A Decade of Phosphorite Research

IGCP Project 156 - Phosphorites - is now in its final year of operations, following ten active years of research. Initiated in 1977 by Co-Leaders P.J. Cook and J.H. Shergold of the Australian Bureau of Mineral Resources, Project 156 was renewed in 1984 for a final four years under new Co-Leaders S.R. Riggs (East Carolina University, U.S.A.) and W.C. Burnett (Florida State University, U.S.A.). Since the outset the objectives of IGCP 156 have been to encourage and coordinate the interchange of scientific research and information for the international research community interested in marine phosphorites and associated sediment systems.

More than 300 scientists are now actively involved in research on phosphorites and associated minerals, as well as their exploration and development. An international communication network has been developed with a newsletter now distributed to over 700 persons in 60 countries, and there are National Committees in 30 countries and correspondents in another 20. IGCP 156 has thus developed a very broad base from which to tackle major global sedimentological questions concerning the genesis of marine phosphorites and associated organic-rich sediments and their relationship to event stratigraphy through global tectonic, paleogeographic, and paleoceanographic processes.

There are four Working Groups within the project: I - Precambrian and Cambrian phosphorites of Australia and Asia, II - International Phosphate Resource Data base, III - Young Phosphogenic Systems of the Upper Cenozoic, IV - Cretaceous and Paleogene Phosphorites. The major emphasis now is on the Cretaceous, Tertiary, and modern phosphates of both Tethys and the modern ocean basins and adjacent continental margins.

The scope of the project has evolved to the modelling of oceanic upwelling and genesis of authigenic and diagenetic sedimentary sequences along continental margins including phosphorite, organic matter, diatomite, dolomite, glauconite, etc. In 1987, the tenth international field workshop and symposium was held in Tunisia, a major world producer and exporter of phosphate. This was the fourth IGCP 156 meeting to be held in the Tethys region, following Morocco (1983), Iraq and Venezuela (both in 1986). The associated field trip was designed to enable participants to compare and contrast important Tunisian deposits with other Cretaceous and Paleogene deposits occurring throughout the

extent of the Tethys Ocean, as well as deposits of similar age occurring in many other regions.

Tunisia is a major world phosphate producer and exporter. Of special interest were trips to examine the phosphate sequences and associated organic-rich sediments that occur within three basins, each of which has a different paleo-oceanographic setting around the major paleo-landmass of Kasserine Island on the southern continental margin of the Tethys Ocean. Sediments within the basins range from shallow, open marine deposits in the Sra Ouertane Basin on the northern side of Kasserine Island, to those deposited in the small, semi-restricted embayments of the shallow Maknassy-Messouna Basin on the east side of the low-lying landmass, to the sediments of the intra-cratonic environments of the Gafsa-Metalaoui Basin within an extended marine gulf south of Kasserine Island and north of the Saharan Platform. An excursion was also made into the sabkha environments and experimental potash brine deposits of Chott Jerid and into the aeolian sediment environments of the northern Sahara Desert.

Project 156 is co-sponsoring, together with the Australian Bureau of Mineral Resources, a major multinational and interdisciplinary research project called PHOSREP, under the leadership of P.J. Cook. This is addressing topics ranging from the formation of phosphorites to changes in the global phosphorus cycle. The Australian deposits offer unique opportunities to explore questions of fundamental importance to our understanding of the formation of phosphorites, and PHOSREP, which will run until later this year, ranks among the most ambitious activities of its kind attempted by an IGCP project.

Figure 1: Habib Belayouni pointing out features of the Jebel Ank phosphate section in the east portion of Gafsa Basin in southern Tunisia.

Within PHOSREP there are three major sub-projects. Under the first of these, on Cambrian Phosphorites of the Georgina Basin, NW Queensland, new sample suites have been collected for detailed biological and chemical studies on the origin of this complex stratigraphic sequence of phosphorite and associated organic-rich sediments. Two deep holes have been drilled to obtain unweathered rock samples of the poorly known down-basin section. A second sub-project is studying Onshore Tertiary Phosphorites. Several major field trips have been carried out to the southern Victoria coast of SE Australia and the east coast of the South Island of New Zealand, where there are known occurrences of Tertiary

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phosphorites and glauconites. These may be equivalent to major phosphorite sediment sequences that formed globally during the mid-Tertiary. The third sub-project, on Offshore Tertiary-Recent Phosphorites, is studying the occurrence and origin of extensive Neogene to modern phosphorite and glauconite sedimentation on the East Australian continental margin.

Planned for 1988 is a Field Workshop and Symposium on "Cretaceous and Tertiary Phosphorites of Jordan." This will consider the nature and origin of phosphorite deposits in Jordan and the Tethys Province, one of the world's most important phosphate belts. A second Field Workshop is being held in Peru on "Genesis of Cenozoic Phosphorites and Associated Organic-rich Sediments: Peruvian Continental Margin." The Pisco Basin is the best exposed of Peruvian marine fore-arc basins and serves as a textbook example of this sedimentary environment. It is one of the few well-exposed, young, tectonically simple settings in which ancient high productivity marine sediments are preserved on land.

Sediments of the Pisco Basin are the subaerial equivalents of sediments cored offshore during ODP Leg 112 (von Huene et al., Episodes, June 1987), and they provide excellent

examples of primary sedimentologic and diagenetic results of upwelling and include phosphate, chert, and dolomite. The region is ideal for studying the history of coastal upwelling on the western margin of South America and for examining the link between upwelling and Cenozoic Antarctic glaciation. This system provides a Southern Hemisphere counterpart to better known, contemporaneous, and economically important units such as the Monterey, Pungo River, and Hawthorn formations of the United States. Thus, it should be possible to determine whether patterns of sedimentation and facies changes within each of these formations are local features or whether they represent important features of common global oceanic processes.

The final conference of IGCP 156 entitled "Phosphorites, A Decade of Progress in Research and Development" will be held in Oxford, England in September 1988, and will highlight the scientific achievements that have resulted from the decade of phosphorite research and the unanswered questions that require continued investigations. □

After report by S.R. Riggs and W.C. Burnett

ILP Reviewed

The solid earth sciences are organized in two different Unions, the International Union of Geodesy and Geophysics (IUGG) and the International Union of Geological Sciences (IUGS). Although the background of each and of their member scientists is different, it is quite obvious today that new understanding on how the Earth operates at present and in the past requires a joint approach to the study of our planet. It is the task of the Inter-Union Commission on the Lithosphere (ICL) to establish this link and to provide the base for such tasks as require inputs from both Unions. Cooperation in the field of the solid earth sciences between the two Unions has a long tradition. The need for close links was manifested in the past by the Upper Mantle Program, the Geodynamics Project and now by its continuation in the International Lithosphere Program (ILP), run by the ICL.

Among the current ILP projects, the largest is on "Global Geoscience Transects" (GGT). This uses existing geological, geophysical and geochemical data to produce interpretative cross-sections, drawn to the base of the crust, and deeper where data permit (see article by Monger in Episodes, December, 1986). GGT encourages geoscientists in all countries to compile transects in a common format so that crust in all parts of the world can be directly compared. The cross-sections, which emphasize continental regions but not to the exclusion of ocean basins, are in effect vertical tectonic maps of the Earth's crust, and ideally portray its evolution along the transect line.

Figure 1 shows the 126 transects already proposed for 58 countries. It is obvious from this map that GGT has generated a great deal of international interest, enthusiasm and cooperation, partly because it is a natural next step beyond traditional surface-bound studies, partly because it encourages geologists and geophysicists to work together, and partly because it involves geoscientists with local and regional knowledge in a project of global scope.

Since August 1987 GGT has been run by ICL Coordinating Committee 7, chaired by J.W.H. Monger, from whom detailed guidelines for transect compilation are available (Geological Survey of Canada, 100 West Pender Street,

Vancouver, BC V6B 1R8). Close links are being developed between GGT and programs like the Circum-Pacific and Circum-Atlantic map projects and the European Geotraverse. Some preliminary transects have already been presented and a more complete set will be presented at the 1989 International Geological Congress in Washington.

The Reflection Survey of the Continental Crust is another successful project with a long time component. The number of participating countries has been steadily increased. The same is true for the number of new scientific results, such as the high reflectivity of the laminated lower crust discovered in many parts of the continental crust and the first clear reflections from the subcrustal lithosphere obtained to the north of the British Isles. Closely linked is Deep Continental Drilling, which has been recognized from the beginning of the ILP as a key project that can open new doors for the geosciences. More and more countries are now drilling, or planning to drill into the crystalline crust, and ILP is presently the only international platform for coordination of these efforts.

Seismic tomography and digital seismic networks provide new tools to understand how the Earth works at depth. Accordingly, another long-term project of the ILP is

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entitled Global Seismic Tomography and its Relation to Processes and Composition of the Earth Interior. And at the initiative of ICL a Federation of Digital Seismic Networks was formed in 1986 and is now affiliated to ICL and to IASPEI.

To understand plate tectonics and tectonic stresses in the lithosphere requires a detailed knowledge of the state of stress in the crust. This is being studied in another global ILP project, the World Stress Map, which aims to compile all reliable data on stress at depth from various sources, such as fault plane solutions, hydrofrac experiments and analysis of borehole breakout orientations. Global, regional and local maps of stress trajectories, will be produced and will be of interest to global modellers, and rock mechanics specialists, reservoir engineers and others.

One concern of ICL is to improve communication within ILP, with member countries and with the Unions. This is being done through the ICL Newsletter, which includes reports from ICL working groups and coordinating committees. The 1987 Directory is a very practical tool for finding persons and linking them across the broad disciplinary spectrum of ICL. Reports on ILP activities are published from time to time in IUGS and IUGG publications as well as in other journals and newsletters.

Once a year ICL joins in the preparation of a larger congress, where meetings of the ICL Bureau, the Commission and the various Working Groups and Coordinating Committees are held. In August 1986, this was held at the Circum-Pacific Conference on Mineral and Energy Resources at Singapore, in 1987, during the IUGG General Assembly in Vancouver, and in 1988 the link will be with the Latin American Geological Congress at Belem, Brazil. In 1989 ICL will participate in the International Geological Congress at Washington with about 16 co-sponsored symposia presently being organized.

The results of the first five years of the International Lithosphere Program are being published in the well-known Geodynamics Series of the American Geophysical Union and the Geological Society of America. Seven volumes were scheduled for appearance in 1987.

Unfortunately, the present funding of ICL by ICSU, both Unions, Unesco and by voluntary contributions from a few member countries does not allow ICL to provide more than seed money to its projects and to participants in its scientific meetings. ICL tried to overcome this difficult financial situation by co-sponsoring, with little or no financial input, meetings already scheduled, but there is also a need to organize dedicated meetings on topics which the ICL community wants to pursue in depth.

In view of the 1986 decision by ICSU to extend the ICL mandate beyond 1990, ICL can now sponsor international and interdisciplinary research programs with a long-term perspective, without the need to re-establish new cooperative links between IUGS and IUGG every ten years or so, as in the past. Accordingly, the ICL Bureau has approached all member countries for financial contributions to special ICL projects, in the hopes of an improved financial situation. The two parent unions have now charged ICL with the preparation of a science policy and plan for the 1990s. This will involve not only organizational changes but will also evaluate whether a more project-oriented structure would be better for the program. ICL must improve its ability to recognize, identify and sponsor key projects in the solid earth sciences that are of prime interest to both Unions. The plan is now being readied for submission to both Unions and to ICSU at the end of 1988, with review and decisions in 1989 to allow for a smooth transition into the new decade. □

- after reports by K. Fuchs and J.W.H. Monger

New IGCP Projects Approved

The Scientific Committee and Board of the International Geological Correlation Programme (IGCP, sponsored jointly by IUGS and Unesco) met recently to review the activities of 1987. IGCP received another strong endorsement from the Unesco General Conference in late 1987. As IUGS President Seibold pointed out, funds provided by Unesco and IUGS are now multiplied 50 to 200 times when other contributions are considered. The "fruits of the tree," he reminded Board members, now amount to more than 40,000 publications. However, gaps in the program still persist, Seibold said, for example, in studies of shallow marine and continental environments, especially in the Pleistocene, and in areas related to global change and natural hazards.

In his address, V. Sibrava, Director of Unesco's Earth Sciences Division, recalled the substantial influence that IGCP was having on the increased attendance at scientific meetings of scientists from developing countries. He stressed the need to ensure that IGCP project leaders and participants from the Third World would be able to attend the 1989 International Geological Congress in Washington, D.C.

It is clear that IGCP is now very strong in Latin America, both in terms of quality and extent of the work being done. Activities in Africa, however, need to be expanded. E. Dudich, the IGCP Secretary, noted efforts to organize IGCP regional meetings in Arab countries, in northeast Asia and in eastern Europe, and the Board resolved to increase efforts to set up national committees for IGCP in countries now

participating in IGCP projects: Albania, Dominican Republic, Fiji, Ghana, Haiti, Kuwait, South Africa, Tanzania and Zimbabwe.

The Board identified several IGCP projects as falling within Unesco's new Subprogramme "Quaternary Geoscience for Human Survival." This had been accepted by the Unesco General Conference in late 1987, and a sum of \$20,000 was allocated for 1988-1989 for a new major regional project on this topic in Southeast Asia and the Pacific. Links were also reviewed between IGCP and the IUGS Commission on Stratigraphy, COGEODATA, ILP, the Intergovernmental Oceanographic Commission, the Deposit Modelling Program (see conference report, this issue, by Cunningham and Erickson), and the U.N.

Twenty projects were scheduled to end in 1987 and twelve were given extensions as follows:

- 5 - Correlation of Pre-Variscan and Variscan events of the Alpine-Mediterranean mountain belt (for 1988)
- 157 - Early organic evolution and mineral and energy resources (for 1988)
- 158 - Paleohydrology of the temperate zone (for 1988)
- 165 - Regional stratigraphic correlation of the Caribbean (for 1988-1989)
- 196 - Calibration of Phanerozoic time scale (for 1988)
- 198 - Evolution of the northern margin of Tethys (for 1988)

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- 199 - Rare Events in geology (for 1988)
- 206 - Comparison of major active faults (for 1988)
- 219 - Comparative lacustrine sedimentology (for 1989)
- 226 - Correlation of manganese sedimentation with paleoenvironments (for 1989-1990)
- 236 - Precambrian events in the Gondwana fragments (for 1989)
- 250 - Regional crustal stability and geological hazards (for 1988).

Twelve new projects were approved as follows:

Project 256 Ophiolite Genesis and Evolution of Oceanic Lithosphere

(1988-1992). Project Leader: L. Beccaluva (Istituto di Mineralogia, Corso Ercole I° d'Este, 32, 44100 Ferrara, Italy). This project will refine the role of ophiolites in different oceanic settings, especially arc and back-arc basins. It will review the "typology" of ophiolites as regards their distinctive petrological character and genesis, and will work to develop genetic models of oceanic accretion in marginal basins and other oceanic settings.

Project 259 International Geochemical Mapping

(1988-1993). Project Leader: A.G. Darnley (Geological Survey of Canada, 601 Booth Street, Ottawa, Ontario, Canada K1A 0E8). The aim here is to promote the compilation of an international series of systematic surficial geochemical maps. These will show abundance levels, regional trends and geochemical provinces and should permit the recognition of large anomalous features.

Project 269 A Global Data Base in Sedimentary Petrology

(1988-1992). Project Leader: N. Nishiwaki (Dept. of Geology and Mineralogy, Faculty of Science, Kyoto University, Kitashirawaka, Sakyo, Kyoto, 606, Japan). Following discussions within the IUGS Commission on Systematics in Petrology, this project will design and construct a prototype global data base for sedimentary petrology. Included will be discussion of the data structure, design of data sheets, collection source data, and input, update and distribution of the data itself.

Project 270 Early Paleozoic Events in Latin America for the Gondwana Genesis

(1988-1992). Project Leaders: F.G. Acenolaza and O.L. Bordonaro (Miguel Lillo 205, 4000 San Miguel de Tucuman, Argentina). This project will evaluate sedimentary events in Andean and related basins during the late Precambrian and early Paleozoic, and "tectosedimentary," magmatic and metamorphic events will be correlated. Attention will also be given to defining important stratigraphic boundaries, to reconstructing paleogeography, paleoclimate and paleo-oceans, and to determining the age and location of related mineral resources.

Project 271 South American Paleozoic Conodontology

(1988-1992). Project Leader: M.A. Ilüinicken (Academia Nacional de Ciencias, Casilla Correo 36, Cordoba 5000, Argentina). The aim here is a systematic study of conodonts and the correlation of their host rocks in the Cambrian-Permian interval. The Color Alteration Index will be applied to problems of geothermometry, metamorphism, structural geology, and hydrocarbon resources.

Project 272 Late Palaeozoic and Early Mesozoic Circum-Pacific Events

(1988-1994). Project Leader: J.M. Dickins (Bureau of Mineral Resources, P.O. Box 378, Canberra, Australia 2601). This project will study faunal-floral, climatic, sedimentary, magmatic, tectonic, sea level and geochemical events of this broad region. It is expected

that the integration and correlation of these events will have great potential for better understanding of Earth history and the origin and distribution of mineral resources.

Project 273 Archaean Cratonic Rocks of Kasai

(1988-1992). Project Leaders: B.T. Rumvegeri and D. Kapenda (Université de Lubumbashi, Dépt. Géologie, B.P. 1825, Lubumbashi, Zaire). The aim is to collect data on the Archaean of the Kasai craton, to analyze its influence in the evolution of the early Proterozoic evolution of Central Africa, and to establish correlations elsewhere in Africa, Australia and the Western Hemisphere.

Project 274 Coastal Evolution in the Quaternary

(1988-1992). Project Leader: O. Van de Plassche (Institute of Earth Sciences, Free University, P.O. Box 7161, 1007 MC Amsterdam, The Netherlands). This project plans to explain local and global variations in the Quaternary evolution of coasts and shelves. A basis for comparative theoretical and applied research will be established, and a program will be developed for integrated and interdisciplinary studies worldwide.

Project 276 Paleozoic in the Tethys

(1988-1992). Project Leaders: D. Papanikolaou (Dept. of Geology, University of Athens, Panepistimioupoli Zografou, 15784 Athens, Greece) and F.P. Sassi (Istituto di Mineralogia e Petrologia, Università di Padova, Corso Garibaldi 37, I-35100, Padova, Italy). The aim is to study the geodynamics of Tethyan Paleozoic formations and their Mesozoic and Cenozoic evolution. This will be done by tracing Paleozoic trends beneath the Alpine imprint and establishing pre-Tethyan configurations. The project will also correlate the pre-Alpine basement rocks of Tethys with those of the Laurasian and Gondwanan margin.

Project 277 Phanerozoic Oolitic Ironstones

(1988-1990). Project Leader: F.B. Van Houten (Dept. of Geological and Geophysical Sciences, Princeton University, Princeton, NJ 08544, U.S.A.). Data on the stratigraphy and sedimentology of oolitic ironstones will be assembled as the basis for a study of their origin. Critical comparative investigations of the possible modes of origin of the ooids and ironstones will be launched.

Project 279 Terranes in Latin America

(1988-1992). Project Leader: F. Hervé (Departamento de Geología y Geofísica, Casilla 13518 Correo 21, Santiago, Chile). The aim is to identify and characterize allochthonous tectonostratigraphic terranes in Latin America and to study the nature and dynamics of the sutures involved. Relationships between the accretion and displacement of the terranes along the continental margin and other major orogenic events will be established, as will the limits of autochthonous Precambrian crust below the Andean region.

Project 280 The Oldest Rocks on Earth

(1988-1992). Project Leaders: B.M. Jahn, A. Kröner, S. Moorbath (c/o A. Kröner, Institut für Geowissenschaften, Universität Mainz, Postfach 3980, 6500 Mainz, Federal Republic of Germany). This project will test the many current hypotheses of crustal evolution during the first billion years or so of earth history by promoting detailed studies of the surviving fragments of the oldest terrestrial crust. The studies will involve field work, structural analysis, isotope and trace element geochemistry, petrology, etc., and the project will act as a forum for international discussion of this fundamentally important topic. □

Third World Geologists and the IGC

One measure of the scientific health of the International Geological Congress is attendance. The number of scientists present has risen irregularly since 1960 (table 1) with an obvious dependence on the location of the Congress. Recent meetings (Paris 1980; Moscow 1984) have been significantly larger, and it is anticipated that the 28th IGC, to be held next July in Washington, D.C., will be as large or larger than these, with a registration of 6,000 or more.

However, the great majority of registrants at all Congresses come from the more developed, relatively wealthy countries: most of Europe, the U.S.A., Canada, Australia, New Zealand, Japan, and the U.S.S.R. The rest of the world is rather sparsely represented. Except for the Paris meeting where representatives from developing countries made up 17.7% of the total, their attendance level has hovered between 7.6 and 10.8% from 1960 to 1984.

The relative scarcity of attendees from developing countries presumably reflects the high cost of attending a foreign meeting. Washington, D.C. is not inexpensive, so the Organizing Committee of the 28th IGC has been particularly concerned with the cost of attending this Congress. Accordingly, the Geohost Grant Program and the Travel Grant Program have been set up to help individual scientists, principally from developing countries.

Geohost will partially subsidize expenses incurred within the U.S.A. - the meeting registration fee, one short course or field trip fee up to \$600, and dormitory-style lodging. Applications for Geohost grants will be reviewed by a selection committee, and grants awarded on a competitive basis. The Organizing Committee has already committed \$50,000 to this program to support about 50 attendees.

The Travel Grant Program will provide additional support for those to whom the basic Geohost grant does not provide enough assistance. It will also consider applications from others who think they may qualify for consideration. This program will provide partial support for travel expenses to and within the U.S.A. Funding for this program includes a

TABLE 1: Attendance Data for Recent International Geological Congresses

Congress Year	21 1960	22 1964	23 1968	24 1972	25 1976	26 1980	27 1984
Location	Copenhagen	New Delhi	Prague	Montreal	Sydney	Paris	Moscow
Total Scientific Attendance	2386	1516	2911	3895	2953	4541	5690
Sub-saharan Africa	67	27	43	74	39	146	78
North Africa and Near East*	67	36	76	38	50	239	168
Asia*	23	38*	53	53	103	140	227
Oceania*	4	4	1	6	25	8	1
Latin America	87	38	48	123	45	268	143
Total from developing countries	248	143	221	294	262	802	617

* Excluding Indian registrants

+ Attendance figures exclude representatives from the more affluent countries, such as Australia, New Zealand, South Africa, Japan, Saudi Arabia and the various Persian Gulf states.

major grant promised by Unesco, and funds set aside by the Organizing Committee. In addition, it is hoped to receive support from the Agency for International Development and the U.S. National Science Foundation. The goal is to provide \$50,000 or more in travel grants.

The selection committee for both programs will include representatives of the 28th IGC Organizing Committee, of IUGS, Unesco and AGID (Association of Geoscientists for International Development). The application deadline for both programs is August 1, 1988. Application procedures are described in detail in the Second Circular of the 28th IGC. For further information, write to: Dr. Bruce B. Hanshaw, Secretary General, 28th IGC, P.O. Box 1001, Herndon, Virginia 22070-1001, U.S.A. □

R.T. Helz
Washington, D.C., U.S.A.

The South Iceland Seismic Zone

A research project involving seismologists from the Nordic countries (Denmark, Finland, Iceland, Norway and Sweden) has been launched to reduce earthquake losses and strengthen the physical basis for earthquake prediction. In a resolution passed in 1980, the Council of Europe stressed the importance of concentrating earthquake prediction research in five test areas in Europe, one of which was the South Iceland Seismic Zone (see Fig. 1). As a result Nordic seismologists agreed to establish an acquisition system for digital data around which geophysical monitoring and other experiments could be designed. A proposal for a five to six year project, submitted to the Nordic Council and the Council of Nordic Ministers, was approved in 1987. Geophysical experiments are now being planned that can give information about changes in physical properties of the crust prior to large earthquakes.

The South Iceland Seismic Zone is the part of the country that has suffered the most damage from earthquakes: 33 major ones in the 1100-year history of Iceland. Some of

these earthquakes caused the collapse of more than half of all houses within areas of around 1000 km². The largest ones exceeded magnitude 7, as estimated from the damage areas and the extent of faulting observed. The last earthquake of that magnitude occurred in 1912, and based on historical recurrence times, a series of large shocks is expected with high probability within the next 20 years.

The earthquakes are caused by transform faulting in a complex zone that connects the spreading center of the Reykjanes Ridge to the neovolcanic rift zones in South Iceland (see Fig. 1). The major activity occurs in a zone 10-20 km by 80 km that bridges the gap between the two branches of the neovolcanic zone here.

Initially the only geophysical sensors planned for the project are seismometers. The network can, however, easily accommodate any other kind of geophysical analyses, such as continuous strain monitoring, gravity and magnetotelluric measurements, tiltmeters, monitoring of radon and ground water levels.

Figure 1: The South Iceland Seismic Zone showing the Western and Eastern Volcanic Zones (WVZ and EVZ). Dots are epicenters for the period 1963-1981, with larger symbols events of $m_b=5$ and larger.

The project is also encouraging geological research that could lead to an improved geodynamical model, and geological mapping, tectonic studies, seismic work and model studies have been suggested. Extensive geodetic measurements both with conventional and GPS methods, have already started and volumetric strainmeters have been operated for several years. Radon sampling and mapping of recent earthquake faults is also in progress.

This research effort is intended as a multidisciplinary project that will lead to deeper understanding of the physical processes in the crust before and during earthquakes - the key to successful earthquake prediction. Although organized as a Nordic cooperative project, participation from other research groups is welcomed. For further information contact the writer at University of Iceland, Science Institute, Dunhaga 3, 107 Reykjavik, Iceland, or Reynir Bödvarsson, Uppsala University, Box 556, 751 22 Uppsala 1, Sweden. □

Páll Einarsson
Reykjavik, Iceland

Working Groups Established for Global Change Program

Changes in the environment on a global scale are causing deepening concern among scientists and some decision-makers. Recent advances in science and technology, such as precise observations of the Earth from satellites and improved analytical techniques, make it timely to carry out a more comprehensive study of the processes involved and their interactions. Accordingly, the International Council of Scientific Unions has launched the International Geosphere-Biosphere Programme: A Study of Global Change to describe and understand the interaction between the biological, chemical and physical processes that regulate the total Earth system.

During its first meeting in Paris in July 1987, the IGBP Committee decided that its main goal would be "to advance our ability to predict change in the global environment." The initial objective will be to obtain the information necessary to improve our understanding of the cycling of elements between the terrestrial, fresh water and marine ecosystems and the atmosphere, the natural and anthropogenic effects on these cycles, the essential linkages between the biosphere and the geosphere and changes in transfer rates between the various components of the total Earth system.

The IGBP Committee has now set up eight working groups and panels to help develop the program.

Global Geosphere-Biosphere Modelling: Models will be developed that link the biosphere and the geosphere, incorporating changes in transfer rates between the different systems with due regard to the interior processes and boundary conditions.

Data and Information Systems: The major task here will be to select the key parameters, obtain information on

the data available, prepare and disseminate appropriate data sets and stimulate the collection of data not yet available.

Techniques for Extracting Environment Data of the Past: The group will assess the present state of the art and of future technological developments for documenting global change through reconstruction of past changes in the environment using ice cores, tree rings, sediments etc., and in real time.

Geo-Biosphere Observatories: A feasibility study will be carried out of the need for and location of a network of geo-biosphere observatories for the generation of long-term data sets, validation of models, ground truth observations linked to remote sensing, etc., especially in zones and ecosystems that are fragile or sensitive to change.

Biosphere Interactions with Atmospheric Chemistry: Significant biospheric sources and sinks of chemical constituents will be identified that are important for understanding atmospheric chemistry on regional and global scales and the impact on climate.

Biospheric Aspects of the Hydrological Cycle: In order to improve the formulation of global climate models, particularly with regard to the role of vegetation in the parametrization of the subgrid-scale hydrological processes, changes in the reservoirs and fluxes of the hydrological cycle will be determined.

Effects of Climate on Ecosystem Changes: Estimates will be made of the effects of climate change on soil, vegetation structure, and species composition of ecosystems.

Understanding the Role of Marine Ecosystems: The principal focus will be on the interplay between physical, chemical and biological processes in the photosynthetically active layer of the oceans.

In concentrating on interactive biological, chemical, and physical processes, the IGBP will put less emphasis on studies that, though they have great strengths and momentum of their own, are already being addressed in existing initiatives, or that will less clearly contribute to our understanding of the changing nature of the global environment. Priority in the IGBP will therefore fall on those areas that deal with key interactions and significant

change on time scales of decades to centuries, that most affect the biosphere, that are most susceptible to human perturbation, and that will most likely lead to practical, predictive capability.

Further information on the IGBP can be obtained from: Professor Thomas Rosswall, Executive Director, Special Committee for the Geosphere/Biosphere Programme, Royal Swedish Academy of Sciences, P.O.B. 50005, S-104 05 Stockholm, Sweden. □

- After report in Science International, August 1987

Sulphide Deposits in Mafic and Ultramafic Rocks

IGCP Project 161, begun in 1977 on the initiative of A.J. Naldrett (Canada), its first leader, aimed to stimulate interest in magmatic sulphide ores associated with mafic and ultramafic rocks through field conferences and the compilation of information on deposits, host rocks and their geological setting worldwide.

At the outset, national working groups were established in Australia (D. Groves and R. Hill), Canada (W. Peredery), Finland (H. Papunen), France (M. Besson), Norway (R. Boyd), Sweden (G. Nilsson), South Africa (G. v. Gruenewaldt) and in U.S.A. (G.K. Czamanske). Later, national correspondents were added for other countries: E. Stumpfl (Austria), R. Cabrera (Cuba), H.C. Schönwandt (Denmark), J. Foldessy (Hungary), J. Dorbor (Liberia), J.L. Moreno (Mexico), A. van der Veen (Netherlands), D.L. Buchanan (U.K.), G.I. Gorbunov (U.S.S.R.), Le Thac Xinh (Vietnam) and R.P. Foster (Zimbabwe). The project participants have included academic, mining, exploration and geological survey geologists.

Field conferences and associated symposia have been one of the main activities of the Project. The first, in Toronto, Canada (1978), visited Sudbury, and Timmins, Ontario, and the Manitoba nickel belt. In 1980, the second meeting started in the Narvik area of Norway, then visited nickel deposits in Sweden and Finland, and concluded with a symposium at the University of Turku in Finland. The next year Project 161 organized a two-week workshop on nickel sulphides at the University of Zimbabwe. Then in 1982, project participants visited Perth, Western Australia, followed by a 10-day field trip to the Eastern Goldfields nickel camp.

A symposium during the Moscow Congress in 1984 was followed the next year by a wide-ranging field conference that began in Ketchikan, Alaska, with a visit to the Duke Island Ultramafic Complex, and then moved to Montana to examine the Stillwater Complex, and to the Duluth Complex of Minnesota. Following this most members participated in the 4th International Platinum Symposium held in Toronto and followed by a field trip to Sudbury. In 1985, the Project also cosponsored the Edinburgh Conference on "The Metallogeny of Basic and Ultrabasic Rocks." The next year, the Project co-sponsored an international symposium on "Layering in Igneous Rocks," held at the annual meeting of the Geological and Mineralogical Associations of Canada in Ottawa, and the last field conference and the final activity of Project 161 took place in Zimbabwe in August 1987.

Figure 1: In a pothole, A.J. Naldrett examining the internal state of rocks of the Mchingwe River, in Zimbabwe.

When Project 161 was initiated there was much discussion of komatiites and their ores, Sudbury was generally regarded as an impact event, a successful Penrose Conference had just been held on the Duluth Complex, and the proceedings of the 2nd International Platinum Symposium had just been published. At another (1979) Penrose Conference, a definition of komatiites was proposed, one that has now achieved general acceptance. Careful study of boreholes and mines at the Kambalda Dome (Western Australia) led to the recognition that there were important differences between ore-bearing and non-ore environments, and soon it was recognized that the ore-bearing environments were not static, but dynamic.

The concept of lava rivers arose, with the suggestion that thermal erosion at the base of these rivers of hot peridotite magma could give rise to, or at least modify the troughs in which so many ore deposits occur. The ensuing idea that erosion and assimilation of barren, sulphide-bearing sediments could give rise to ore-bearing sulphides is still being debated. However, it is now recognized that the Agnew-Mt Keith intrusions (Western Australia) are not fault-controlled dike-like masses of ultramafic rock, but were themselves very large rivers.

News Reports

Following the very early Soviet work at Noril'sk, it is now appreciated that many other Cu-Ni ores, including those in the Duluth Complex, are the consequences of contamination by sedimentary sulphur, distilled out of underlying sediments. Structural work at Duluth has helped to understand the environment of contamination, and why the ores have the compositions and grades they do.

At Sudbury, the pendulum has started to swing away from near universal acceptance of an origin by meteorite impact. Careful studies of the Onaping Formation here have raised some doubts about its interpretation as a fall-back breccia. On the other hand, the extraordinary degree of contamination by assimilation of more than 50% of country-rock material that has been documented as affecting the magma of the complex requires a very special environment. For more typical layered intrusions, careful petrologic and isotopic studies, in particular on the Bushveld and Stillwater Complexes, have shown that they are not single, one shot injections of magma, but are the result of successive influxes of magma, often of changing composition.

Models based on the rigorous application of fluid dynamic theory and scale tank experiments continue to contribute to the understanding of what took place in the part of mafic-ultramafic intrusions that can no longer be seen, the magma overlying the cumulus pile. The last 10 years have also seen a growing appreciation of the role of doubly diffusive convection cells in magma chambers, and their application to a variety of problems, including the lateral growth of rock layers away from the margins of a complex.

A wide range of models has been developed, based on magma mixing in compositionally stratified magma chambers, to explain the concentration of elements of economic interest into flat-lying layers. It is perhaps not surprising that similar models seem to account for both Pt and Cr concentrations, since the problem for both is much the same - the concentration into a single zone of elements weakly and widely dispersed in magma. In the case of Pt, but not Cr, there is still a vigorous debate as to whether the metals come directly from above, highly enriched in sulphide, or from below to enrich pre-existing sulphide. Very important in the latter case are the discoveries of H₂O and Cl concentrations, and the presence of fluid inclusions in the J-M (Stillwater) and Merensky (Bushveld) Reefs, since these point to hydrothermal brines as a possible concentrating mechanism. Transport of PGE by other than magmatic sulphide droplets, while debatable with respect to Merensky-type deposits, seems to have occurred elsewhere, for example in the dunitic pipes of the Bushveld Complex.

Figure 2: Australian participants in IGCP 161 standing on Great Dyke, Zimbabwe.

The understanding of PGE geochemistry has come a long way in the last 10 years. It is now appreciated that fertile mantle has flat chondrite-normalized PGE patterns, that depleted mantle and mantle chromites are depleted in Pt and Pd, and that partial mantle melts are Pt and Pd enriched and Ir depleted. Fractional crystallization of mafic magma also results in Ir depletion and Pd enrichment. PGE abundances characteristic of rocks are also normally characteristic of the sulphide ores associated with them. The interpretation of the geochemical processes leading to these fractionations is greatly assisted by new observations on PGE mineralogy in these different environments.

On the experimental scene, recent phase equilibria studies have resulted in a much better appreciation of the crystallization of PGE minerals in association with base metal sulphides. Experimentally determined partition coefficients allow geochemical processes to be modelled, though some of these data are not so simple as earlier assumed. This is just one area where new approaches are needed. The recent resurgence of interest on the part of mining companies in the metals traditionally associated with mafic and ultramafic magmas is creating an enormous explosion in our knowledge of where these occur.

Figure 3: Examining komatiites in the Belingwe greenstone belt of Zimbabwe.

Of course, the ideas summarized above were not all developed by Project 161 participants, and even those that were would probably have been developed without the Project. They were, however, widely discussed at the project meetings, and as a result, some ideas have been modified and developed and some perhaps stimulated.

Participants in IGCP 161 have presented their achievements in the geological literature, and ten separate books and special issues of journals have resulted directly from the project, together with numerous guide books prepared for the field excursions. One IGCP 161 group headed by G.K. Czamanske (U.S.A.) collected comprehensive bibliographies on mafic-ultramafic rocks of Scandinavia, layered intrusions, and komatiites now available as USGS Open-File Reports.

Project 161 did achieve its goal, but the research continues. Many workers have now convened under the framework of the new IAGOD Commission on Ore Deposits in Mafic and Ultramafic Rocks (CODMUR), the inaugural meeting of which was held in Harare, in August 1987. The Commission will, no doubt, be kept busy re-examining the ideas and results achieved during Project 161. □

After reports by H. Papunen and A.J. Naldrett

NEWS IN BRIEF

IUGS TO STUDY THE TERMINAL PRECAMBRIAN

■ A new Working Group on the Terminal Precambrian System has now been established under the IUGS Commission on Stratigraphy. Its purpose is to study the latest period of the Precambrian, named variously in the past as Sinian, Vendian and Ediacarian, among others. Another aim is to contribute to the global geological time scale by defining the chronostratigraphic base of the period. Fossils are not uncommon in this part of the geological column and include soft-bodied metazoa, acritarchs, *problematica* and trace fossils that may enable biostratigraphic correlations to be made. Other branches of stratigraphy will also be of importance: climatology (especially with respect to late Precambrian ice-ages), magnetostratigraphy, geochronometry and global sedimentary geology, making up the embracing spectrum of *holostratigraphy*. The Chairman is A.H. Knoll (Harvard University) and Vice-Chairman is M.R. Walker (Bureau of Mineral Resources, Australia).

REDUCING NATURAL HAZARDS

■ Following an initiative by the U.S. National Academy of Sciences (see *Episodes*, September 1987, p. 188), the United Nations has now designated the 1990s as an International Decade for Natural Disaster Reduction. The aim will be to reduce, especially in developing countries, loss of life, property damage and social and economic disruptions caused by earthquakes, windstorms, floods, landslides, volcanic eruptions, and other natural disasters such as grasshopper and locust infestations. This will be done by improving national capacities to cope with the effects of such events, by designing guidelines for applying existing knowledge, by fostering scientific and technical research, and by encouraging improvements in the assessment, prediction, prevention and mitigation of natural disasters. The Secretary-General has been given the responsibility of developing the framework for the Decade, in cooperation with various government and non-government organizations.

In a related move, the U.S. Agency for International Development and the USGS are urging a special focus on earthquakes by promoting the exchange of existing information and capability, especially as developed to reduce the human and monetary cost of future earthquakes in the U.S.A. Specific suggestions from the USGS include networking to link existing

geoscience and engineering data bases on earthquakes with "investment agendas of financial communities," in the interests of improved building codes and seismic risk zoning. A global seismic risk map for use in locating and regulating land use is proposed, as is the improvement of design, construction and land-use practices, and of course the provision of training.

NEW FACE FOR GEOLOGY IN BRITISH UNIVERSITIES

■ After several years of discussion, a comprehensive review by the University Grants Commission of earth science departments in the U.K. universities proposes major changes. Aston, Dundee, Strathclyde and Swansea are to lose their departments entirely. Exeter, Hull, Newcastle, Nottingham and Sheffield will retain earth science only within other departments. Aberdeen, Keele and St. Andrews would be small to medium departments offering joint honours and service teaching, without expensive equipment. Aberystwyth, East Anglia, Imperial, Lancaster and Southampton would become medium to large units or groupings in which faculty would contribute both to mainstream and interdisciplinary activity.

Cambridge, Edinburgh, Leeds, Liverpool, Manchester and Oxford would be designated medium to large departments providing teaching and research in mainstream earth sciences, including single honours courses. Some of these would have major equipment, also for use by the wider community. Birmingham, Cardiff, Durham, Glasgow, Leicester, Royal Holloway-Bedford New College, and University College-Birkbeck would be treated like the latter group but would be given fewer students. The British earth science community is, not surprisingly, in turmoil over this restructuring, and implications for staffing are enormous.

LECTURERS FOR DEVELOPING COUNTRIES

■ The first list of speakers available under the ICSU-TWAS Lectureship Programme has just been released. The roster of scientists willing to lecture in developing countries contains some names familiar to geoscientists: B.A. Bolt (University of California - seismology), J.C.I. Dooge (Royal Irish Academy - hydrology and climate change), F. El-Baz (Center for Remote Sensing, U.S.A. - deserts and mapping from space), C.H. Holland (Trinity College, Dublin - cephalopods,

evolution), K. Kelts (Switzerland - sediments, climates, geochemistry), L. Knopoff (University of California - earthquake prediction, mantle structure), S.K. Runcorn (University of Newcastle, U.K. - geophysics), and R. Trümpy (ETH, Switzerland - mountain belts, international collaboration in earth sciences). The International Council of Scientific Unions and the Third World Academy of Sciences will finance the travel of lecturers, and host country institutions will be expected to cover local costs and to make all local arrangements. For further information contact TWAS, P.O. Box 586, Trieste 34100, Italy.

LOS APPROVES FIRST CLAIMS FOR SEA-BED

■ Under the terms of the UN Convention on the Law of the Sea (LOS), the first four applications for registration as a "pioneer investor" in deep sea minerals were approved last December. These are for areas (each 75,000 km²) in the Eastern Pacific by France (on behalf of the Institut Français de Recherche pour l'Exploitation de la Mer), Japan (the Japanese enterprise Deep Ocean Resources Development Co., Ltd.) and the U.S.S.R. (the state enterprise, Yuzhmorgeologiya), and one in the Central Indian Ocean (52,300 km²) by the Government of India. In each case another area nearby has been reserved for the International Sea-Bed Authority on the basis of estimates that it contains deposits equal in commercial value to those allocated to the pioneer investors. In each case the areas are beyond the limits of national jurisdiction, and each investor has agreed to act in accordance with the LOS and to pay a fee of \$250,000 to the Preparatory Commission for the International Sea-Bed Authority.

K/T BOLIDES: THE CANDIDATE FROM IOWA

■ The Manson structure of Iowa, recognized in 1988 as an impact site buried by glacial deposits, has now been dated at 67±2 Ma, very close to the time of the Cretaceous-Tertiary boundary. This suggests a possible link between the impact and the K/T boundary extinctions. An investigation into this possibility is now underway in the U.S.A. involving drilling to various depths to define both the shallow and deeper structure of the feature.

... AND IMPACTS THAT WARM

■ Meanwhile ideas are rapidly changing about possible environmental

effects of a bolide collision with the Earth. J.D. O'Keefe and T.J. Ahrens (California Institute of Technology) suggest that a large impact into carbonate-rich rocks could have released great quantities of CO₂ to the atmosphere, trapping the Sun's heat. They calculate (*Science News*, March 26, 1988) that a comet with a 50 km radius striking a 4 km-thick carbonate layer would result in an immediate 100 x increase in atmospheric CO₂, leading to a rise in temperatures of 20°C within only 10 days. Even a 20 km radius meteorite hitting a 1 km layer would result in a world-wide increase of 5°C.

M. Rampino and T. Volk (New York University) also hypothesize a global warming due to an impact that would have triggered the death of calcareous nannoplankton. Because these normally cool the Earth by producing a S compound that helps form water particles in clouds over the oceans, their death would weaken the planet's ability to reflect solar radiation, and the result would be a 6°C rise in surface temperatures that might have lasted for several hundred thousand years (*Nature*, March 3, 1988).

GARS MOVES TO SOUTH AMERICA

■ The joint Unesco-IUGS program, Geological Applications of Remote Sensing (GARS), is now being extended to South America with an initial focus on geohazard problems in the Andes

(landslides, floods and earthquakes). A test area is proposed in the Eastern Cordillera of Colombia where high-resolution, multispectral and stereoscopic satellite data will be applied to geological and geomorphological mapping, slope stability and other relevant analyses.

Meanwhile, the first GARS project in the Kibaran of Burundi and Tanzania continues to produce results, with details published in a variety of papers. Ground surveys were carried out in 1987 (radiometrics structural mapping), and mapping lithologies using TM data supplemented by the ground surveys has brought useful results. SPOT imagery is being used to good effect in mapping a granitic terrain, for a morphologic study of Proterozoic rocks, and for investigation of soils and laterites.

THE DECCAN TRAPS REVISITED

■ A new theory of clock-like volcanism for the origin and evolution of the Deccan Traps of India based on geophysical and geochemical analyses, rejects the view that these widespread volcanics originated 65 Ma ago as India glided northward over a mantle at the Réunion island in the central Indian Ocean.

In an earlier analysis of 98 major global volcanic episodes during the last 250 Ma, O.P. Pandey and J.G. Negi (National Geophysical Research Institute, Hyderabad) found that a

significant enhancement of volcanism takes place every 33 Ma. They related these episodes to periodic disturbances in earth processes connected with movements of the Solar System in the Milky Way. Four cycles of volcanism are recognized in India at 135 Ma (Meghalaya, Sylhet and Bengal Basin), 100 Ma (Rajmahal and Dhandhuka), 66 Ma (major parts of Deccan Traps), and 33 Ma (Koyana, Dohad, etc.). These match well with volcanic events elsewhere (*Tectonophysics*, v. 142, 1987, p. 329-335).

The 135 Ma event is attributed to volcanism during the separation of India from Antarctica, and the Deccan volcanics are linked to the attainment around 65 Ma ago of maximum speed (15-20 cm/y) in the north drift of the Indian plate. The 33 Ma event is matched with another change of speed after the collision with Eurasia and the Himalayan uplift.

The 135, 100 and 33 Ma events of drifting India are clearly un-connected with the gliding of India over the mantle hot spot fixed near Réunion, and Pandey and Negi argue that the range of Mg/Mg+Fe ratios (0.35-0.55) in parts of the Deccan Traps suggests a crustal not mantle origin. The periodic volcanism in India matches the recently discovered 33 Ma periodicity in geomagnetic reversals, impact cratering, and other geological rhythms. The authors state that extinction of life and volcanism have nearly the same periodicity.

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