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Are the Proterozoic Fold Belts of Australia Ensialic?

Darwin, Australia, 7-14 August 1985

Ensialic versus plate margin evolution of Proterozoic fold belts was the focus of the first international meeting on Proterozoic geology ever held in Australia. The conference was organized by the Bureau of Mineral Resources, Geology and Geophysics (BMR) in cooperation with the Geological Surveys of the Northern Territory and Western Australia and was sponsored by IGCP Projects 215 (Proterozoic Fold Belts) and 217 (Proterozoic Geochemistry), and by Working Group 3 (Proterozoic Lithospheric Evolution) of the International Lithosphere Program. It was attended by some 120 participants of whom 18 came from abroad.

Following the opening by M.A. Etheridge (Australia), the principal organizer of the conference, A. Kröner (F.R.G.) gave an overview of new results on Proterozoic research during the first 5 years of the International Lithosphere Program. He stressed that there is now increasing evidence for a significant mid-Proterozoic crust-forming event at about 1.9-1.7 Ga ago that required lateral and/or vertical accretion of juvenile continental material.

A discussion of the regional tectonics, geochronology and isotope geochemistry of the Australian Proterozoic provinces was opened by Etheridge and others with a model of ensialic Proterozoic tectonics developed from BMR studies. This involves basin formation by limited stretching of Archaean continental lithosphere over polygonal-shaped convection cells in the upper mantle and massive magmatic underplating between about 2.0-1.87 Ga ago. Basin closure and bimodal I-type magmatism occurred between 1.87 and 1.84 Ga in all

terraces of north and central Australia. This model requires the existence of older crust between and beneath the Proterozoic belts. R. Needham (Australia) and P. Stuart-Smith (Australia), and their colleagues discussed the tectonic and geochemical evolution of the Pine Creek Geosyncline, stressing that the rock types and their chemistry required an ensialic evolution, an interpretation that was echoed by almost all of the Australian contributions and which provoked considerable debate.

Uranium-lead geochronological data for the igneous events in northern Australia were reviewed by R.W. Page (Australia) within the framework of the BMR model, and his excellent

Figure 2: Renaud Caby (France), chairman of IGCP Project 215 (Proterozoic Fold Belts), makes a point during discussion with Australian field geologist Dr. Skippy.

Figure 1: Distribution of Early to Middle Proterozoic fold belts in Australia.

and precise results document a major (ensialic?) crust-forming event at 1.87-1.84 Ga ago, in which juvenile magmatic additions, considered to be derived from an extensive underplated reservoir, dominated greatly over reworking of older crust. In contrast, W.R. Van Schmus and colleagues (U.S.A., read by P.F. Hoffman) argued on the basis of equally precise zircon ages that the Trans-Hudson Orogen in Saskatchewan, Canada, records plate margin igneous events related to subduction at 1880-1850 Ma ago, associated with an early Proterozoic assembly of new crust during a continent-wide episode of lateral accretion.

Evidence for lateral accretion and crustal growth in Proterozoic provinces of North America, the Baltic Shield and northeastern Africa, was reviewed by K.C. Condie (U.S.A.), P.F. Hoffman (Canada), R. Gorbatschev (Sweden) and A. Kröner. R. Caby (France) demonstrated extensive nappe tectonics in NE Brazil, which caused reworked Archaean gneisses to be thrust over the early Proterozoic cover sequences during the Brazilian orogeny.

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The geochemistry and isotopic systematics of Australian Proterozoic granitoids and mafic volcanics were reviewed by L. Wyborn (Australia) and S.S. Sun (Australia) respectively. In view of the apparent lack of calcalkaline affinities, both favoured underplated source regions rather than subduction settings for these rocks. A.Y. Glikson (Australia) suggested that residues of underplated magma are preserved in early Proterozoic mafic granulites of the Arunta Block of central Australia.

The high quality of structural work in Australia was demonstrated by P.R. James, in an excellent strain and displacement analysis of a nappe sequence in the eastern Arunta Block. Evidence for extensive nappe and thrust tectonics was also provided by papers on the Namaqua mobile belt of South Africa (D. Strydom and H.E. Praekelt, South Africa) and on the (Grenvillian?) Colonsay Group of northwest Scotland (M. Bentley, U.K.). Bentley suggested that rigid footwall ramps may give rise to domains in the allochthon where stretching lineations are oriented transverse to the direction of gross tectonic transport.

The conference ended with a discussion of Proterozoic crustal evolution, once again focussing on the BMR model and on metallogenetic patterns. Although no consensus was reached, most conference participants agreed that there are both important similarities and significant differences in Proterozoic terranes worldwide, and these may relate to different tectonic processes, such as those seen in the present plate tectonic regime. The geochemical signature of Australian Proterozoic granitoid suites seems remarkably different from "classical" modern plate margin settings, and economic geologists also emphasized that most Proterozoic base-metal deposits occur in environments that cannot be reconciled with modern accretion or collision belts. Finally, there was general agreement that the present reliable palaeomagnetic data base for the Proterozoic is too small and too little time-constrained to justify its use in global crustal evolution models.

After report by A. Kröner, P.F. Hoffman
J.-P. Burg and R. Caby

GSA Reviews the Geology of Africa

Gaborone, Botswana, 4 - 7 November 1985

Africa is of increasing geological interest, not only because of its mineral, petroleum and water resources, but also because it offers unique opportunities to study fundamental processes such as continental rifting and because it provides in its cratons clear windows to the Archaean. The Seventh Conference on the Geology of Africa, organized recently by its Geological Society, drew together 135 registrants from 25 African countries, Europe, North and South America and Israel.

The continental sediments of Africa were the subject of the largest group of papers presented, many by members of IGCP Project 210. These ranged from a comprehensive review of the climates during the Palaeozoic by J. Fabre (France) to descriptions of particular regions or periods such as the Palaeozoic of Algeria by S. Guerrak (France), the uraniferous series of Zaire by M. Cazoulat (France), Karroo sediments in

Tanzania (D. Kaiser, F.R.G.), Zambia, Zimbabwe and Botswana (K.-U. Reimann, F.R.G.), the Chad Basin by M. Mbaitoudji (Chad), the structural development and sedimentary cycles of NE Africa by E. Klitzsch (F.R.G.), and aspects of the Togo Basin by A.K. Johnson (France).

N. Petit-Maire (France) reviewed a wealth of data linking changes of ocean temperatures to desertification processes and concluded that man-made effects were only peripheral to the natural cycles during the Quaternary. An invited review paper by Petroconsults (presented by J.-Y. Chatellier, Ireland) considered the petroleum resource potential of the many sedimentary basins and concluded that the large continental basins of southern Africa had a high prospectivity, though political considerations often determined actual areas of activity.

Groundwater resources were another point of interest, not only in the sedimentary basins but also in basement areas. H.H. Nkotagu (Tanzania) discussed the groundwater recharge potential in a part of the Tanzanian basement and concluded it was reasonable, but E. Klitzsch in his detailed discussion of the sediments in northeastern Africa warned that much of the water now being utilized was fossil water and that recharge was dependent on climatic changes. Exploration for groundwater in western Kenya was discussed by P.G. Van Dongen (Kenya) who stressed the need to integrate several techniques, with different areas perhaps requiring different techniques.

Many of the papers on basement geology and mineral exploration were the result of work sponsored by Unesco's "Geology for Development" program, which is concerned with research and training activities on the Precambrian, especially the Kibaran of East and Central Africa, and the Birrimian of West Africa. Other papers by J. Klerkxx (Belgium) and A.B. Kampunzu (Zaire) described different parts of the Kibaran belt, and they arrived at somewhat different conclusions concerning its evolution, with Kampunzu favouring an island-arc accretionary model.

G.O. Kesse (Ghana) and I. Yace (Ivory Coast) described the geotraverses undertaken by this project in Ghana and the Ivory Coast. They highlighted the problems of correlating the Birrimian throughout this region and stressed the need for further work in view of the important associated mineral deposits. C. Frick (R.S.A.) gave an excellent paper on the stream sediment geochemical survey being undertaken in South Africa and its application to the identification of new exploration targets.

A dominant theme throughout the meeting was the development and utilization of Africa's mineral resources. C. Kogbe (France) and J.O. Afilaka (Nigeria) provided an overall review of Africa's mineral production. Many discussions centered on the need to expand the use of mineral resources within Africa to break the current cycle of exporting raw mineral materials and importing finished and processed mineral-based products. The plight of many geological surveys and training institutions was highlighted by several horrific examples. However, signs of progress include the setting up of a geochronology laboratory at the University of Zimbabwe and the establishment of closer research links between African and European institutions, both under Unesco's "Geology for Development" program.

The new Council of the Geological Society of Africa for the period 1985-1988 was announced and includes C.A. Kogbe (France, President) and Getanah Assefa (Ethiopia, Past President); Regional Vice-Presidents, A.A. Hussein (Egypt, North), E. Shannon (Liberia, West), A.B. Kampunzu (Zaire, East and Central) and A. De Araujo (Angola, South); F. Theuri (Kenya, General Secretary); S. Alidou (Benin, Assistant General Secretary); M. Sekwale (Botswana, Treasurer); and Council Members, K. Barning (Ghana), S.J. Gaciri (Kenya), I.G. Hughes (U.K.), M. Mbaitoudji (Chad), S.M. Muhungu (Tanzania) and P. Nyaba (Sudan). National representatives

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were also appointed to ensure better communication between members. The Society hopes to become more dynamic and to play an effective role in the growth of African geoscience and its application to development, especially in the fields of minerals, water and energy.

A word of special praise should be directed to the Local Organizing Committee, under the chairmanship of Moremi Sekwale, for its hard work under trying and difficult circumstances. The problems of Africa are not least in the fields of communication and transport. Thus, the organizers had little warning of who would be present each day to give papers; yet a schedule was maintained. Finally a word of praise to the delegates who often had to travel for 4 or 5 days to reach this Conference. So complex are the air schedules and regulations governing travel in Africa that Angola to Botswana via Paris is still sometimes the quickest route! The proceedings will be published by the Journal of African Earth Sciences.

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The Geology of Trinidad and Tobago

Port-of-Spain, Trinidad, 10 - 12 July 1985

The first conference of the Geological Society of Trinidad and Tobago (GSTT), held recently, was an excellently organized meeting, small enough to enable easy contact between the participants and to allow all 30 papers to be heard without the bugbear of parallel sessions. The consistently high percentage of attendees listening to each of the papers showed that, in a regional meeting of this kind, everybody is interested in all aspects of the studies presented.

As was to be expected, there was a strong focus on the oil fields, with contributions from staff of both the national oil company and the international companies that are producing hydrocarbons onshore and offshore. Several papers by geochemists showed the importance of studies of the thermal history of the various sedimentary sequences. The consensus is that all Trinidad's oil originates from Paleogene or Cretaceous source rocks, from which it has migrated into Neogene turbidites and into the immensely thick deposits of the Orinoco delta.

Much of the work is, however, still in a youthful stage, and the need for future close cooperation between geologists, geochemists and biostratigraphers was apparent. A plea for the release of subsurface data after a reasonable length of time was made by L. Algoo, President of the GSTT, and one felt the wisdom of his words when listening to both the papers and the lively discussions. Sometimes both were hampered by the confidential nature of information that would by now be in the public domain in many oil producing countries.

The position of Trinidad and Tobago in the wider setting of the southeastern Caribbean was covered by a symposium of invited papers on the last day of the conference. Plate

reconstructions presented for the area from Jurassic to the present showed that there are still widely divergent views. It is apparent that we have not yet accumulated enough geological and geophysical facts to make the best interpretation and, in Trinidad, this particularly concerns the amount of strike slip motion that has taken place along the El Pilar Fault, on parallel faults offshore to the north of Trinidad, and on associated wrenches across central and southern Trinidad. The accumulation of such data is of prime importance if the complicated interaction of continental South America with the Caribbean and Atlantic plates through time is to be understood. Such an understanding is far from academic, for the design of future oil and gas exploration can be strongly affected by it.

The Conference Transactions should be available by the time of the 11th Caribbean Geological Conference to be held in Barbados in July 1986. For information contact the GSTT, Box 771, Port-of-Spain, Trinidad.

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Petroleum Source Rocks in Lakes

London, U.K., 10 - 11 September 1985

In 1983, there was an excellent conference on marine source rocks organized by the Petroleum Group of the Geological Society of London. There was a familiar air then, as most of the scientists had been acquainted for years. This time it was different, for when IGCP 219 proposed to the Petroleum Group a similar meeting to consider organic-rich lake deposits, we were not even sure who were the interested scientists. In the event, this second meeting brought together a variety of specialists that provided a kaleidoscope view of the diversity of lacustrine environments, an exciting new field in hydrocarbon exploration.

This two day conference was the first official meeting of IGCP Project 219 on Comparative Lacustrine Sedimentology in Space and Time. The goals of the project are to show the geologic importance of lacustrine deposits by 1) a global compilation of lacustrine giants according to geologic time intervals and 2) a focus on the criteria for recognizing diverse lacustrine environments by a comparative analysis of modern and ancient deposits. The meeting revolved around a central theme concerning controls on the carbon budget in various lake types and deposits, and the question of whether or not there is a unique environment for source rocks.

The meeting reviewed freshwater to hypersaline evaporite lakes with low to extreme alkaline affinities and located from tropical to arctic latitudes. In a session on tectonic, geochemical and biological frameworks, rift systems were emphasized, perhaps because these collect sediments that have a high potential for surviving in the geological record. E.I. Robbins and R.F. Meyer (U.S.A.) emphasized the combined economic importance for hydrocarbons, minerals and

ores of ancient rifts. An overview by J.F. Talling (U.K.) showed the biological diversity and range of productivity in modern systems. Indeed, in this regard, the meeting showed that most lake basins could be of interest.

Sulphate concentration is an important control on diagenetic carbonates (K. Kelts), but its role in the preservation of organic carbon was controversial. There is a need for more information on the "Lupton effect," the inhibition of sulphate reducers by very high salinities or alkalinities. P. De Deckker (Australia) further developed models based on experience with Australian salt lakes and concluded that deeper lakes are a better bet. C.P. Summerhayes (U.K.) illustrated how the mapping of lacustrine source environments in geologic time slices can begin with the University of Chicago paleoclimate models.

As regards productivity, sedimentation and preservation of organic matter, many diverse modern lakes have abundant organic matter in the sediments, but according to M.R. Talbot (Norway), none seem to show type 1 pyrolysis characteristics. There are difficulties with extrapolating modern data, but it seems that we do not yet fully understand the mechanisms for type 1 kerogen. Hypersaline, alkaline high pH lakes (a confusing term to many geologists) provide unusual and poorly studied microbial systems where, for example, methanogenesis is prolific even in the presence of sulphate (R.S. Oremland and others, U.S.A.). Coastal saline lakes in Australia (R.V. Burne and J. Bauld, Australia) have prolific cyanobacterial mats and conspicuous Botryococcus algal films. The controversial point is whether these have a reasonable preservation potential.

A session on organic and inorganic geochemical indicators of paleoenvironment showed that whereas marine studies focus on distinguishing terrestrial from marine input, the first hurdle in lacustrine studies is to distinguish them from marine - a far from simple organic-geochemical problem.

However, various lipid bio-markers show promise (J.K. Volkman, Australia) and pyrolysis techniques have been greatly refined (M. Vandenbroucke and F. Behar, France). B.J. Katz (U.S.A.) contrasted the yield of carbonate from the Eocene Green River Formation with the dominance of clastics in East Africa. D.M. McKirdy and his Australian colleagues elegantly argued for the presence of major Cretaceous lacustrine source rocks off south Australia on the basis of biomarkers in hydrocarbons washed on shore. According to a series of papers dealing with biomarkers in diverse China basins, their source rocks, with surprisingly low total organic carbon contents, are thought to represent a range from fresh to brackish, saline, swampy to coastal lake environments.

Several types of geochemical markers show promise as paleoenvironmental indicators, though data from modern systems is insufficient. These include C/S ratios, where the overlap with marine can be eliminated (W. Davison, U.K.), the variability of clays (R.F. Yuretic, U.S.A.), the C^{13} and O^{18} records for authigenic, biogenic and diagenetic carbonates, and elemental ratios in carbonate fossils. Two worlds merged as L.A. Slezak and W.M. Last (Canada) reviewed the variety of salt lake deposits in western Canada.

The conference left an impression that most large-scale source rocks reflect low to medium salinities. Considerable basic process research, however, and new data collection and syntheses are needed so as to integrate geologic research on lacustrine basins. The potential is amazing.

The proceedings will be published in 1986 as a special publication of the Geological Society of London.

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Ecostratigraphy and Mineral Deposits

Budapest, Hungary, 15 - 22 September 1985

The present state of knowledge of Mediterranean Neogene stratigraphy, environmental evolution, paleogeography and geodynamics offers unique possibilities for pioneer studies on the origin, accumulation and distribution of Late Cenozoic mineral resources, both in time and space. This is one of the most important conclusions to be drawn from the 8th Congress of the IUGS Regional Committee on Mediterranean Neogene Stratigraphy (RCMNS), which took place recently in Budapest. The 470 specialists in attendance from 33 countries presented some 300 papers, poster sessions and other contributions in a highly successful meeting.

The Congress included a special symposium on mineral resources, the presentation of the first results of the IUGS-sponsored research project "Paleogeographic Map Series of the Neogene of Central and Eastern Europe", a discussion of results and problems arising from the work of the IUGS Working Group on the Paleogene-Neogene Boundary, and a workshop organized by the Working Group on Benthic Foraminifera of the IUGS Subcommittee on Neogene Stratigraphy.

The Congress had three major themes: Relative and Numerical Time-scales, Geo-history of the Mediterranean and the Paratethys, and Paleogeography-Ecostratigraphy. Contributions revealed the progress recently made in understanding the factors controlling the temporal and spatial distribution of fauna and flora. This progress can mainly be attributed to the increased knowledge of the complex interplay between environmental (e.g. climatic) trends and fluctuations, and the effects of geodynamic events on paleogeography and basin configurations. New biostratigraphical and physico-chemical data also made it possible to further refine the relative and numerical time-scales for the Neogene of the Mediterranean and Paratethys.

Figure 1: Members of the excursion to Soviet Georgia on the southern limb of the Kvabebian Syncline where transgressive Aktsagilian conglomerates overlie continental sediments of the Shirakian suite. Photo by T. Cserny.

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The research goals of the RCMNS set during the 7th Congress in Athens, 1979, which emphasized ecostratigraphy (see Episodes vol. 1979/4), are thus now firmly established. This is also evident from the four "interim-colloquia" organized in the time-span between the 7th and 8th RCMNS Congresses. Proceedings of a meeting in Utrecht, The Netherlands (1983: Reconstruction of Marine Paleoenvironments; Principles and Methods) and a colloquium in Montpellier, France (1983: Continental Paleoenvironments and Climatic Evolution) have been published in the Utrecht Micropaleontological Bulletins and in *Paleobiologie Continentale*, respectively. The results of the interim-colloquium on Marine Megafossil Biostratigraphy and Paleoenvironments (Athens, Greece, 1984) will be published in *Annales Geologiques des Pays Helleniques*, and those of the conference on Paleogeography and Geodynamics of the peri-Tyrrhenian area (Firenze, Italy, 1984) are in press in *Giornale di Geologia*.

Bridging the gap between pure and applied research was the main goal we had in mind by organizing the special Symposium on European Late Cenozoic Mineral Resources during the RCMNS Congress. This reviewed various aspects of resources such as hydrocarbons, lignites, diatomites, evaporites, metallic ores and hydrothermal energy. Case histories challenged RCMNS to contribute to model studies on the origin, accumulation and distribution of mineral resources, especially with regard to Neogene ecostratigraphy, basin development and geodynamics. Indeed, during a business meeting sponsored by Unesco, 64 scientists from 22 countries decided to initiate just such a project.

A prominent feature of the Congress was the publication of 19 nicely printed and well-illustrated books, field guides and special issues of journals. These are listed separately in the For Your Bookshelves section of this issue. The Congress was organized by the Hungarian Geological Survey and Geological Society under the capable direction of G. Hármor.

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Neogene Phosphorites of Southeastern U.S.A.

Florida, U.S.A., 6 - 17 May 1985

Although there is no global shortage of phosphate, the billions of tons of ore that have been identified are rather inequitably distributed. Morocco and the U.S.A. now dominate the phosphate export trade. Many countries, especially in Asia, Africa and Latin America, have no domestic production and lack hard currency to pay for phosphate imports. Accordingly, there is much under utilization of phosphate-based fertilizers by Third and Fourth World countries, those most in need of increasing food production. Clearly, the uneven supply of phosphate rock is one of the key factors preventing maximization of agriculture in many parts of the globe.

An IGCP project to address the question of world phosphate resources as well as scientific questions concerning the age, distribution, and origin of marine sedimentary phosphate

Figure 1: Discussing phosphorites on board the Cape Hatteras.

deposits was initiated in 1978 by two Australian scientists, Peter Cook and John Shergold. Project 156 - Phosphorites - has since become one of the most active within IGCP, and field workshops, training courses and seminars have been held in Australia, U.S.A., India, Mongolia, China, Morocco, Thailand, and the U.S.S.R. The Project is currently in the process of producing a series of four volumes, entitled "Phosphate Deposits of the World," which is to be published by the Cambridge University Press.

The 8th International Field Workshop and Seminar of Phosphorites, held recently in North Carolina and Florida, was attended at least in part by over 150 scientists from some 40 countries. It was preceded by a short course for geologists from developing countries at East Carolina University on phosphate geology.

The phosphate resource potential of the southeastern U.S.A. is extremely large. However, mounting land use and environmental pressures cause considerable uncertainty regarding the availability of future land-based phosphate reserves, particularly in Florida. The result has been an increased interest in the deeper and lower-grade deposits of other portions of the southeast U.S., including the extensive offshore resources of the Atlantic continental shelf.

The first phase of the field trip was an examination of the deep and totally unweathered stratigraphic section in the recently developed Aurora, North Carolina, phosphate district. Future potential of the newly discovered deposits on the continental shelf were considered during a cruise on board the National Science Foundation vessel R/V Cape Hatteras. Exploration techniques including geologic sampling, high-precision seismic profiling, and side-scan sonar were emphasized during this cruise. Also included was an aerial excursion, which permitted excellent views of the phosphate deposits together with the large-scale structures that have controlled their deposition. The geology of the modern and Pleistocene barrier island and estuarine coastal systems was also clearly visible.

In Florida the phosphatic sequences, which are regarded as originally similar to those in North Carolina, are altered by a major weathering profile. The group examined the least-weathered portion in drill cores from south Florida, and then traced the increasing degree of weathering in shallow mines of the updip area of central Florida. The extremely weathered portions were visited in the hardrock phosphate district on the Ocala Upland. Unraveling the stratigraphic and

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mineralogical complexities produced by the diagenetic processes of weathering is critical to an understanding of the depositional history of the central Florida deposits.

Following the field trip a symposium was held in Tallahassee, Florida, on "Genesis of Neogene to Modern Phosphorites." This was designed to synthesize knowledge concerning the southeastern U.S. phosphate system, compare it to other deposits, and discuss its origin in light of recent studies on modern ocean-floor phosphorites. Papers on modern phosphorite environments were followed by a review of the Neogene environment including its global paleogeography, the effect of changing conditions on the geochemical cycles of S, C, O and phosphate, and the relationships between changing climates, cyclic sedimentation, and the development of the extensive U.S. phosphatic sediments. The proceedings of the symposium will be published by Cambridge University Press.

Plans are currently being finalized for the next Project 156 Field Workshop and Seminar to be held in Venezuela, March 16-26, 1986. A special Project 156 symposium on "Cyclicality and Phosphogenesis" has also been planned for the 1986 International Sedimentological Congress to be held in Canberra, Australia, August 24-30. Further details of this and other Project activities are available from W. Burnett (Dept. Oceanography, Florida State Univ., Tallahassee, FL 32306, U.S.A.) or S. Riggs (Dept. Geology, East Carolina Univ., Greenville, NC 27834, U.S.A.), the current Project Leaders.

After report by W.C. Burnett, S.R. Riggs and R.P. Sheldon

Natural Zeolite '85

Budapest, Hungary, 12 - 16 August 1985

An international conference on the Occurrence, Properties and Utilization of Natural Zeolites was held recently in Budapest, sponsored by the International Committee on Natural Zeolites and several Hungarian organizations. It attracted 158 specialists from 34 countries, from geologists to users, with the natural zeolites serving as a common link. The interdisciplinary nature of the conference was shown by the spread of topics discussed, from geological occurrences, mineralogical properties, crystal chemistry and physical properties, to synthesis and stability, catalysis, adsorption, water purification, ion-exchange and agricultural applications.

In his critical commentary on the development of uses for natural zeolites, F.A. Mumpton (U.S.A., Chairman of the International Committee) emphasized that the natural zeolites have not yet achieved the success that was predicted two decades ago. Their development has been hindered by efforts to market the natural product for sophisticated uses without performing the necessary research to match the specific zeolite with the intended application. An international program of natural zeolite characterization could prove a major step in this direction by determining what properties are important for what applications and by evaluating how best to measure these properties.

J.R. Boles (U.S.A.) reviewed the modes of zeolite occurrences and pointed out the need for research related to their genesis, especially the influence of fluid composition on zeolite mineralogy, the nature and significance of associated clays, the PT stability relations between different types of zeolites, and the reaction kinetics. Other invited lectures dealt with the structural classification of zeolites (W.M. Meier, Switzerland), the tetrahedral framework of natural zeolites (G. Gottardi, A. Alberti, Italy), the perspectives of natural zeolites (G.V. Tsitsishvili, U.S.S.R.), and clinoptilolite and mordenite as catalysts (D. Kallo, Hungary).

Papers reviewing the geology of deposits from the U.S.A., Japan, Czechoslovakia, Hungary, Bulgaria, Yugoslavia, Italy, and Turkey provided prominent examples of the process of zeolitization during burial metamorphism, diagenetic transformation, formation from hydrothermal solutions, as well as on the genetic aspects of marine and lacustrine zeolites. I. Iijima (Japan) showed that in silicic vitreous volcanoclastic rocks interbedded within thick marine sequences, the alkali-zeolite reaction series can be used as a geothermometer. The temperature-dependent zeolite zones so determined can be used in petroleum exploration to estimate both the maturity of hydrocarbons and the paleogeothermal gradient in sedimentary basins.

The bulk of the papers presented concerned the application and uses of zeolites. These included encouraging results obtained in ammonium yield in water purification, and the extraction of Cu, Pb, Ag, Zn, and Cd from galvanic waste waters. Participants visited the first water purification plant in Hungary to use natural zeolites to clear urban waste waters. Another promising technique involves the sorption of radioactive materials (Cs, Sr) in the safe disposal of nuclear wastes.

Studies were presented on the adsorption of different poisonous organic materials and gases (e.g. aromatic chlorine, As-bearing organic compounds, NH_3 , SO_2 , NO_2), in which natural zeolites pre-treated by acids are used. As regards catalysis, the discussions centered on the application of pre-treated natural zeolites. Included here were papers on the production of hydro-sulphurization catalysts by means of de-alumination of natural mordenite and clinoptilolite with simultaneous Co and Mo exchange, and the increase of the specific surface of mordenite by acidic treatment.

The conference also considered the use of zeolites in agriculture, increasing the potential of fertilizers, improving animal feeds and purifying the animal waste waters. Finally, several papers were read on the application of zeolites to the storage of solar energy, in order to solve heating and cooling

Figure 1: Visiting a zeolite processing plant in the Tokaj Hills near Budapest. Photo by P. van Straaten.

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problems. The Conference proceedings are being published in 1986 by the Akadémiai Kiado (Publishing House of the Hungarian Academy of Science) and by Reidel.

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Assessing and Predicting Earthquake Hazards

Tokyo, 26 - 30 August 1985

A symposium held recently during the 23rd General Assembly of the International Association of Seismology and Physics of the Earth's Interior (IASPEI) was somewhat unusual in that it brought together scientists assessing regional earthquake hazards with those attempting to predict the time of occurrence and location of specific events. Traditionally these topics have been considered as quite separate, mainly because the nature of the phenomena being studied is often quite different.

The IASPEI Bureau has felt for some time that the separation between seismic hazard assessment and earthquake prediction is unfortunate and somewhat artificial, and at the 1983 IUGG Assembly in Hamburg a Commission on Earthquake Hazards was formed to address both topics. The Tokyo symposium was the first activity organized by the new Commission and its success, therefore, was all the more gratifying.

The 121 contributions presented as talks and posters ranged over the complete spectrum of hazard assessment and earthquake prediction. In theme papers that opened the meeting, M.J. Berry (Canada) emphasized the fundamental problems in the assessment of seismic hazards, while F.F. Evison (New Zealand) explained both the nature of the continuum between the topics and the need for clearly defined hypotheses against which predictions can be tested.

Developments in seismic hazard assessment techniques were presented by several speakers, with considerable emphasis being placed on the nature of the uncertainties in the process. R.K. McGuire (U.S.A.) pointed out that uncertainties in seismicity, geology, tectonics, and in estimating strong ground motion all play an important role. He showed by the extensive use of logic trees that the consequences of uncertainties in the input parameters can be explored. The advantage of performing large numbers of computations is that all possible hypothesized states of nature can be considered in a properly weighted context.

New techniques of hazard assessment, as well as more traditional approaches, were applied by several authors to a wide variety of geological environments, illustrating many of the difficulties that remain to be solved. The maximum magnitude to be associated with future events remains a

major problem, as does the regional variation of the attenuation of strong ground motion and the manner of its scaling with earthquake magnitude. Careful studies of seismicity patterns were used to develop models for both statistical predictions of future ground motion and the occurrence of specific future earthquakes. Much emphasis was placed on seismic gaps, especially by those making predictions.

A number of papers presented the results of recent studies of crustal deformation, tilt, strain and stress-related precursors. Some remarkable data were presented, especially for Japan, where an extensive program devoted to earthquake prediction has shown that variations of tilt and strain can be quite large and not obviously correlated with recent seismicity. Studies on the Tokai Peninsula, where a large earthquake is forecast, are particularly comprehensive and clearly will provide, in due time, the basis for a textbook study of precursory phenomena.

While no specific conclusions were reached during the symposium, two general themes were stressed or implied. It is clear that there is an increasing need for the development of slowly time-varying probabilistic regional estimates of strong ground motion, particularly in areas subject to great earthquakes with long return periods (i.e. time-varying seismic hazard assessment). In the shorter time frame, there continues to be a major requirement for an improved understanding of the physics of the earthquake process. We still do not fully understand how regional stress fields are perturbed by local structures to produce local stresses that exceed the breaking strength of rocks, nor how such stresses relate to the wide variety of signals that we are now measuring at the earth's surface.

The symposium was co-sponsored by the ICL, and its success has led to plans for a second symposium with the same twin themes to be held during the 1987 IUGG in Vancouver.

M.J. Berry, Ottawa, Canada
and F.F. Evison, Wellington, New Zealand

Granite-Related Ore Deposits

Halifax, Nova Scotia, 15 - 17 September 1985

Originally planned as a response to a burgeoning worldwide growth in exploration, a Conference on Granite-Related Mineral Deposits was held recently in eastern Canada under the sponsorship of the Canadian Institute of Mining and Metallurgy. Though the exploration fervour for metals associated with granitic rocks has cooled somewhat since the conference was first planned, the ardour of the geologists attempting to explain these deposits has not. Several papers described recent occurrences and even new deposit types, while others focused on detailed descriptive studies of long-known deposits. The participants were left with the impression that the nature of many tin, tungsten, and molybdenum deposits is relatively well-known and that exploration for them has been quite successful. However, many genetic problems remain to be solved.

M. Pichavant (France) presented compelling evidence that the sort of metal-rich melts that many of us have postulated for years can exist in nature. He presented field occurrence and comprehensive chemical data for Tertiary volcanic rocks near Macusani, Peru, that show abundant mineralogical evidence for derivation from the partial melting of a pelitic metasedimentary source. Derivative melts, as shown by

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analysis of aphyric obsidian, contain as much as 1.3% F, 80 ppm W, and 200 ppm Sn. Isotopic data discussed by B. Taylor (Canada) show that simple degassing of rhyolite plutons can result in decreasing deuterium values with decreasing water content. Similar patterns have sometimes been interpreted to demonstrate subsequent hydrothermal activity.

Two papers reported the existence of a new type of deposit that may contain substantial resources of Be, Zr, Y, Nb, Ta, Ga, and rare-earth elements. The Thor Lake deposit in the Northwest Territories (D.L. Trueman, J.C. Pedersen, L. de St. Jorre, and D.G.W. Smith, Canada) and the Strange Lake deposit on the Labrador-Quebec border (R. Miller, Canada) appear to be the result of magmatic and hydrothermal events associated with highly-evolved alkaline intrusives. Potential ore is found both as primary igneous rocks of exotic composition (Thor Lake) and as greisen-like altered rocks (Strange Lake). Both occurrences are Precambrian in age and strongly peralkaline in their petrotextonic affinity, though carbonatite seems not to be present.

Detailed studies at Henderson and other Climax-type porphyry molybdenum deposits in Colorado were also reviewed. R. Carten, B. Walker, and E. Geraghty (U.S.A.) showed from very detailed underground mapping that the Henderson orebody is the result of at least 12 separate intrusions, each with an accompanying mineralizing event. The distribution in time and space of a wide variety of alteration assemblages was then related by E. Seedorf (U.S.A.) to the individual plutons and to groups of intrusions closely spaced in time. H. Stein (U.S.A.) presented abundant lead, strontium, oxygen, and sulphur isotopic data that strongly suggest that Climax-type granites and associated mineral deposits were produced by deep crustal melting of a unique source, and that the stocks were the source of most, if not all, of the metals in the deposits.

A perennial problem concerns the nature of the source material for granite magmas that give rise to ore deposits. Granite types delineated recently on the basis of their source region have been correlated by many with the occurrence of specific deposit types. Yet abundant evidence was presented in Halifax suggesting that the processes that concentrate metals enough to make ore deposits occur largely within individual magma bodies with volumes of 1 km³ or less, rather than in source regions of the mantle or lower crust.

On the other hand, the existence of identifiable metallogenic provinces, as exemplified by the tin-rich terrane of Bolivia and southern Peru, is a strong argument for the importance of source. However, the paucity of regional petrochemical data in most terranes leaves undemonstrated the idea that homogenous sources result in homogenous igneous products. Likewise, the existence of igneous suites that cut across the boundaries dividing I- and S-type granites casts some doubt on the discriminatory power of the classification schemes we use, though not necessarily on the validity of the concepts themselves.

Though the importance of processes was highlighted, there remains considerable controversy over their nature. There is little consensus within the granite community about the nature of the processes that result in highly evolved granitic melts. Many scientists continue to find abundant evidence for the role of crystal fractionation, whereas others prefer more poorly understood processes that primarily involve liquids and vapours. Whatever the answer, it seems probable that metal concentration at the magmatic stage is a vital link in the chain of events that results in a lode deposit of tin, tungsten, or molybdenum. Conspicuously absent from the discussions were any suggestions that meteoric waters have a significant role in the primary deposition of the ores discussed.

A further topic that needs attention is the manner in which metal-rich fluids developed within the pluton are able to collect, escape, and ultimately deposit their metals exterior to cooling plutons. That such a mechanism exists and operates seems no longer in doubt, but the detailed controls of ore deposition are far from clear.

Selected papers from the conference will be published in 1986 under the title "Granite-Related Mineral Deposits: Geology, Petrogenesis and Tectonic Setting". Further details may be obtained from the convenor R. P. Taylor, Dept. of Geology, Carleton University, Ottawa, Ontario, Canada K1S 5B6.

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Geomorphology, Environmental Management and the Developing World

Manchester, England, 15 - 21 September 1985

A remarkably successful first International Conference on Geomorphology was held recently at the University of Manchester and organized by the British Geomorphological Research Group. With an estimated attendance of over 500, there were large delegations from many countries, including Canada, France and the Peoples' Republic of China (believed to be the largest delegation from that country to attend a scientific congress), and small contingents from an amazing array of nations - a truly international gathering.

Among the scientific workshops was one on drumlins, organized by J. Rose (U.K.) and J. Menzies (Canada). It is apparent that the time has come for a major rethinking on the mechanism of formation of these fascinating landforms. John Shaw (Canada) presented compelling evidence for the formation of drumlin-like features beneath large ice sheets by large-scale sheet flow of water, and several speakers reported elegant field work showing the stratified nature of drumlins. The book, to be edited by Rose and Menzies, which will result from this workshop, will be a milestone in drumlin studies.

Peter Fookes (U.K.) showed convincingly the growing relationship between engineers and geomorphologists - to their mutual advantage. The interest in process is still apparent, and the great exploits of geomorphologists in this area are still being applauded, but the emphasis of today is on applied geomorphology. A lecture by R.U. Cooke (U.K.) on "The Use of Geomorphology," included a particularly interesting story of salt weathering. He showed that contrasts between the rate of thermal expansion of salts and of rocks were an important contributor to weathering, as seen, for example, in current attempts to save the stonework of St. Pauls Cathedral.

A session on loess was a fine example of international contributions, and many significant papers were presented. Alan Lutenecker (U.S.A.) showed that loess derived from the sandhills of Nebraska is recent and can be considered a real desert loess - justification for the long neglected views of the late A.L. Lugin (U.S.A.). G. Coude-Gaussen (France) discussed dust derived from the Sahara and the significance of observations of palygorskite. It is interesting to note that

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palygorskite has been observed by investigators of the aeolian sediments of S.E. Australia and may perhaps be a significant indicator for desert deposits. E. Derbyshire (U.K.) showed beautiful slides of loess material in Qinghai Province, China. Loess is found well up into the Chinese highlands, which are presumably source areas for the great deposits in the lower regions - but we still appear to lack a convincing mechanism for producing finer loess particles.

Various working groups and commissions of IGU met during the conference, and several associated organizations produced special publications for the meeting: the NASA mega-geomorphology volume was widely distributed, the Geographical Institute of the Hungarian Academy of Sciences produced several impressive volumes, and there was even a special issue of *Loess Letter*. Of the publishers who came, Geo Books of Norwich put on the best display, offering books at half-price to the delegates. They seem to have grasped the basic point that all earth scientists appreciate books that they can afford, and that novel publishing ideas are welcome. Their bibliographic series is particularly impressive, and some excellent volumes were on display.

It was a good conference. One was impressed by the strength and vigour of British geomorphology, pleased that Leszek Starkel of Poland was given the David Linton award, and excited by the prospect of doing it again in four years time when a second conference will be held in West Germany. The quadrennial geomorphology conference looks set to join

Figure 1: Relaxing in Manchester. l-r: R. Barsch (F.R.G.), A. Yamamoto (Japan), D.A. St-Onge and M. St-Onge (Canada), L. Starkel (Poland) and A. Pissart (Belgium).

INQUA, IGU and IGC as a major meeting. The INQUA posters were highly visible at Manchester - the Canadian planners are making a good job of informing us that we should all be in Ottawa in 1987.

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