juni 135, D-1000 Berlin 12, F.R.G.)

June 4 - 6, 1984
▲ **PALAEOCLIMATOLOGY OF LAKES, RIVERS AND GLACIERS** (International Symposium), Innsbruck, Austria. Co-sponsored by ICCL and INQUA. (Prof. M. Kuhn, Institute for Meteorology and Geophysics, Schopfstrasse 41, A-6020 Innsbruck, Austria)

June 4 - 7 , 1984
SOIL MECHANICS AND FOUNDATION ENGINEERING (8th African Regional Conference), Harare, Zimbabwe. (ARC-8, P.O. Box MP 155, Mount Pleasant, Harare, Zimbabwe)

June 4 - 8, 1984
● **DEEP SEA CLASTIC SEDIMENTATION** (Short course and Field Trips) French Maritime Alps. (Ph. Riché ENSPM, Institut Français du Pétrole, 4 Ave. de Bois-Preau, 92506-Rueil Malmaison, France)

June 4 - 10, 1984
● **READING PROVENANCE FROM ARENITES** (NATO Institute), Rende (Cosenza), Italy. (G.G. Zuffa, Dip. Scienze della Terra, Univ. Calabria, 87030 Castiglione Cosentino, Stazione Cosenza, Italy)

June 5 - 11, 1984
GEOLOGY OF THE HIMALAYAS (International) Symposium), Chengdu City, Sichuan Province, P.R. China. Languages: Chinese, English, French. Excursions. (Li Tingdong, Secretary-General, Organizing Committee, International Symposium on Geology of the Himalayas, c/o Chinese Academy of Geological Sciences, Baiwanzhuang Road 26, Fuchengmenwai, Beijing, People's Republic of China)

June 6 - 9, 1984
COORDINATION IN FLOOD CONTROL (INTERPRAEVENT 1984), Villach, Austria. (Interpraevent 1984, Postfach 134, A-9501, Villach, Austria)

June 10 - 14, 1984
PRECIOUS METAL RECOVERY (International Symposium), Reno, Nevada, U.S.A. Post-symposium tour. (International Symposia for Mining, 500 Howard Street, San Francisco, CA 94105, U.S.A.)

June 11 - 12, 1984
ENVIRONMENTAL POLLUTION (5th European Conference), Amsterdam, The Netherlands. (Dr. V.M. Bhatnager, Box 1779, Cornwall, Ontario, Canada K6H 5V7)

June 15 - 17, 1984
SEDIMENTOLOGY OF SHELF SANDS AND SANDSTONES (Research Symposium), Calgary, Canada. (R. John Knight, Petro-Canada, P.O. Box 2844, Calgary, Alberta, Canada T2P 3E3)

June 18 - 23, 1984
7th INTERNATIONAL PEAT CONGRESS, Dublin, Ireland. Study tours and post-congress tours. (International Peat Congress, c/o Bord na Mona, Lower Baggot Street, Dublin 2, Ireland)

June 19 - 22, 1984
● **EUROPEAN ASSOCIATION OF EXPLORATION GEOPHYSICISTS** (46th Meeting), London. (Conference Co-Ordinates, 70 Richmond Road, Twickenham, Middlesex, TW1 3BE, U.K.)

June 20 - 23, 1984
GEOMEMBRANES (International Conference), Denver, Colorado, U.S.A. Precedes the Impermeable Barriers for Soil and Rock Symposium. (A. Ivan Johnson, Woodward-Clyde Consultants, P.O. Box 4036, Denver, CO 20204, U.S.A.)

June 23 - 26, 1984
PRACTICAL APPLICATIONS OF GROUNDWATER GEOCHEMISTRY (Workshop), Banff, Alberta, Canada. (Dr. E.I. Wallick, Alberta Research Council, 5th Floor Terrace Plaza, 4445 Calgary Trail South, Edmonton, Alberta, Canada T6H 5R7)

June 23 - 30, 1984
MELANGES OF THE APPALACHIAN OROGEN (Penrose Conference), Stephenville, Newfoundland. (H. Williams, Department of Earth Sciences, Memorial University, St. Johns, Newfoundland, Canada A1B 3X5)

Coming Events ...

June 24, 1984
IMPERMEABLE BARRIERS FOR SOIL AND ROCK (International Symposium), Denver, Colorado, U.S.A. (P.B. Whiteaker, American Society for Testing and Materials, 1916 Race Street, Philadelphia, PA 19103, U.S.A.)

June 24 - 27, 1984
CODATA (9th International Conference), Jerusalem, Israel. (The Secretariat, 9th International CODATA Conference, 122 Hayarkon Street, P.O. Box 3054, 61030 Tel Aviv, Israel)

June 24 - 30, 1984
MATHEMATICAL GEOPHYSICS (14th International Conference), Loen, Norway. (Dr. Durk Doornbos, NTNF/NORSAR, P.O. Box 51, N-2007 Kjeller, Norway; or Dr. Frank Richter, University of Chicago, Chicago, IL 60637, U.S.A.)

June 25 - 29, 1984
• **THE CHEMISTRY OF WEATHERING** (NATO Workshop), Bonas, France. (J.I. Drever, Geology Dept., Univ. of Wyoming, Laramie, WY 82071, U.S.A.)

June 25 - July 7, 1984
▲ **COSPAR** (25th Meeting), Graz, Austria. Symposia and Workshops co-sponsored by IUGS include: Planetology of Venus, Mars, and satellites of Outer Planets; and satellite remote sensing of interest to developing countries. Also includes symposium on space observations for climate studies. (COSPAR Secretariat, 51 Boulevard de Montmorency, 75016 Paris, France)

June 26 - 28, 1984
DEEP STRUCTURE OF THE CONTINENTAL CRUST (International Symposium), Ithaca, N.Y., U.S.A. (Muawia Barazangi, Department of Geological Sciences, Cornell University, Ithaca, NY 14853, U.S.A.)

June 27 - 29, 1984
• **CANNING BASIN** (Symposium), Perth, Western Australia. (Phil Connard, Shell Development Pty. Ltd., G.P.O. Box W2050, Perth WA 6001, Australia)

July 1984
VOLCANIC SOILS (International Panel), Tenerife, Canary Islands. (M.E. Fernandez Caldas, Dpto. de Edafologia, Univ. de la Laguna, Tenerife, Islas Canarias, Spain)

July 1984
EROSION AND DESERTIFICATION IN AFRICA (International Workshop), Nigeria. (E.O. Oladipo, Dept. Geography, Ahmadu Bello University, Zarie, Nigeria)

July 1984
RADIOLARISTES (4th Meeting, Eurorad), Leningrad, U.S.S.R. (P. de Wever, Université des Sciences de Lille, Eurorad, U.E.R. Sciences de la Terre, 59655 Villeneuve - d'Ascq, Cedex, France)

July 3 - 5, 1984
•▲ **PALEOHYDROLOGICAL CHANGES IN THE TEMPERATE ZONE IN THE LAST 15000 YEARS** (Annual Meeting IGCP 158b), Marseille, France. Co-convened by Euro-Siberian Sub-commission of INQUA-Holocene Commission. (Dr. J.-L. de Beaulieu, Université des Sciences et Techiques de Marseille St. Jérôme, Labo de Botanique, F-13397 Marseille Cedex 13, France)

July 9 - 12, 1984
GROUND MOVEMENTS AND STRUCTURES (3rd International Conference), Cardiff, Wales, U.K. (The Conference Secretary, Department of Civil Engineering and Building Technology, UWIST, Colum Drive, Cardiff CF1 3EU, South Glamorgan, Wales, U.K.)

July 9 - 13, 1984
• **SPACE TECTONICS FOR GEODYNAMICS** (International Symposium), Sopron, Hungary. Cosponsored in part by IAG. (Ch. Reigber, Deutsches Geodätisches Forschungsinstitut, Abt. I, Marstallplatz 8, D-8000 Munich 22, F.R.G.)

July 15 - 18, 1984
FOSSIL FUELS OF EUROPE (AAPG International Conference), Geneva, Switzerland. (AAPG Convention Department, P.O. Box 979, Tulsa, OK 74101, U.S.A.)

July 16 - 30, 1984
• **THE DEEP PROTEROZOIC CRUST IN THE NORTH ATLANTIC PROVINCES** (NATO Institute), Moi, Norway. (J. Touret, Inst. Aardwetenschappen, Vrije Univ., Postbus 7161, 1007 MC Amsterdam, Holland)

July 16 - 18, 1984
MIDDLE TO LATE PROTEROZOIC LITHOSPHERE EVOLUTION (International Conference), Cape Town, South Africa. (Secretary, Precambrian Research Unit, University of Cape Town, Rondebosch 7700, South Africa)

July 21 - 28, 1984
EARTHQUAKE ENGINEERING (8th World Conference), San Francisco, Calif., U.S.A. (R.B. Matthisen, Chairman - 8WCEE, Earthquake Engineering Research Institute, 2620 Telegraph Ave., Berkeley, CA 94704, U.S.A.)

July 23 - 26, 1984
• **URBAN HYDROLOGY** (11th International Symposium), Lexington, Kentucky, U.S.A. (E. Haden, Office of Continuing Education/Engineering, 223 Transportation Research Building, University of Kentucky, Lexington, KY 40506-0043, U.S.A.)

July 23 - 27, 1984
▲ **CHALLENGES IN AFRICAN HYDROLOGY AND WATER RESOURCES** (International Symposium), Harare, Zimbabwe. Sponsored by IAH, IAHS, Unesco. Post-symposium tour. Languages: English and French. (Dr. J.C. Rodda, Institute of Hydrology, Wallingford, Oxon., X10 8BB, U.K.)

July 24 - 26, 1984
ROCK-OLYMPIC USA (International Symposium, rock engineering), Las Vegas, Nevada, U.S.A. (Dr. Yung Sam Kim, Nevada Institute of Technology, P.O. Box 8894, Campus Station, Reno, NV 89507, U.S.A.)

July 29 - August 4, 1984
EUROGEOPHYSICS (10th Assembly), Louvain-la-Neuve, Belgium. Sponsored by European Geophysical Society. (Prof. A. Berger, Institut d'Astronomie et de Geophysique, B-1348 Louvain-la-Neuve, Belgium)

July 31 - August 1984
• **FISSON TRACK DATING** (Workshop), Troy, New York, U.S.A. (Donald S. Miller, Department of Geology, Rensselar Polytechnic Institute, Troy, NY 12181)

August 1984
MAPPING OF THE SOIL-WATER BALANCE (Meeting), Budapest, Hungary. (Dr. W.G. Sombroek, ISSS, International Soil Museum, 9 Duivendaal, POB 353, 6700 A.J. Wageningen, The Netherlands)

August 4 - 14, 1984
▲ **27th INTERNATIONAL GEOLOGICAL CONGRESS**, Moscow, U.S.S.R. (N.A. Bogdanov, Secretary General, 27th IGC, Staromonetny per. 22, Moscow 109180, U.S.S.R.) See detailed list below.

August 6 - 8, 1984
STABILITY IN UNDERGROUND MINING (2nd International Conference), Lexington, Kentucky, U.S.A. (Department of Mining Engineering, University of Kentucky, Lexington, KY 40506, U.S.A.)

August 6 - 9, 1984
• **FINE-GRAINED SEDIMENT: ORIGINS, TRANSPORT AND DISTRIBUTION** (SEPM Research Conference), San Jose, California. (D.S. Gorsline, Dept. Geological Sciences, University of Southern California, Los Angeles, CA 90089-0741, U.S.A.)

August 9 - 18, 1984
CRYSTALLOGRAPHY (13th General Assembly), Hamburg, F.R.G. (E.E. Snider, American Crystallographic Association, 335 East 45th Street, New York, NY 10017, U.S.A.)

August 10 - 14, 1984
AUSTRALASIAN INSTITUTE OF MINING AND METALLURGY (Annual Conference), Darwin, Northern Territories, Australia. (A.P. Bravo, Aus. IMM Darwin Branch, P.O. Box 1510, Darwin, NT 5794, Australia)

August 13 - 17, 1984
• **CHEMICAL OCEANOGRAPHY** (Gordon Research Conference), Meriden, New Hampshire. (A.M. Cruickshank, Pastore Chemical Laboratory, Univ. of Rhode Island, Kingston, RI 02281, U.S.A.)

August 18 - 24, 1984
INTERNATIONAL PALEOBOTANICAL CONFERENCE, Edmonton, Alberta, Canada. Sponsored by the International Organization of Paleobotany, to take place before the 6th International Palynological Conference. Field excursions. (Dr. Ruth A. Stockey, Dept. of Botany, The University of Alberta, Edmonton, Alberta, Canada T6G 2E9)

August 18 - 28, 1984
•▲ **RELATIONSHIP BETWEEN GLACIAL TERRAIN AND GLACIAL SEDIMENT FACIES** (Annual Meeting INQUA Commission on Genesis and Lithology of Quaternary Deposits), Lethbridge, Alberta, Canada. (Dr. Mark M. Fenton, Alberta Geological Survey, 4445 Calgary Trail South, Edmonton, Canada T6G 5R7)

August 19 - September 2, 1984
• **FIELD SYMPOSIUM ON THE CALEDONIDES OF THE BRITISH ISLES** (NATO Institute), U.K. (A.L. Harris, Dept. of Geology, University of Liverpool, Box 147, Liverpool, L69 3BX, U.K.)

August 20 - 24, 1984
• **ORGANIC GEOCHEMISTRY** (Gordon Research Conference), Plymouth, New Hampshire, (R.H. Reitsma, Marathon Oil Co., Box 269, Littleton, CO 80160, U.S.A.)

August 20 - 24, 1984
• **ORIGIN OF LIFE** (Gordon Research Conference), New London, N.H., (A.M. Cruickshank, Pastore Chemical Laboratory, Univ. of Rhode Island, Kingston, RI 02281, U.S.A.))

August 24 - 30, 1984
▲ **6TH INTERNATIONAL PALYNOLOGICAL CONFERENCE**, Calgary, Alberta, Canada. Sponsored by ICP, CSPG, the University of Calgary, and Arctic Institute. Pre- and post-conference excursions. (L. Kokoski, Conference Office, Faculty of Continuing Education, Education Tower Room 102, Calgary, Alberta, Canada T2N 1N4)

August 26 - 31, 1984
▲ **THE ROLE OF AUSTRALIA IN STRENGTHENING THE GEOSCIENCES IN DEVELOPING COUNTRIES** (Seminar), Canberra, Australia. Sponsored by AGID and ILP. (M.B. Katz, School of Applied Geology, University of New South Wales, Box 1, Kensington, N.S.W. 2033, Australia)

August 26 - 31, 1984
GEOLOGICAL CONVENTION AND GEOSCIENTIFIC EXHIBITION (7th Australian), North Ryde, NSW. (Secretary 7AGC, P.O. Box 383, North Ryde, NSW 2113, Australia)

August 27 - 31, 1984
• **SYMPOSIUM ON ICE** (7th IAHR), Hamburg, F.R.G. (J. Schwarz, Ice Engineering Div., Hamburgische Schiffbau-Versuchanstalt GmbH., P.O. Box 600 929, 2000 Hamburg, F.R.G.)

August 27 - 31, 1984
25TH INTERNATIONAL GEOGRAPHICAL CONGRESS (and Meeting of the 16th General Assembly of the International Geographical Union), Paris, France. Languages: French, English, German, and Italian. (Comité d'Organisation du Congrès International de Géographie, 19 rue Isidore-Pierre, 14000 Caen, France)

August 27 - 31, 1984
WATER MOVEMENT IN HEAVY CLAY SOILS (In-

ternational Symposium), Wageningen, Netherlands. (Dr. W.G. Sombroek, ISSS, International Soil Museum, 9 Duivendaal, POB 353, 6700 A.J. Wageningen, The Netherlands)

August 28 - 31, 1984
WATER AND WASTE ENGINEERING FOR DEVELOPING COUNTRIES. (Conference), Singapore. (John Pickford, WEDC Group Leader, University of Technology, Loughborough, Leics. LEII 3TU, U.K.)

September 1984
• **MINING TECHNIQUES FOR ALLUVIAL TIN DEPOSITS** (International Seminar), Ipoh, Malaysia. (The Director, SEATRAD Centre, Tiger Lane, Ipoh, Malaysia)

September 1984
▲ **TYRRHENIAN OF ALGERIA** (International Field Meeting), Algeria. Organised by INQUA. (Centre de Recherches Anthropologiques, Préhistoriques et Ethonographiques (CRAPE), Institut des Sciences Humaines, Le Bardo, 3, rue Franklin D. Roosevelt, Alger, Algeria)

September 1984
▲ **INTERGLACIAL MARINE DEPOSITS, PAST AND PRESENT** (Symposium), Schleswig-Holstein, F.R.G. Sponsored by INQUA. (Dr. H. Streiff, Niedersächs, Landesamt für Bodenforschung, Postfach 51 01 52, D-3000 Hannover 51, F.R.G.)

September 2 - 7, 1984
SNOW AND ICE PROCESSES AT THE EARTH'S SURFACE (Symposium), Sapporo, Japan. (Mrs. H. Richardson, Secretary General, International Glaciological Society, Lensfield Road, Cambridge CB2 1ER, U.K.)

September 3 - 5, 1984
• **DYNAMIC SOIL STRUCTURE INTERACTION** (International Symposium), Minneapolis, U.S.A. (International Symposium on Dynamic Soil-Structure Interaction, Department of Civil and Mineral Engineering, 500 Pillsbury Drive SE, University of Minnesota, Minneapolis, MN 55455, U.S.A.)

September 3 - 6, 1984
•▲ **JURASSIC STRATIGRAPHY** (IUGS Subcommission International Symposium), Erlangen, F.R.G. (Prof. Dr. A. Zeiss, Paläontol. Inst. Univ. Loewenichstrasse 28, D-8520 Erlangen, F.R.G.)

September 3 - 6, 1984
DESIGN AND PERFORMANCE OF UNDERGROUND EXCAVATIONS (International Symposium), London, U.K. (Miss Y. Brooks, ISRM 1984 Symposium Conference Office, Institution of Civil Engineers, Great George Street, Westminster, London SW1 3AA, U.K.)

September 3 - 8, 1984
▲ **EVOLUTION OF THE CALEDONIAN-APPALACHIAN OROGEN** (Final Symposium of IGCP Project 27), Glasgow, Scotland. (A.L. Harris, The University of Liverpool, Jane Herdman Laboratories of Geology, Brownlow Street, P.O. Box 147, Liverpool L69 3BX, U.K.)

September 6 - 9, 1984
•▲ **MEDITERRANEAN NEOGENE, MARINE MEGAFAUNAL PALAEOENVIRONMENTS, AND BIOSTRATIGRAPHY** (Interim Colloquium, RCMN), Athens, Greece. (Prof. E. Georgiades-Dikeoulia, Laboratory of Stratigraphy and Palaeontology, Athens University, Panepistimiopolis, Post Office Zografou, Athens 15701, Greece)

September 6 - 11, 1984
MESOZOIC TERRESTRIAL ECOSYSTEMS (Symposium), Stuttgart - Tübingen, F.R.G. Language: English. (Dr. Frank Westphal, Institut und Museum fur Geologie und Paläontologie, Sigwartstrasse 10, D-7400 Tübingen 1, F.R.G.)

September 8 - 13, 1984
▲ **EUROPEAN ASSOCIATION OF SCIENCE EDITORS** and **COUNCIL OF BIOLOGY EDITORS** (Conference), Cambridge, U.K. (EASE Secretary/Treasurer, Nancy Morris, P.O. Box 33, Farnham, Surrey GU10 3JX, U.K.)

September 10 - 12, 1984
• **OCEANS 84** (Conference), Washington, D.C. (Oceans 84 Technical Program Committee, 1730 M St. NW, Suite 412, Washington, D.C. 20036, U.S.A.)

September 10 - 14, 1984
TITANIUM (5th International Conference), Munich, F.R.G. (Deutsche Gesellschaft fur Metallkunde EV, Adenauerallee 21, D-6370 Oberursel 1, F.R.G.)

September 11 - 12, 1984
HABITAT OF PALAEOZOIC GAS IN NW EUROPE (Meeting), London, U.K. Geological Society-Petroleum Group. (Geological Society, Burlington House, Piccadilly, London W1V OJU, U.K.)

September 11 - 15, 1984
• **GEOLOGY OF BOLIVIA** (2nd Congress), Cochabamba, Bolivia. Language: Spanish. (Secretary General, II Geological Congress of Bolivia, Casilla 183, Cochabamba, Bolivia)

September 12 - 14, 1984
• **DEGRADATION, RETENTION, AND DISPERSION OF POLLUTANTS IN GROUNDWATER** (Seminar), Copenhagen, Denmark. (Erik Arvin, Department of Environmental Engineering, Building 115C, Technical University of Denmark, DK-2800 Lyngby, Denmark)

September 12 - 14, 1984
• **ALKALINE IGNEOUS ROCKS** (Geological Society of London Symposium), Edinburgh, Scotland. (J.G. Fitton, Grant Institute of Geology, West Mains Road, Edinburgh EH9 3JW, Scotland, U.K.)

September 13 - 19, 1984
•▲ **DYNAMICAL AND CHRONOLOGICAL RELATIONS BETWEEN GLACIAL AND PERIGLACIAL DEPOSITS** (Annual Meeting INQUA Subcommission on European Quaternary Stratigraphy), Besançon, France. (Dr. Michel Campy, Labo de Géologie Historique, Institut des Sciences Naturelles, Place Leclerc, F-25030 Besançon, France)

September 14 - 16, 1984
• **GEOLOGY AND GENESIS OF MINERAL DEPOSITS IN IRELAND** (International Conference), Dublin, Ireland. (J. Ashton, Tara Mines Geology Dept., Knockumber, Co. Meath, Ireland)

September 16 - 22, 1984
▲ **LANDSLIDES** (4th International Symposium), Toronto, Canada. Sponsored in part by IAEG. (Mr. J.L. Seychuk, Chairman, Organizing Committee, ISL/84, P.O. Box 370, Station A, Rexdale, Ont., Canada M9W 5L3)

September 17 - 20, 1984
AQUATECH '84. (12th International Congress), Amsterdam, The Netherlands. Sponsored by the International Association for Water Pollution Research. (IAWPR, Alliance House, 29/30 High Holborn, London WC1V 6BA, U.K.)

September 20 - 25, 1984
• **RECENT ADVANCES IN PETROLEUM EXPLORATION AND DEVELOPMENT** (Meeting), Beijing, P.R. China. Co-sponsored by CPEMRC and Chinese Petroleum Geology Society, (R.J. Foster, BHP Petroleum, G.P.O. Box 1911R, Melbourne, 3001 Australia)

September 23 - 28, 1984
• **TRANSPORT PROCESSES IN FRACTURE ROCK** (Penrose Conference), Park City, Utah. (L.J. Smith, Dept. of Geological Sciences, Univ. of British Colombia, Vancouver, B.C., Canada V6T 2B4)

September 24 - 28, 1984
• **ASSESSMENT OF SOIL SURFACE SEALING AND CRUSTING** (International Symposium), Ghent, Belgium. Language: English. (Organizing Committee, International Conference, Department of Soil Physics, State University of Ghent, Coupure Links 653, 9000 Ghent, Belgium)

September 24 - 28, 1984
ICSU (20th General Assembly), Ottawa, Canada. (K. Charbonneau, Conference Office, National Research Council, Ottawa, Canada K1A 0R6)

September 25, 1984
• **GLOBAL CHANGE** (ICSU Symposium), Ottawa, Canada. (K. Charbonneau, Conference Office, National Research Council, Ottawa, Canada K1A 0R6)

September 25 - 27, 1984
• **FOSSIL ARTHROPODS AS LIVING ORGANISMS** (International Symposium), Edinburgh, U.K. (Royal Society of Edinburgh, 22-24, George St., Edinburgh EH2 2PQ, U.K.)

September 26 - 28, 1984
SEDIMENTATION IN THE AFRICAN RIFT SYSTEM (Geological Society Meeting), London, U.K. (L.E. Frostick, Dept. of Geology, Birkbeck College, 7/15 Gresse Street, London W1P 1PA, U.K.)

September 30 - October 6, 1984
▲ **LATE QUATERNARY SEA-LEVEL CHANGES AND COASTAL EVOLUTION** (International Symposium and Field Meeting), Argentina and Chile. IGCP-200 and INQUA Commission on Quaternary Shorelines. (Dr. Enrique Schnack, International Sea-level Symposium, Casilla 722, Correo Central, 7600 Mar del Plata, Argentina)

October 1 - 5, 1984
• **SCIENTIFIC COMMITTEE ON ANTARCTIC RESEARCH** (18th Meeting), Bremerhaven, F.R.G. (G. Hemmen, Scott Polar Research Institute, Lensfield Road, Cambridge, U.K. CB2 1ER)

October 1 - 5, 1984
EUROPEAN SEISMOLOGICAL COMMISSION (Assembly), Moscow, U.S.S.R. (Prof. A.V. Nikolayev, Institute of Physics of the Earth, Academy of Sciences of U.S.S.R., Bolshaya Gruzinskaya, 10, Moscow 123 242, U.S.S.R.)

October 1 - 5, 1984
REMOTE SENSING OF ENVIRONMENT (18th International Symposium), Paris, France. (Environmental Research Institute of Michigan, P.O. Box 8618, Ann Arbor, MI 48107, U.S.A.)

October 1 - 6, 1984
• **CENTRAL ANDEAN TECTONICS** (Symposium), La Paz, Bolivia. (Secretaria, Commission National de Estudios Geofisicos, Casilla 5939, La Paz, Bolivia)

October 5, 1984
• **WATER RESOURCES PLANNING AND MANAGEMENT** (International Conference), Athens, Greece. (Prof. A. Aureli, Via Cimarosa 10, 95124 Catania, Italy)

October 7 - 12, 1984
•▲ **BUENOS AIRES COASTAL PLAIN – NORTH PATAGONIA COAST** (Field Meeting), Mar del Plata, Argentina. INQUA Shorelines Commission. (Dr. Enrique Schnack, Casilla 722, Correo Central, RA - 7600 Mar del Plata, Argentina)

October 8 - 10, 1984
• **ASSOCIATION OF EARTH SCIENCE EDITORS** (Annual Meeting), Portland, Oregon, U.S.A. (Beverly Vogt, Oregon Department of Geology, 1005 State Office Building, Portland, OR 97201, U.S.A.)

October 8 - 12, 1984
• **BIOGEOCHEMICAL CYCLING OF S AND N IN REMOTE AREAS** (NATO Workshop), St. Georges, Bermuda. (J.N. Galloway, Environmental Studies Dept., University of Virginia, Charlottesville, VA 220903, U.S.A.)

October 9 - 14, 1984
IN SITU SOIL AND ROCK REINFORCEMENT (International Conference), Paris, France. (Conference Director, ENPC/DFCAI, 52, rue Madame, 75006 Paris, France)

October 13 - 16, 1984
• **ORIGIN OF THE MOON** (Topical Conference), Kona, Hawaii. (P. Jones, LPI, 3303 NASA Road One, Houston, TX 77058, U.S.A.)

Coming Events ...

October 14 - 20, 1984
MINERAL PROCESSING AND EXTRACTIVE METALLURGY. (International Conference), Kunming, P.R. China. (The Secretary, Institution of Mining and Metallurgy, 44 Portland Place, London W1N 4BR, U.K.)

October 15 - 17, 1984
• **SINKHOLES** (1st Multidisciplinary Conference), Orlando, Florida, U.S.A. (College of Extended Studies, University of Central Florida, Orlando, Fl 32816)

October 15 - 18, 1984
• **LATIN AMERICAN CONGRESS OF PALAEONTOLOGY** (3rd Congress), Oaxtepec, Morelos, Mexico. (Dr. Jose C. Guerrero, Universidad Nacional Autonoma de Mexico, Mexico D.F., Mexico)

October 17 - 19, 1984
• **AIPG** (Annual Meeting), Orlando, Florida, U.S.A. (Bobby J. Timmons, Timmons Associates, P.O. Box 50606, Jacksonville Beach, FL 32250, U.S.A.)

October 17 - 20, 1984
AMERICAN ASSOCIATION OF STRATIGRAPHIC PALYNOLOGISTS (Annual Meeting and Field Trip), Arlington, Virginia, U.S.A. (N.O. Frederiksen, U.S. Geological Survey, M.S. 970, Reston, VA 22092, U.S.A.)

October 21 - 25, 1984
SOCIETY OF EXPLORATION GEOPHYSICISTS (54th Annual Meeting), Denver, Colorado, U.S.A. (H. Breck, Society of Exploration Geophysicists, P.O. Box 3098, Tulsa, OK 74101, U.S.A.)

October 24 - 26, 1984
▲ **NATURE OF THE LOWER CONTINENTAL CRUST** (Joint Meeting Geological Society of London with 3rd Alfred Wegener Conference), London. Co-sponsored by ILP. (Prof. J.B. Dawson, Department of Geology, The University, Sheffield, S1 3JD, England, U.K.)

October 25 - November 5, 1984
• **GEOLOGY OF TIN DEPOSITS** (International Symposium), Nanning City, Guangxi Zhuang Autonomous Region, P.R. China. (Mr. Zhang Sihui, Chinese Academy of Geological Sciences, Baiwanzhuang Road 26, Fuchengmenwai, Beijing, People's Republic of China)

October 29 - November 2, 1984
INTERNATIONAL WATER SUPPLY ASSOCIATION (15th International Congress), Tunis, Tunisia. (R. Clark, International Water Supply Association, 1 Queen Anne's Gate, London SW1H 9BT, U.K.)

October 31 - November 7, 1984
▲ **SEISMOLOGY AND PHYSICS OF THE EARTH'S INTERIOR** (Regional Assembly of the International Association), Hyderabad, India. Plus short course for developing countries on inversion of geoscience data. Co-sponsored in part by ILP. (Organising Committee, IASPEI Regional Assembly, National Geophysical Research Institute, Hyderabad 500 007, India)

November/December 1984
LAND EVALUATION FOR SOIL EROSION HAZARD ASSESSMENT (Meeting), Enschede, Netherlands. (Dr. W.G. Sombroek, ISSS, International Soil Museum, 9 Duivendaal, POB 353, 6700 A.J. Wageningen, The Netherlands)

November 5 - 8, 1984
GEOLOGICAL SOCIETY OF AMERICA (Annual Meeting), Reno, Nevada, U.S.A. (S.S. Beggs, Geological Society of America, P.O. Box 9140, 3300 Penrose Place, Boulder, CO 80301, U.S.A.)

November 5 - 9, 1984
ARGENTINE GEOLOGICAL CONGRESS (9th), Bariloche, Argentina. Field trips. Languages: Spanish, English, and French. (IX Congreso Geológico Argentino, Maipú 645 Piso 1, 1006 Buenos Aires, Argentina)

November 6 - 7, 1984
NORTH ATLANTIC PALAEOCEANOGRAPHY (Marine Studies Group Meeting), London. (Geological Society, Burlington House, Piccadilly, London W1, U.K.)

November 12 - 17, 1984
WATER FOR SOUTH AFRICA (Exposition and Conference), Johannesburg, South Africa. Sponsored by National Water Well Association (U.S.) and Borehole Water Association (S.A.). (Pat Alcorn, NWWA, 500 W. Wilson Bridge Road, Worthington, Ohio 43085, U.S.A.)

November 12 - 30, 1984
• **RURAL HYDROGEOLOGY AND HYDRAULICS IN FISSURED BASEMENT ZONES** (Workshop), Roorkee, India. (Prof. B.B.S. Shinghal, Department of Earth Sciences, University of Roorkee, Roorkee 247667, India)

November 13 - 15, 1984
• **OPHIOLITES TROUGH TIME** (Conference), Nancy, France. (J. Desmons, University de Nancy I, Lab. de Petrologie, B.P. 239, F-54506 Vandoeuvre-les-Nancy Cedex, France)

November 15 - 17, 1984
•▲ **MINERAL POLICY FOR SMALL-SCALE MINING** (Workshop), New Delhi, India. Cosponsored by AGID in conjunction with World Mining Congress. (Co-ordinator, Regional Mineral Resources Development Centre, P.O. Box 19, Bandung, Indonesia)

November 19 - 23, 1984
12th WORLD MINING CONGRESS, New Delhi, India. (Organizing Committe, Institute of Engineers, 8 Gokhale Road, Calcutta 700 020, India)

December 1984
•▲ **CLIMAT – MILIEU – HOMME** (Colloquium), Dakar, Senegal. Co-sponsored in part by INQUA and Unesco. (Dr. E.S. Diop, University of Dakar, Department of Geography, Dakar-Fann, Senegal)

December 2 - 5, 1984
FUTURE PETROLEUM PROVINCES OF THE WORLD (AAPG W.E. Pratt Memorial Conference), Phoenix, Ariz., U.S.A. (AAPG, P.O. Box 979, Tulsa, OK 74101, U.S.A.)

December 2 - 6, 1984
SOCIETY OF EXPLORATION GEOPHYSICISTS (54th Annual Meeting), Atlanta, Georgia, U.S.A. (J. Hyden, SEG, Box 3098, Tulsa, OK 74101, U.S.A.)

1985

January 1985
ACID-SULPHATE SOILS (Meeting), Dakar, Senegal. (Dr. W.G. Sombroek, ISSS, International Soil Museum, 9 Duivendaal, POB 353, 6700 A.J. Wageningen, The Netherlands)

January 7 - 10, 1985
▲ **HYDROGEOLOGY OF ROCKS OF LOW PERMEABILITY** (17th International Congress of IAH), Tucson, Arizona, U.S.A. (Eugene S. Simpson, Department of Hydrology and Water Resources, College of Earth Sciences, The University of Arizona, Tucson, AZ 85721, U.S.A.)

February 1985
INTERGOVERNMENTAL OCEANOGRAPHIC COMMISSION ASSEMBLY (13th Session), Paris, France. (Unesco, 7, place de Fontenoy, 75700 Paris, France)

February 11 - 14, 1985
GEOMECHANICS IN TROPICAL LATERITE AND SAPROLITIC SOILS (1st International Conference), Sao Paulo, Brazil. (Dr. W.C. Hachich, Secretary ISTS-BMS, C.P. 7141, 01000 Sao Paulo, SP, Brazil)

February 11 - 14, 1985
ASIAN MINING '85 (2nd Conference), Manila, Philippines. (Meeting Secretary, The Institution of Mining and Metallurgy, 44 Portland Place, London W1N 4BR, U.K.)

February 27 - March 2, 1985
• **GEOLOGY OF THE OCEANS** (75th Annual meeting of the Geologische Vereinigung), Kiel, West Germany. Languages: English and German. (M. Sarnthein, Geologisch-Palaeontologisches Institut, Universitaet, Olshausenstrasse, D-2300 Kiel, F.R.G.)

March 11 - 15, 1985
SE ASIAN GEOTECHNICAL CONFERENCE (8th), Kuala Lumpur, Malaysia. Language: English. (The Hon. Secretary, 8th SEAGC, The Institution of Engineers, Malaysia, P.O. Box 223, Petaling Jaya, Selangor, Malaysia)

March 11 - 15, 1985
• **TUNNELLING 85** (4th International Symposium), Brighton, England. (Tunnelling 85, The Secretary, Institution of Mining and Metallurgy, 44 Portland Place, London W1N 4BR, U.K.)

April 1 - 4, 1985
• **EUROPEAN UNION OF GEOSCIENCES** (Biennial Conference), Strasbourg, France. (Organizing Committee, Department of Earth Sciences, University of Cambridge, Downing Street, Cambridge CB2 3EQ, U.K.)

April 1 - 5, 1985
NUMERICAL METHODS IN GEOMECHANICS (5th International Conference), Nagoya, Japan. (Prof. T. Kawamoto, Department of Civil & Geotechnical Engineering, Nagoya University, Chikusa, Nagoya 464, Japan)

April 9 - 12, 1985
EVOLUTION OF THE EUROPEAN LITHOSPHERE (MEGS 4: Meeting of European Geological Societies), Edinburgh, U.K. (Dr. S.K. Monro, Institute of Geological Sciences, Murchison House, West Mains Road, Edinburgh EH9 3LA, Scotland, U.K.)

April 14 - 17, 1985
PROSPECTING IN AREAS OF DESERT TERRAIN (Conference), Rabat, Morocco. (Conference Office, IMM, 44 Portland Place, London W1N 4BR, U.K.)

April 28 - May 1, 1985
▲ **GEOCHEMICAL EXPLORATION** (11th International AEG Symposium), Toronto, Canada. (Dr. W.B. Coker, Kidd Creek Mines Ltd., 357 Bay St., Ste. 300, Toronto, Ontario, Canada M5H 1T7)

May 6 - 17, 1985
•▲ **NEOGENE PHOSPHORITES OF THE SE UNITED STATES** (International field workshop and seminar, IGCP 156), Greenville, N.C., to Tallahassee, Florida. (W.C. Burnett, Dept. of Oceanography, Florida State University, Tallahassee, FL 32306, U.S.A.)

May 13 - 17, 1985
• **TUNGSTEN** (3rd International Symposium), Madrid. (Mr. M.R.P. Maby, Secretary, Primary Tungsten Association, 280 Earls Court Road, London SW5 9AS, U.K.)

May 15 - 17, 1985
TURBIDITE-HOSTED GOLD DEPOSITS (International Symposium), Fredericton, New Brunswick, Canada. Symposium held with Geological Association of Canada Annual Meeting. (Simon J. Haynes, Nova Scotia Department of Mines and Energy, P.O. Box 1087, 1690 Hollis Street, Halifax, Nova Scotia, Canada B3J 2X1)

May 27 - 31, 1985
AMERICAN GEOPHYSICAL UNION (Spring Meeting), Baltimore, Md. (Meetings, AGU, 2000 Florida Avenue, NW, Washington, DC 20009, U.S.A.)

May 27 - June 1, 1985
CORAL REEF CONGRESS: Reef and Man (5th International), Papeete, Tahiti. (Antenne Museum Ephe, Congrès Récifs Coral liens 1985, B.P. 562, Papeete, Tahiti, French Polynesia)

June 2 - 9, 1985
• **INTERNATIONAL MINERAL PROCESSING CONGRESS** (15th), Cannes, France. Languages French

and English. (International Mineral Processing Congress Secretary, BRGM SGN/Mineralurgie, B.P. 6009-45060 Orléans Cedex, France)

June 9 - 15, 1985
WATER RESOURCES (5th World Congress), Brussels, Belgium. (Dr. L.W. Debacker, c/o Brussels International Conference Centre, Parc des Expositions, Place de Belgique, B-1020 Brussels, Belgium)

June 16 - 21, 1985
SEISMICITY AND SEISMIC RISK (3rd International Symposium), Liblice, Czechoslovakia. (Dr. Z. Schenkova, Geophysical Institute, Bocni II, 14131 Prague 4, Czechoslovakia)

July 7 - 19, 1985
KARST WATER RESOURCES (International Symposium), Antalya/Ankara, Turkey. Sponsored by IAHS. (Prof. G. Gunay, Hydrogeological Engineering Department, Hacettepe University, Beytepe, Ankara, Turkey)

July 14 - 30, 1985
•▲ **MAGMATIC SULFIDES IN MAFIC ROCK** (IGCP 161 - Field Conference 4), Ketchikan, Alaska to Duluth, Minn. (Gerald K. Czamanske, M.S. 984, U.S. Geological Survey, Menlo Park, CA 94025, U.S.A.)

July 27 - August 7, 1985
• **4th INTERNATIONAL PLATINUM SYMPOSIUM**, Duluth, Minnesota, to Sudbury, Ontario. (A.J. Naldrett, Department of Geology, University of Toronto, Toronto, Ontario, Canada M5S 1A1)

July 28 - August 2, 1985
▲ **8th INTERNATIONAL CLAY CONFERENCE**, Denver, Colorado, U.S.A. Sponsored by AIPEA. (Dr. A.J. Herbillon, Groupe de Physico-Chimie Minérale et de Catalyse, Univ. Catholique de Louvain, Place Croix du Sud 1, B-1348 Louvain-la-Neuve, Belgium)

July 29 - August 1, 1985
• **OSTRACODA** (9th International Symposium), Shizuoka, Japan. (Dr. Tetsuro Hanai, Institute of Geosciences, University of Shizuoka, Shizuoka, 422, Japan)

August 5 - 17, 1985
• **MAGNETIC ANOMALIES OVER MARGINS OF CONTINENTS AND PLATES** (IAGA Symposium), Prague, Czechoslovakia. (W.J. Hinze, Department of Geosciences, Purdue University, West La Fayette, IN 47907, U.S.A.)

August 6 - 10, 1985
• **SCIENCE AND TECHNOLOGY EDUCATION AND THE QUALITY OF LIFE** (International Conference), Bangalore, India. Sponsored by ICSU/CTS (J. Lewis, Physics Department, Malvern College, Malvern, Worcs., U.K.)

August 6 - 10, 1985
GROUND FREEZING (4th International Symposium), Sapporo, Japan. (ISGF85, Institute of Low Temperature Science, Hokkaido University, Sapporo 060, Japan)

August 11 - 15, 1985
INTERNATIONAL SOCIETY FOR SOIL MECHANICS AND FOUNDATION ENGINEERING (11th International Conference), San Francisco, California, U.S.A. (K. Hyland, American Society of Civil Engineers, 345 East 47th Street, New York, NY 10017, U.S.A.)

August 19 - 23, 1985
▲ **SIXTH GONDWANA SYMPOSIUM.** Columbus, Ohio, U.S.A. Sponsored by IUGS and Geological Society of America. (D. Elliott, Inst. of Polar Studies, Ohio State University, 103 Mendenhall, 125 South Oval Mall, Columbus, OH 43210, U.S.A.)

August 19 - 30, 1985
IASPEI (23rd General Assembly), Tokyo, Japan. (Prof. R. Sato, c/o Inter Group Corp., Akasaka Yamakatsu Building, 8-5-32 Akasaka, Minato-ku, Tokyo 107, Japan)

August 24 - September 2, 1985
•▲ **GRAPTOLITES** (3rd International Conference, Graptolite Working Group IPA), Helsingør, Denmark. (Dr. M. Bjerreskov, Institute of Historical Geology and Palaeontology, University of Copenhagen, Øster Voldgade 10, DK-1350, Copenhagen K, Denmark)

August 26 - 29, 1985
• **GLACIER MAPPING AND SURVEYING** (Symposium), Reykjavik, Iceland. (Mrs. H. Richardson, Secretary General, International Glaciological Society, Lensfield Road, Cambridge CB2 1ER, U.K.)

September 1985
• **VARIATIONAL METHODS IN GEOSCIENCES** (International Symposium), Norman, Oklahoma, U.S.A. (CIMMS, Attn: Y.K. Sasaki, The University of Oklahoma, 815 Jenkins, Norman, Oklahoma 73019, U.S.A.)

September 1985
ROLE OF ROCK MECHANICS IN MINING (International Symposium), Mexico City, Mexico. (Sociedad Mexicana de Mecanica de Rocas AC, Camino a Santa Teresa 187, Villa Olimpica, MEX-14020 Mexico DF, Mexico)

September 2 - 7, 1985
•▲ **FORELAND BASINS** (Research Symposium), Fribourg, Switzerland. Sponsored by IAS. (P. Homewood, Institut de Géologie, Université de Fribourg, Pérolles, CH-1700 Fribourg, Switzerland)

September 3 - 5, 1985
EROSION DEBRIS FLOW AND DISASTER PREVENTION (International Symposium), Tsukuba, Japan. (Dr. S. Kobaski, ISEDD 1985, Department of Forestry, Kyoto University, Kyoto 606, Japan)

September 5 - 10, 1985
•▲ **CARPATHO-BALKAN GEOLOGICAL ASSOCIATION** (13th Congress), Krakow, Poland. (Oddzial Karpacki Instytutu Geologiczhego, ul. Skrzatow 1, 31-560 Krakow, Poland)

September 8 - 13, 1985
▲ **HYDROGEOLOGY IN THE SERVICE OF MAN** (18th IAH Congress – International Symposium), Cambridge, U.K. (J. Day, Hydrogeology Unit, Maclean Building, Crowmarsh Gifford, Wallingford, 0X10 8BB, U.K.)

September 9 - 13, 1985
FOSSIL AND LIVING BRACHIOPODS (Meeting), Brest, France. (Congrès Brachiopodes, Univ. Bretagne Occidentale, Laboratoire du Paléozoique - 6, av. Le Gorgen, 29283 Brest Cedex, France)

September 15 - 20, 1985
BASEMENT TECTONICS (6th International Conference), Santa Fe, New Mexico, U.S.A. Sponsored by Basement Tectonics Association. Pre- and post-conference field trips. (Dr. M. James Aldrich, Mail Stop D461, P.O. Box 1663, Los Alamos National Laboratory, Los Alamos, NM 87545, U.S.A.)

September 15 - 21, 1985
GEOMORPHOLOGY, RESOURCES, ENVIRONMENT AND THE DEVELOPING WORLD (International Conference), Manchester, U.K. (Prof. Ian Douglas, School of Geography, University of Manchester, Manchester M13 9PL, U.K.)

September 15 - 22, 1985
▲ **REGIONAL COMMITTEE ON MEDITERRANEAN NEOGENE STRATIGRAPHY** (8th Congress), Budapest, Hungary. Excursions. Language: English. (Organizing Committee of the 8th Congress of the RCMNS, Hungarian Geological Survey, Népstadion ut 14. H-1442 Budapest, P.O.B. (Pf.) 106, Hungary)

September 16 - 21, 1985
• **GEOPHYSICAL AND PETROLOGICAL CONSTRAINTS TO MAGMA GENERATION** (IAVCEI Scientific Assembly), Catania, Italy. (G. Frazetta, Istituto Internazionale di Vulcanologia, Viale Regina Margherita 6, 95123 Catania, Italy)

September 19 - 21, 1985
GEOLOGICAL SOCIETIES OF THE BRITISH ISLES (6th Meeting), Birmingham, U.K. (Prof. P.A. Garrett, Department of Geological Sciences, The University of Birmingham, P.O. Box 363, Edgbaston, Birmingham B15 2TT, U.K.)

September 22 - 26, 1985
HIGH HEAT PRODUCTION, GRANITES, HYDROTHERMAL CIRCULATION AND ORE GENESIS (Conference), St. Austell, Cornwall, U.K. (IMM, 44 Portland Place, London W1N 4BR, U.K.)

September 22 - 28, 1985
CHEMRAWN IV: CHEMISTRY AND RESOURCES OF THE GLOBAL OCEAN (Meeting), Woods Hole, Mass., U.S.A. (Prof. G. Ourisson, Centre de Neurochimie, Université Louis Pasteur, 5 rue Blaise Pascal, F-67084 Strasbourg, France)

October 5 - 12, 1985
•▲ **DISPOSAL OF HAZARDOUS CHEMICAL DEPOSITS** (IAEG International Symposium), Winston Salem, N.C., U.S.A. (Dr. M. Primel, L.C.P.C., 58, bould. Lefebvre, 75732 Paris Cedex 15, France)

October 6 - 10, 1985
SOCIETY OF EXPLORATION GEOPHYSICISTS (55th Annual Meeting), Washigton, D.C., U.S.A. (Convention Assistant, Society of Exploration Geophysicists, P.O. Box 3098, Tulsa, OK 74101, U.S.A.)

October 14 - 18, 1985
COAL RESEARCH (7th International Conference), Pretoria, South Africa. (W.G. Jensen, International Committee for Coal Research, Bte 11, B-1150 Bruxelles, Belgium)

October 14 - 18, 1985
• **MATHEMATICAL METHODS IN GEOLOGY** (International Symposium), Pribram, Czechoslovakia. (Sekretariat symposia, Hornicka Pribram ve vede a Technice, post. schranka 41, Pribram 261 02, Czechoslovakia)

October 28 - 31, 1985
GEOLOGICAL SOCIETY OF AMERICA (Annual Meeting), Orlando, Florida, U.S.A. (S.S. Beggs, Geological Society of America, P.O. Box 9140, 330 Penrose Place, Boulder, CO 80301, U.S.A.)

October 29 - November 2, 1985
• **INDONESIAN MINING** (International exhibition), Jakarta, Indonesia. (Overseas Exhibition Services, 11 Manchester Square, London W1M 5AB, U.K.)

November 1985
DESERTIFICATION (International Symposium), Khartoum, Sudan. (Dr. W.G. Sombroek, ISSS, International Soil Museum, 9 Duivendaal, POB 353, 6700 A.J. Wageningen, The Netherlands)

1986

February 1 - 9, 1986
• **INTERNATIONAL VOLCANOLOGICAL CONGRESS**, Auckland, Hamilton, Rotorua, New Zealand. Sponsored by IAVCEI. (P.E. Baker, Department of Earth Sciences, University of Leeds, Leeds LS2 9JT, U.K.)

May 11 - 16, 1986
MINING AND METALLURGICAL CONGRESS (13th), Canberra, Australia. (Council of Mining and Metallurgical Institutions, 44 Portland Place, London, W1N 4BR, U.K.)

June 1 - 5, 1986
•▲ **GEOSCIENCE INFORMATION** (3rd International Conference) Adelaide, South Australia. (Conference Secretariat 31CGI, c/o Australian Mineral Foundation, Private Bag 97, Glenside, South Australia, 5065, Australia)

June 2 - 5, 1986
• **DINOSAUR SYSTEMATICS** (Symposium) Drumheller, Alberta, Canada. (Kenneth Carpenter, Academy of Natural Sciences, 19th and the Parkway, Philadelphia, PA 19103, U.S.A.)

Coming Events ...

ummer 1986
GEOCHRONOLOGY, COSMOCHRONOLOGY AND ISOTOPE GEOLOGY (6th International Conference), Cambridge, U.K. Sponsored by IAVCEI, (P.E. Baker, Department of Earth Sciences, University of Leeds, Leeds LS2 9JT, U.K.)

uly 13 - 18, 1986
INTERNATIONAL MINERALOGICAL ASSOCIATION (General Meeting), Stanford, Calif., U.S.A. (Prof. C.T. Prewitt, Department of Earth and Space Sciences, State University of New York, Stony Brook, NY 11794, U.S.A.)

ugust 1986
IAGOD (7th Symposium), Luleå, Sweden. (G. Leech, Geological Survey of Canada, 601 Booth Street, Ottawa, Ontario, Canada K1A OE8)

ugust 11 - 15, 1986
KIMBERLITE (4th International Conference), Perth, Western Australia. (Dr. A.F. Trendall, Geological Survey of Western Australia, 66 Adelaide Terrace, Perth, W.A., Australia)

ugust 13 - 20, 1986
SOIL SCIENCE (13th ISSS International Congress), Hamburg, F.R.G. (Prof. Dr. K.H. Hartge, Inst. für Bodenkunde, Univ. Hannover, Herren-häser-strasse 2, D-3000 Hannover 21, F.R.G.)

ugust 25 - 29, 1986
IAS SEDIMENTOLOGICAL CONGRESS (12th International), Canberra, Australia. (Dr. K.A.W. Crook, Department of Geology, Australian National University, P.O. Box 5, Canberra, A.C.T., 2600 Australia)

September 7 - 12, 1986
• **REMOTE SENSING IN GLACIOLOGY** (Symposium), Cambridge, England. (Secretary General, International Glaciological Society, Lensfield Road, Cambridge CB2 1ER, England, U.K.)

September 8 - 12, 1986
•▲ **SECOND INTERNATIONAL CONFERENCE ON PALEOCEANOGRAPHY**, Woods Hole, U.S.A. (W.A. Berggren, Woods Hole Oceanographic Institute, Woods Hole, MA 02543, U.S.A.)

October 20 - 26, 1986
•▲ **IAEG** (5th Congress), Buenos Aires, Argentina. (Dr. M. Primel, L.C.P.C., 58, boulevard Lefebvre, 75732 Paris Cedex 15, France)

November 2 - 6, 1986
SOCIETY OF EXPLORATION GEOPHYSICISTS (56th Annual Meeting), Houston, Texas, U.S.A. (Convention Assistant, Society of Exploration Geophysicists, P.O. Box 3098, Tulsa, OK 74101, U.S.A.)

November 10 - 13, 1986
GEOLOGICAL SOCIETY OF AMERICA (Annual Meeting), San Antonio, Texas, U.S.A. (S.S. Beggs, Geological Society of America, P.O. Box 9140, 3300 Penrose Place, Boulder, CO 80301, U.S.A.)

1987

July 31 - August 9, 1987
▲ **INQUA** (12th Congress), Ottawa, Ontario, Canada. (Dr. Alan V. Morgan, Department of Earth Sciences, University of Waterloo, Waterloo, Ontario, Canada N2L 3G1)

August 9 - 22, 1987
IUGG (XIX General Assembly), Vancouver, Canada (R.D. Russell, Dept. Geophysics and Astronomy, University of British Columbia, Vancouver, B.C., Canada V6T 1W5)

September 1987
INTERNATIONAL SOCIETY FOR ROCK MECHANICS (6th International Congress), Montreal, Canada. (Prof. B. Ladanyi, Dept. Civil Engineering, Ecole Polytechnique, Box 6079, Stn.A, Montréal, Canada H3C 3A7)

Wish to announce meetings of international significance? Send brochure or details to Editor, EPISODES, Room 177, 601 Booth Street, Ottawa, Canada K1A 0E8, at least four months in advance.

LIST OF ABBREVIATIONS

AGU	American Geophysical Union
ASCOPE	ASEAN Council on Petroleum
BRGM	Bureau de Recherches Géologiques et Minières
CCOP	ESCAP Committee for Co-ordination of Joint Prospecting for Mineral Resources in Asian Offshore Areas
CGMW	Commission for the Geological Map of the World
CEPHPT	Commission on Experimental Petrology at High Pressure and Temperatures
CIFEG	Centre International pour la Formation et les Echanges Géologiques
CODATA	ICSU Committee on Data for Science and Technology
COGEODATA	IUGS Committee on Storage, Automatic Processing and Retrieval of Geological Data
COSPAR	ICSU Committee on Space Research
CRNS	Centre Nacional de la Recherche Scientifique
IAEA	International Atomic Energy Agency
IAG	International Association of Geodesy
IAGC	International Association of Geochemistry and Cosmochemistry
IAH	International Association of Hydrogeologists
IAHR	International Association for Hydraulic Research
IAHS	International Association of Hydrological Sciences
IASPEI	International Association of Seismology and Physics of the Earth's Interior
ICS	International Commission on Stratigraphy
IGCP	International Geological Correlation Programme
ICSU	International Council of Scientific Unions
IGC	International Geological Congress
ILP	International Lithosphere Program
IMA	International Mineralogical Association
IMM	Institute of Mining and Metallurgy
INHIGEO	International Committee on the History of Geological Sciences
INQUA	International Union for Quaternary Research
IOC	International Oceanographic Commission
ISSS	International Society of Soil Science
IUGG	International Union of Geodesy and Geophysics
SEG	Society of Economic Geologists
SEPM	Society of Economic Palaeontologists and Mineralogists

TRAINING COURSES

Designed primarily for geoscientists from developing countries, and run mainly on a post-graduate level.

• *Signifies first announcement in EPISODES.*

April 23 - May 25, 1984
APPLICATIONS IN GEOLOGIC AND HYDROLOGIC EXPLORATION AND PLANNING (Sioux Falls, South Dakota, U.S.A.). International Workshop.
For Information: Chief, Training and Assistance, U.S. Geological Survey, EROS Data Center, Sioux Falls, SD 57198, U.S.A.

May 28 - June 29, 1984
REMOTE SENSING: GEOLOGIC APPLICATIONS (Flagstaff, Arizona, U.S.A.). Advanced training program for foreign scientists organized by U.S. Geological Survey. English.
For Information: U.S. Geological Survey Training Center, 917 National Center, Reston, Virginia 22092, U.S.A.

June 1984 - August 1984
PRINCIPLES AND METHODS OF ENGINEERING GEOLOGY (Budapest, Hungary). Certificate course organized by the Hungarian Geological Institute and sponsored by Unesco. English.
For Information: Hungarian Geological Institute, Népstadion ut 14, P.O. Box 106, H 1142 Budapest, Hungary.

June 12 - August 10, 1984
TECHNIQUES OF HYDROLOGIC INVESTIGATIONS (Washington, D.C. and Denver, Colorado, U.S.A.). Annual training course for international participants.
For Information: Office of International Hydrology, Water Resources Division, U.S. Geological Survey, 470 National Center, Reston, Virginia 22092, U.S.A.

June 27 - July 9, 1984
• **WATER RESOURCES OF SMALL ISLANDS,** (FIJI). Training workshop.
For Information: Kate Gass, Project Officer, Commonwealth Science Council, Marlborough House, Pall Mall, London SW1Y 5HX, U.K.

July 1984 - August 1984
SUMMER COURSE ON EARTH SCIENCES: CRYSTALLOGRAPHY, MINERALOGY, METALLOGENY (Madrid, Spain). Annual course organized by the Department of Geology and Geochemistry of the Universidad Autónoma de Madrid and sponsored by Unesco. Spanish.
For Information: Prof. T. Monseur, Departamento de Geología y Geoquímica, Facultad de Ciencias, Universidad Autónoma de Madrid, Canto Blanco, Madrid 34, Spain.

July 2 - 28, 1984
• **INTERNAL GEOPHYSICS AND SPACE** (Toulouse, France). CNES summer school. French and English.
For Information: Centre National d'Études Spatiales, Départment des Affaires Universitaires, 18, Avenue Edouard-Belin, 31055 Toulouse Cedex, France.

July 16 - 28, 1984
• **REGIONAL COURSE IN GEOTECHNICAL PRACTICE FOR ENGINEERS** (Cochabamba, Bolivia). Co-sponsored by AGID and Bolivian organizations. Spanish.
For Information: Victor Ricaldi, Coordinator de Curso, Casilla 183, Cochabamba, Bolivia.

August 1984 - June 1986
• **SOIL SCIENCE AND WATER MANAGEMENT** (Wageningen, The Netherlands). Two-year M.Sc. course designed for B.Sc. graduates from developing countries. English.
For Information: Director of Studies of the M.Sc. course in Soil Science and Water Management, P.O. Box 37, 6700 AA Wageningen, The Netherlands.

August - October 1984
• **GEOLOGY AND GEOTECHNICS OF THE QUATERNARY SEDIMENTS.** Co-sponsored by AGID. (Bangkok, Thailand). Training program organized by the Asian Institute of Technology, Bangkok.
For Information: Dr. Prinya Nutalaya, AGID, Asian Institute of Technology, G.P.O. Box 2754, Bangkok 10501, Thailand.

September 1984 - November 1984
GEOTHERMAL ENERGY (Kyushu, Japan). Annual short course organized by the Government of Japan and sponsored by Unesco. English.
For Information: Japan International Cooperation Agency (2nd Training Division, Training Affairs Department), P.O. Box 216, Shinjuku Mitsui Building, 2 - 1, Nishi-shinjuku, Shinkuku-ku, Tokyo 160, Japan.

September 1984 - November 1985
MINING EXPLORATION AND EXPLORATION GEOPHYSICS (Delft, The Netherlands). Annual diploma courses organized by the International Institute for Aerial Survey and Earth Sciences and sponsored by Unesco. English.
For Information: ITC (ME), 3, Kanaalweg, 2628 Delft, The Netherlands.

October 1984 - November 1984
TECTONICS, SEISMOLOGY AND SEISMIC RISK ASSESSMENTS (Potsdam, G.D.R.). One-month training course organized annually by East German Academy of Sciences in collaboration with Unesco. English.
For Information: Prof. Dr. H. Kautzleben, Director, Central Earth's Physics Institute, Academy of Sciences of the German Democratic Republic, Telegraphenberg, DDR 1500 Potsdam, G.D.R.

October 1 - November 2, 1984
REMOTE SENSING: GEOLOGIC APPLICATIONS (Flagstaff, Arizona, U.S.A.). Advanced training program for foreign scientists organized by U.S. Geological Survey. English.
For Information: U.S. Geological Survey Training Center, 917 National Center, Reston, Virginia 22092, U.S.A.

October 1984 - September 1985
FUNDAMENTAL AND APPLIED QUATERNARY GEOLOGY (Brussels, Belgium). Annually organized training course leading to a Master's degree in Quaternary Geology by the Vrije Universiteit Brussel (IFAQ) and sponsored by Unesco. English and French.
For Information: Prof. Dr. R. Paepe, Director of IFAQ, Kwartairgeologie, Vrije Universiteit Brussel, Pleinlaan 2, B-1050, Brussels, Belgium.

October 1984 - September 1985
HYDRAULIC ENGINEERING AND HYDROLOGY (Delft, The Netherlands). Diploma courses organized annually by the International Institute for Hydraulic and Environmental Engineering and sponsored by Unesco for professionals from developing countries. English.
For Information: International Institute for hydraulic and Environmental Engineering (IHE), Oude Delft 95, P.O. Box 3015, 2601 DA Delft, The Netherlands.

November 1984 - December 1984
METHODS AND TECHNIQUES IN EXPLORATION GEOPHYSICS (Hyderabad, India). Diploma course organized annually by the National Geophysical Research Institute of the Council of Scientific and Industrial Research, Hyderabad, India, and sponsored by Unesco. English.
For Information: The Director, International Training Course on methods and techniques in geophysical exploration, National Geophysical Research Institute, Hyderabad, 500 007 (A.P.) India.

November 1984 - December 1984
SMALL MINE POTENTIAL AND TECHNOLOGY (Leoben, Austria). Annual training course sponsored by the Republic of Austria and Unesco. English.
For Information: Prof. Wolfbauer, Forschungsgesellschaft Joanneum, Roseggerstrasse 15, A-8700 Leoben, Austria.

January 1985 - March 1985
REMOTE SENSING APPLICATION AND DIGITAL IMAGE PROCESSING (Enschede, The Netherlands). Certificate courses on techniques for national resources surveys, organized annually by the International Institute of Aerial Surveys and Earth Sciences (ITC). Sponsored by Unesco. English.
For Information: ITC Student Affairs Office, P.O. Box 6, 7500 AA Enschede, The Netherlands.

February 1985
METALLOGENY (Quito, Ecuador). Annual training course for Latin Americans organized by Central University of Quito, the Autonomous University of Madrid (Spain), and Unesco. Spanish.
For Information: Ing. Antonio Salgado, Director, Curso Internacional de Metalogenia, Escuela de Ingeniería en Geología, Minas y Petroleos, División de Post-grado, Universidad Central, Quito, Ecuador.

February 1985 - March 1985
GEOCHEMICAL PROSPECTING TECHNIQUES (Tervuren, Belgium). Annual course sponsored by the Royal Museum of Central Africa and UNDP. French.
For Information: Musée royal de l'Afrique centrale, Steenveg op Leuven, 13, B-1980 Tervuren, Belgium.

February 1985 - June 1985
MINERAL EXPLORATION (Leoben, Austria). Diploma course organized annually by the University of Mining and Metallurgy in Leoben and sponsored by Unesco. English.
For Information: University for Mining and Metallurgy, Postgraduate course on mineral exploration, Montanuniversität, Leoben, A-8700, Austria.

February 1985 - November 1985
PHOTOINTERPRETATION APPLIED TO GEOLOGY AND GEOTECHNICS (Bogota, Colombia). Course organized by the Interamerican Centre of Photointerpretation (CIAF) in cooperation with ITC and Unesco. Spanish.
For Information: Academic Secretariat of the CIAF, Apartado Aéreo 53754, Bogota 2, Colombia.

February 1985 - December 1985
GEOTHERMICS (Pisa, Italy). Certificate course organized annually by the Istituto Internazionale per le Ricerche Geotermiche and sponsored by Unesco, UNDP and Italy. English.
For Information: Dr. Mario Fanelli, Istituto Internazionale per le Ricerche Geotermiche, Via Buongusto 1, 56100 Pisa, Italy.

March 1985 - April 1985
MINERAL EXPLORATION (Paris, France). Short course based on a simulation method organized annually by the Ecole Nationale Supérieure des Mines and sponsored by Unesco. French.
For Information: Prof. H. Pélissonnier, École des Mines, 60 Bd Saint Michel, 75272 Paris, Cedex 06, France.

International Geological Congress
Moscow, August 1984

(C. - Themes. S. - Intersectional Symposia. S.S. -Special Symposium).
Conveners listed for main sections. Co-sponsors listed in brackets ( ).

A. PLENARY SESSIONS

OPENING SESSION (August 5)

RECENT ACHIEVEMENTS IN GEOLOGY
E. Seibold (F.R.G.) and V.V. Menner (U.S.S.R.)

Ye.A. Kozlovsky (U.S.S.R.): Geology in the national economy of the U.S.S.R.

W. Hay (U.S.A.): The past and future of scientific ocean drilling.

V.L. Barsukov (U.S.S.R.) and H. Masursky (U.S.A.): Comparative planetology in earth history studies.

R.A. Price (Canada): Dynamics and evolution of the lithosphere: the framework for earth resources and the reduction of hazards.

A.L. Yanhsin (U.S.S.R.): Evolution of geological processes in earth history.

M.T. Halbouty (U.S.A.): Basins of the world and new frontiers.

CLOSING SESSION (August 14)

GEOLOGICAL ASPECTS OF ENVIRONMENTAL PROTECTION
Ye.A. Kozlovsky (U.S.S.R) and M. Tolba (Kenya)

Ye.A. Kozlovsky (U.S.S.R.): Geological aspects of environmental protection.

G. Castany (France): Impacts des projets de développement des ressources en eau sur l'environnement.

G. Lüttig (F.R.G.): Influence of mining activities on the environment.

E.M. Sergeev (U.S.S.R.): Advance in science and technology and the environment.

M. Suk and J. Vrba (Czechoslovakia): Integrated use of natural resources and geoenvironment.

L. Königsson (Sweden): The management of the environment and its background in natural history.

B. TECHNICAL SECTIONS

C.01. **STRATIGRAPHY.** (ICS)
M.G. Bassett (U.K.), I. Chlupac (Czechoslovakia), A.I. Zhamoida (U.S.S.R.)

C.01.1.1. Principles and Methods of Stratigraphy. Stratigraphy and Geochronology.
C.01.1.2. Limits of Precision and Geographic Stability of Stratigraphic Units.
C.01.1.3. Nature and Types of Stratigraphic Boundaries. (IGCP 153)
C.01.1.4. Problems of Phanerozoic Stratigraphy.
S.01.2.1. Correlation of Sediments Belonging to Different Facies and Biogeographic Provinces.
S.01.2.2. Vendian (Terminal System of Precambrian) and the Precambrian-Phanerozoic Boundary. (IGCP 29)
S.01.2.3. Permian System.
S.01.2.4. Palynostratigraphy.

C.02. **PALAEONTOLOGY.** (IPA)
A. Yu Rozanov (U.S.S.R.), O.H. Walliser (F.R.G.).

C.02.1.1. Early Stages of Organic Life.
C.02.1.2. Palaeoecology and Evolution of Ecological Systems.
C.02.1.3. Origin and Distribution of Vertebrates, Including Early Tetrapods.
C.02.1.4. Architectonics and Constructional Morphology as a Key to the Analysis of Phylogeny.
C.02.1.5. Microstructural and Chemical Aspects of Fossils.
S.02.2.1. Fundamental Biotic Changes in the Earth's History and Extinction of Fossil Groups.
S.02.2.2. Stromatolites, Stromatolitic Microbiotas and Calcareous Algae in the Earth's History.
S.02.2.3. Cancelled
S.02.2.4. Evolution, Migration and Provincialism of Cambrian Faunas and Floras.

C.03. **QUATERNARY GEOLOGY AND GEOMORPHOLOGY.**
H. Faure (France), K.V. Nikiforova (U.S.S.R.).

C.03.1.1. Quaternary Chronostratigraphy of Eurasia. (IGCP 41)
C.03.1.2. Stratigraphy of Pliocene-Quaternary Sediments of Oceans and Seas.
C.03.1.3. Fluctuations of the Ocean Basins Level and Quaternary Palaeoclimates.
C.03.1.4. Geomorphology, Palaeogeomorphology and Neotectonics.
S.03.2.1. Regularity of Tectonic Movements during the Late Tertiary and Quaternary.

C.04. **SEDIMENTOLOGY.**
K. Crook (Australia), P.P. Timofeev (U.S.S.R.)

C.04.1.1. Hypergenesis (Chemical and Physical Weathering) and Sedimentogenesis (sedimentation, including transportation and depositional processes).
C.04.1.2. Sedimentological Processes and their Controlling Factors.
C.04.1.3. Palaeogeographic and Facies Analysis. Facies models.
C.04.1.4. The Role of Climate in Sedimentation and Sedimentary Processes.
C.04.1.5. Carbonate and Halogenic Deposits. (IAS)
S.04.2.1. Sedimentation and Geotectonic Regimes.
S.04.2.2. Evolution of Sedimentary Ore Deposits.

C.05. **PRECAMBRIAN GEOLOGY.**
H.L. James (U.S.A.), W. Neumann (D.D.R.), N.P. Shcherbak (U.S.S.R.)

C.05.1.1. Principles of Precambrian Stratigraphy and the Main Subdivisions of the Precambrian. Isotopic Geochronology of the Precambrian.
C.05.1.2. Archaean Sedimentation and the Archaean Proterozoic Boundary. (IGCP 160)
C.05.1.3. Life and Organic Matter in the Precambrian. Origin of the Atmosphere and Hydrosphere. (IGCP 157 & 160)
C.05.1.4. Principles of Proterozoic Stratigraphy.
S.05.2.1. Precambrian Metallogeny. (IGCP 91)
S.05.2.2. Early Stages of Lithosphere Evolution. (IGCP 160)
S.05.2.3. Fold Belts and Plate Tectonics in the Precambrian. (ILP-WG3)

C.06. **GEOLOGY OF OCEAN BASINS.**
W. Hey (U.S.A.), Yu.M. Pushcharovsky (U.S.S.R.)

C.06.1.1. Sedimentary Layers in Oceans and Seas: Formation and Structure.
C.06.1.2. Palaeoceanology.
C.06.1.3. Natural Laws Controlling the Distribution and Origin of Metalliferous Deposits and Ferromanganese Nodules.
C.06.1.4. Petrochemical and Geochemical Provinces of the Basaltic Layer of the Ocean.
C.06.1.5. Geophysical Studies of the World Ocean Floor: Methods and Results.
S.06.2.1. Global Stratigraphic Correlation of Mesozoic-Cenozoic Sediments of Oceans and Continents. (IGCP 183)
S.06.2.2. Correlation of Tectonic Events in Oceanic Areas and on Continental Margins During the Mesozoic and Cenozoic.
S.06.2.3. Origin and History of Marginal and Inland Seas. (IGCP 195 & ILP-WG8)

C.07. **TECTONICS.**
A.V. Peyve (U.S.S.R.), R. Trümpy (Switzerland)

C.07.1.1. Principles of Tectonic Zonation of Continents.
C.07.1.2. Transition Zones between Continents and Oceans.
C.07.1.3. Tectonics of Continental Fold Belts. (IGCP 5 & ILP-WG2)
C.07.1.4. Tectonic Stratification of the Lithosphere.
C.07.1.5. Continental and Oceanic Rift Systems.
C.07.1.6. Deformation Processes in Rocks.
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S.07.2.2. Tectonics of the North Pacific and its Framework.

C.08. **GEOPHYSICS.**
V.V. Belousov (U.S.S.R.), St. Müller (Switzerland), D.A. Valencio (Argentina).

C.08.1.1. Structure of the Earth's Crust and Lithosphere Based on DSS Data.
C.08.1.2. The Asthenosphere: Distribution, Characteristic Features, Nature.
C.08.1.3. Geophysical Fields, Nature and Geological Interpretation.
C.08.1.4. Seismicity; Relations with Geophysical Fields, Tectonics and Recent Movements; Earthquake Prediction.
C.08.1.5. Geophysics and Volcanism. Prediction of Volcanic Eruptions.
C.08.1.6. Applied Geophysics.
S.08.2.1. Palaeomagnetism and Tectonics.

C.09. **PETROLOGY (IGNEOUS AND METAMORPHIC ROCKS).**
O.A. Bogatikov (U.S.S.R.), I. Kushiro (Japan).

C.09.1.1. Igneous, Metamorphic and Metasomatic Rocks as Indicators of the Earth's Deep Structure.
C.09.1.2. Comparative Characteristics of Oceanic and Continental Magmatic Rock Formations.
C.09.1.3. Evolution of Magmatic and Metamorphic Processes in the Earth and its Major Regions. (ILP-CC4)
C.09.1.4. Capacity of Ore-Deposit Production of Magmatic, Metamorphic and Metasomatic Rocks.
S.09.2.1. Origin and Evolution of Magmas.
S.09.2.2. Experimental Phase Equilibria Studies as Indicators of the Physico-Chemical Conditions of Magmatic, Metamorphic and Metasomatic Rock Formation.
S.09.2.3. Nature and Origin of Trondhjemites, Plagiogranites and Related Rocks.

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F.V. Chukhrov (U.S.S.R.), S. Hafner (F.R.G.), I.N. Kostov (Bulgaria).

C.10.1.1. Typomorphism of Minerals.
C.10.1.2. New Data on the Crystal Chemistry of Minerals.

C.10.1.3. Physics of Minerals.
S.10.2.1. Thermodynamics of Mineral Formation. (CEPHPT and IAGC)
S.10.2.2. Molten and Gas-Liquid Microinclusions in Mineral-Forming Substances.

C.11. GEOCHEMISTRY AND COSMOCHEMISTRY.
V.L. Barsukov (U.S.S.R.), M.H. Grünenfelder (Switzerland), B. Hitchon (Canada)

C.11.1.1. Geochemical Cycles and Natural Laws Governing the Distribution of Elements in the Earth's Crust.
C.11.1.2. Geochemistry of Ore-Forming Processes.
C.11.1.3. Geochemistry of Magmatic Processes.
C.11.1.4. Applied Geochemistry; Geochemical Ore Prospecting and Earthquake Prediction.
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C.11.1.6. Origin and Evolution of Solar System.
C.11.1.7. Geochemistry of Extraterrestrial Matter.
C.11.1.8. Cancelled
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S.11.2.3. Rare Gases and the Origin and History of the Earth and Other Planets. (IAGC)

C.12. METALLOGENESIS.
N. Fisher (Australia), L. Kostelka (Austria), N.P. Laverov (U.S.S.R.)

C.12.1.1. Comparative Metallogenesis of the Archaean, Proterozoic and Phanerozoic.
C.12.1.2. Sources of Ore-Forming Substances.
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S.S.12.3.1. Geology and Conditions of Formation of Copper Deposits. (IAGOD, SEG, SGA)
S.S.12.3.2. Metallogenesis and Uranium Deposits (IAEA)

C.13. OIL AND GAS FIELDS.
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C.13.1.5. Oil and Gas in Deep Zones of the Lithosphere.
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V.S. Borisov (U.S.S.R.), R. Feis (France)

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C.14.1.2. Tectonics of Coal and Oil-Shale Basins.
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C.14.1.4. Minerals Associated with the Solid Fuels and Geological and Geochemical Aspects of their Study.
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G. Castany (France), G.V. Kulikov (U.S.S.R.)

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C.16.1.2. Forecasting Changes in Chemical Composition of Underground Water Reserves.
C.16.1.3. Methods of Modelling Hydrogeological Processes.
C.16.1.4. Hydrogeological Problems in Optimum Underground Water Utilization and Control of Underground Water Regimes.
C.16.1.5. Ecological Consequences of Artificial Changes in the Hydrogeological Regime.
S.16.2.1. Hydrogeological and Engineering-Geological Studies Relative to Land Reclamation.
S.16.2.2. Trace-Element Geochemistry of Underground Drinking Water.

C.17. ENGINEERING GEOLOGY.
M. Arnould (France), M. Langer (F.R.G.), E.M. Sergeev (U.S.S.R.)

C.17.1.1. Theoretical Problems of Engineering Geology.
C.17.1.2. Engineering-Geological Fundamentals for the Rational Use and Protection of the Geological Environment.
C.17.1.3. Engineering-Geological Problems in Studying Rocks and their Properties.
C.17.1.4. The Quantitative and Temporal-Spatial Prediction of Development of Geological and Engineering-Geological Processes.
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S.17.2.1. Application of the Airborne and Satellite Methods in Engineering-Geological and Hydrogeological Mapping.
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C.18. REMOTE SENSING.
P. Bankwitz (D.D.R.), W.D. Carter (U.S.A.), N.V. Mezhelovsky (U.S.S.R.), V.M. Moralev (U.S.S.R.)

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C.18.1.6. Origin and Significance of Ring Structures in the Structure of the Earth's Crust.

C.19. COMPARATIVE PLANETOLOGY.
M.S. Markov (U.S.S.R.), H. Mazursky (U.S.A.), L. Silver (U.S.A.)

C.19.1.1. Geomorphology, Tectonics and Deep Structure of Terrestrial Planets and their Satellites.
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S.19.2.1. Origin and Evolution of Life on Earth. (IGCP 157)

C.20. MATHEMATICAL GEOLOGY.
D. Merriam (U.S.A.), D.A. Rodionov (U.S.S.R.), R. Sinding-Larsen (Norway)

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C.20.1.2. Mathematical Approaches to Geological Classification. (IGCP 148)
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S.20.2.2. Geological Information: Collection, Storage, Distribution and Management of Geological Data.
S.20.2.3. Quality and Quantity of the Jurassic Time Scale. (IGCP 148, 171 & ICS)

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R. Hooykaas (Netherlands), V.V. Tikhomirov (U.S.S.R.), T. Vallance (Australia)

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S.21.2.1. History of Mineralogy (INHIGEO & IMA)

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D.E. Ajakaiye (Nigeria), V.E. Khain (U.S.S.R.), Ch. Pomerol (France)

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C.22.1.2. Co-Ordination between Disciplines of Geology, Geophysics and Geochemistry in Geological Education.
C.22.1.3. Relative Proportions of Theoretical and Practical Geological Training; Field, Geophysical and Drilling Practice.
S.22.2.1. Geological Education and Environmental Protection.
S.22.2.2. Geological Education in Developing Countries and Assistance by Developed Countries.

C. COLLOQUIA

K.01. GEOLOGY OF THE U.S.S.R.
L.I. Krasni (U.S.S.R.), V.M. Volkov (U.S.S.R.)

K.02. ENERGY RESOURCES OF THE WORLD.
M. Halbouty (U.S.A.), R.W. Hutchison (Canada), R.F. Meyer (U.S.A.), R.A. Sumbatov (U.S.S.R.)

K.03. PALAEOCEANOGRAPHY. (CMG, DSDP & ILP-WG2, WG3)
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K.05. TECTONICS OF ASIA.
T.K. Huang (China), A.L. Yanshin (U.S.S.R.)

K.06. EARTHQUAKE AND GEOLOGICAL HAZARD PREDICTION.
H. Berckhemer (Denmark), S.A. Fedotov (U.S.S.R.)

D. INTERNATIONAL LITHOSPHERE PROGRAMME – SPECIAL SESSION

R. Price (Canada), A.L. Yanshin (U.S.S.R.)

L.01. Evolution of Sedimentary Basins and their Mineral and Energy Resources.
L.02. Circum-Pacific Orogenic Belts and Evolution of the Pacific Ocean Basin.
L.03. Archaean Lithosphere and Early Crustal Evolution.
L.04. Recent and Quaternary Plate Motions.
L.05. Palaeoenvironmental Evolution of the Oceans and the Atmosphere.
L.06. Geochemical and Geophysical Modelling of Plate Tectonics.
L.07. Geological, Geophysical and Geochemical Constraints on the Deep Structure of the Continents and Ocean Basins.
L.08. Continental Drilling.
L.09. Groundwater Exploration and Development in Semi-Arid Zones.
L.10. Proterozoic Crustal Dynamics and Lithospheric Evolution.

CANADIAN SOCIETY OF PETROLEUM GEOLOGISTS

Memoir 9

THE MESOZOIC OF MIDDLE NORTH AMERICA

Proceedings of CSPG conference held in
Calgary, Alberta, May 1983

The articles describe Mesozoic rocks in areas from the Beaufort Sea in the north to the San Juan Basin in the south. They include reports on palynology, paleontology, sedimentology and economic geology.
Some of the 33 papers are:

Marine cycles - Lower Cretaceous . . . . Caldwell

Lower Cretaceous Mannville Group, northern Williston Basin . . . . Christopher

Cretaceous alluvial deposits, southern Rocky Mountain basins . . . . Flores

Paleoecology and Paleoceanography, Greenhorn Eustatic Cycle . . . . Kauffman, Arthur & Pratt

Storm event sedimentation; Cardium Formation, Pembina Oilfield . . . . Krause & Nelson

Pembina — in retrospect . . . . Nielsen and Porter

The Jurassic from 49° to Beaufort Sea . . . . Poulton

Hydrocarbon potential of low-permeability Cretaceous sandstones . . . . Simpson

Regional paleogeography of the Early Cretaceous seaway, southwestern Montana . . . . Vuke

Edited by
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