Circum-Pacific Phanerozoic Granites

Tucumán, Argentina, 14 - 18 September 1987

The Tenth Argentinian Geological Congress held last September was the occasion for a special IGCP 249 symposium on granites around the Pacific. It was organized by Carlos W. Rapela (La Plata, Argentina) and Miguel A. Parada (Chile), with the help of Alejandro Toselli and his associates from the University of Tucumán.

Many symposium contributors concentrated on the Mesozoic-Cenozoic "Andean" plutonic arc. In the most southerly contribution from the Antarctic Peninsula, B.A. Piercy and S.M. Harrison (U.K.) described a sequence of mid-Palaeozoic orthogneisses, partly deformed Jurassic plutons and undeformed Cretaceous plutons, all of I-type and becoming younger towards the west. They drew attention to the occurrence of Palaeozoic plutonism in a discontinuous band parallel to the former boundary of a reconstructed Gondwanaland. This point was taken up by B. Mason (New Zealand) who gave an account of the Palaeozoic S-type and Mesozoic I-type granitoids of New Zealand and by S. Shaw (Australia) in his account of the geological affinities between the granites of the Lachlan and New England fold belts.

The I-type Patagonian Batholith in Argentina was described by Rapela who showed that it was composed of many units, each with distinctive chemical signatures and evolutionary pathways. The batholith ranges from Early Cretaceous to Miocene in age, with the younger granites being more differentiated, and Rapela correlated the compositional evolution with changes in the obliquity of convergence of the oceanic plate.

In the Chilean sector of the Patagonian batholith, according to S. Weaver (U.S.A.), Sr and Nd isotopes display a pattern of progressively higher mantle component as the plutons become younger to the west. He suggested that the crustal component was provided by the Palaeozoic accretionary prism. On the other hand, R.J. Pankhurst (U.K.) in a review of isotope data from Antarctica and central Chile, preferred an interpretation that related the more primitive magmas to a steep subduction zone and those with crustal signatures to shallow subduction. The latter he regarded as related to melting and hybridization with either deep crustal material or anomalous lithospheric mantle at the crust-mantle interface.

Contributions on the central sector of the Chilean Arc by Parada, K. Berg, R. Charrier, D. Espineira, and F. Hervé (all from Chile) all emphasized the composite nature and I-type character of the Chilean batholiths and their eastward transistion from Jurassic to Cenozoic age. The question of magma mixing was raised by Espineira, and a model for this process was later provided by T. Frost (U.S.A.) from the Lamarck granodiorite in the Sierra Nevada Batholith. He suggested that multiple generations of mafic enclaves resulted from subsequent injection of mafic magmas and their mixing with a more felsic host.

In the Peruvian sector P. Soller (France) showed that in the Cretaceous Coastal Batholith there was cyclic evolution towards higher $^{87}\text{Sr}/^{86}\text{Sr}$ ratios followed by reversals to more primitive values. This pattern is interpreted as indicating subduction-related alteration of the mantle wedge followed by re-establishment of normal values by

mantle wedge convection. Soller also attributed the broader spread and more easterly location of the Cenozoic inner arc to the increased rate of subduction of the oceanic plate.

From the Northern Andes in Colombia, J.J. Restrepo reported that Cenozoic plutons become younger towards the present volcanic chain. The heterogenous Altavista stock of Cretaceous age has now been shown to have a different origin from the neighbouring Antioquia composite batholith of similar age.

Contributions on the Mesozoic plutonic arc system from elsewhere in the Americas were provided by S.M. Kay (U.S.A.) and her co-workers in the Aleutians, and C. Miller (U.S.A.) on the Mesozoic "inner arc." Kay showed that plutons in the Aleutian islands were very primitive with initial $^{87}\text{Sr}/^{86}\text{Sr} = 0.7027-0.7039$ and an age range from 33 to 11 Ma. She considered that the origin of the plutons was similar to that of the volcanics and that plutons might be considered as 'dead' volcanoes. Miller showed that a very broad inner arc of peraluminous granites was essentially coeval with the Sierra Nevada Batholith and was characterized by markedly crustal isotopic signatures. However, these granitoids did not appear to be typical S-types; rather they show I-type characteristics with respect to such features as Na_2O content ($\sim 4\%$), low LIL content and low R/Sr ratios. E.J. Cobbing (U.K.) commented that the peraluminous I-type granite of the Miocene Cordillera Blanca Batholith from the inner arc in Peru had very similar geochemical features but a low initial $^{87}\text{Sr}/^{86}\text{Sr}$ ratio of 0.705.

Many contributions on the pre-Andean, largely Palaeozoic, plutonism revealed the wide, and sometimes fragmentary distribution of these granitoids in the Andean region. E. Llambias and co-workers described a double arc of I-type batholiths in the Frontal ranges showing ages of 274-224 Ma, younger ages eastward and polarity in geochemical differentiation. Granites of similar age and character are abundant in the Eastern Cordillera of Peru and continue southwards into the Cordillera Real of Bolivia. Here they form a mixed population of I and S-type granites that are tin bearing and for which O. Avila (Bolivia) advocated an anatectic origin. In the Patagonia Andes near Bariloche, L.

Figure 1: Field excursion participants face the camera in the Sierras Pampeanas.

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Dalla Salda (Argentina) reported I-type and S-type granitoids of migmatitic character associated with lower Palaeozoic metamorphic rocks.

Perhaps the predominant manifestation of Palaeozoic plutonism is that of the Pampean ranges where regionally metamorphosed Ordovician pelitic metasediments are cut by widespread peraluminous granitoids, followed by an equally widespread post orogenic Devonian to Carboniferous plutonism. Several presentations, mainly by representatives from the school of geology at Tucumán under Dr. Toselli, gave detailed accounts of the Ordovician granitoids. These are peraluminous granodiorites with high levels of Na₂O (3-4%), CaO and MgO and low levels of K₂O and Rb/Sr. They appear to be analogous in some respects to the "inner arc" granites of Miller and are, in fact, regarded as such by the Tucumán school, possibly related to an outer calc-alkali plutonic arc in the region of the Famatina Belt. This, however, is not at present well established.

The low initial ⁸⁷Sr/⁸⁶Sr values of 0.705 are quite different from the North American case but not dissimilar to the inner arc Cordillera Blanca granite of Peru. The post orogenic granites, which form major batholiths and plutons in the region, especially around Córdoba, were described by A.M. Kirschbaum, M.G. Lopez de Luchi, R. Lira, and N. Brogioni (all from Argentina). They are mainly coarse pink or red porphyritic calc-alkaline granites with distinct alkaline affinities that are compatible with their post-orogenic back-arc situation.

Much more puzzling is the occurrence in Salta Province of Precambrian granites, which chemically resemble the mid-Ordovician granitoids, as described by K. Damm (F.R.G.) and co-workers, and by R.H. Omarini (Argentina) and co-workers. Further, in the same region a Cambrian trondhjemite reported by M. Galliski (Argentina) as intruding a flysch sequence is of evident primitive origin. Damm and co-workers have conducted a traverse from Antafogasta to Salta and reported the occurrence of Palaeozoic granitoids at points along the whole traverse. They attributed this pattern of distribution to a continental reactivation of the continental margin by alternating compression and tension throughout Phanerozoic time.

Turning to the Circum-Pacific dimension, T. Nozawa (Japan) drew attention to the major contrast in granitoid plutonism on opposing sides of the Pacific. In both North and South America, Mesozoic plutonism was dominated by magnetite series I-type granitoids as exemplified by those in the Sierra Nevada and the Andes, whereas on the Asian margin the granites formed an inner belt of ilmenite series I-types and S-types flanked by an outer belt of predominantly magnetite series I-types and subordinate S-types. Nozawa suggested that the scale of this contrasted development required major differences in the pattern of subduction on opposing sides of the Pacific basin during the Mesozoic. The ilmenite series I-type granitoids were designated as intermediate I-types and appeared to be present in a variety of tectonic settings.

This point was supported by Cobbing, who compared Andean and Southeast Asian granitoids and noted similarities between Permo-Triassic, ilmenite series, I-type granitoids of Peninsular Malaysia, formed in a volcanic arc/collisional setting, and the Permo-Triassic I-type granitoids of the Eastern Cordillera in Peru, emplaced during an episode of post-orogenic rifting. He suggested that in this and other instances, granites of similar typology were generated in different tectonic settings, and that in such cases the influence of the local crustal source was the predominating factor.

The very interesting post-conference excursion to the Sierras Pampaneas was extremely well planned and every stop was chosen with the greatest care. The excursion guide was a model of its kind and was full of information, much of it still unpublished. It was an amazing experience for most participants to find a microscope, with a set of thin sections and analytical data, available for browsing over in the evenings.

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Quantitative Stratigraphy in Brazil

Rio de Janeiro, Brazil, 9 - 13 November 1987

Research in stratigraphy has been considerably advanced by the work of IGCP Project 148 (Quantitative Stratigraphic Correlation Techniques) and its successor, the Committee on Quantitative Stratigraphy (CQS) of the IUGS Commission on Stratigraphy. An excellent example of this has been the recent implementation by the Geoinformation group at Petrobras, the Brazilian state oil company, of a series of mainframe and microcomputer programs developed by Project 148 and CQS. These include the following:

Unconstrained and constrained seriation. This is a non-parametric method that uses distribution data on the presence or absence of type fossils in several sections either to find biogeographic or paleoecologic trends (co-occurrences) for groups of taxa, or to order groups of taxa along a single

axis representing time. Seriation results resemble the Braun Blanquet method of arranging taxa in vegetation quadrants in natural communities. The latter also works with a sample/species matrix, but taxa are added to assemblages, using co-occurrence with a-priori selected indicator species.

A batch-run program for micros or mainframe computers on ranking and scaling (RASCO). This finds the average sequence of microfossil events (e.g. stratigraphic tops) in wells. The distance in relative time is calculated between the events in the average (optimum) sequence, using cross-over frequency of all pairs of events from well to well. The final result is a scaled optimum sequence that closely resembles an interval zonation. Large inter-event distances in the sequence reflect unconformities or pronounced

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physical changes through time in a basin. Several tests are available to compare or display the goodness of fit between individual (well) and average sequences of events.

SPLIN is an interactive microcomputer program with graphic displays that first scales the biozonation produced through ranking and scaling (RASC) in linear time, using selected age marker for tiepoints. Next, this regional time scale (biochronology) is correlated (with error bars) from well to well. The results represent isochron correlation charts and can match seismic sections. The age/depth results are also used for automated burial and subsidence histories with error analysis. The program makes extensive use of smoothing spline functions and cross-validation to calculate optimal (objective) regression of the RASC scaled optimum sequence on the individual well sequences of microfossil events.

The method of **unitary association** tabulates those species that co-occur in samples and those that do not. The final result is a stratigraphic succession of intervals of co-occurring taxa (concurrent range zones). Valuable as the method is for data that include first and last occurrences of many taxa, it is not easily programed or implemented on different computers.

DEPOR is an interactive program for microcomputers with graphics displays. It calculates the initial (restored) porosities and change of porosities through time for successive formations in a well. The basis is porosity/depth data per lithology, or sonic velocity in micro seconds per foot and depth/lithology data from top to bottom in boreholes. The results from **DEPOR** are fed into **BURSUS**, another interactive program with extensive graphics display on a microcomputer. This calculates compacted and restored sedimentation and burial rates for all age levels in a borehole, as well as sediment load and water load corrected subsidence. The results provide direct feedback on the quality of age/depth, paleo-water depth and depth/porosity data for basin analysis.

Against this background CQS, in cooperation with COGEO-DATA and Petrobras, held a short course in Brazil late last year. Five lecturers from the U.S.A., Canada, The Netherlands, and the U.K. reviewed various aspects of quantitative

Figure 1: At the CQS short course, L-R, H. Chaves (Petrobras), J.C. Della Favera (Petrobras), J.C. Brower (U.S.A.), F.M. Gradstein (Canada), F.P. Agterberg (Canada), J. Van Hinte (The Netherlands) and W. Schwarzacher (U.K.).

stratigraphy for 35 participants, mostly from Brazil. The excellent facilities at Petrobras and the enthusiasm and high level of professional scientific knowledge of the participants contributed in large measure to the spirited and informal atmosphere. Following the course, the lecturers spent several days at Petrobras to discuss Brazilian data sets for quantitative analysis and to actually process these data. It is this aspect of implementation and familiarization with software that often is most laborious and tedious. Plans are underway to continue this course for modern sedimentary basin analysis in other South American countries and in North America or Europe in 1989.

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COGEODATA Applies Computers to South American Resources and Stratigraphy

Ouro Preto, Brazil, 23 - 26 November 1987

In the past ten years COGEODATA, the IUGS Commission on Storage, Automatic Processing and Retrieval of Geological data, has shifted its main concern with databases, storage and retrieval of geodata towards the methodology of computer use and computerized mathematical methods. This trend was amply reflected late last year in the Fourth South American Symposium organized for COGEODATA by H. Chaves and H. Roeser and attended by 86 geoscientists from nine countries including Argentina, Brazil, Canada, Federal Republic of Germany, Finland, Peru, Northern Ireland, Venezuela and the U.S.A.

On the topic of computerized mineral resource analysis, D. Harris (U.S.A.) reviewed his current research on mineral resource prediction based on coherency analysis of Fourier harmonics derived from geochemical, geophysical and geological data. The use of computers in assessing mineral resources in Finland, Norway and Sweden was reviewed by G. Gaal (Finland), who presented the results of the Nordkalott Project, a fine example of regional cooperation. B. Johnson (U.S.A.) detailed the design of a widely used computerized mineral occurrence database system developed by the U.S. Geological Survey. L.P.V. Braga and M.E.

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Silva (Brazil) applied geostatistics to multivariate simulation of a bauxite deposit, and G.G. Pereira, Jr. (Brazil) reported the uses of microcomputers in an economical feasibility study of open pit mining.

Papers on quite a different topic - computerized quantified stratigraphy - were also presented. The Chairman of the IUGS Committee on Quantitative Stratigraphy, F. Gradstein (Canada), outlined the construction of time scales and their application to sequence stratigraphy in petroleum basins, using the RASC (ranking and scaling) probabilistic sequencing method. F. Agterberg (Canada) applied the same method in studying frequency distribution of highest occurrences of Cenozoic foraminifera along the northwestern Atlantic margin. The effect of random sedimentation rates on the preservation of short sedimentary cycles was reviewed by W. Schwarzscher (Northern Ireland), and J.C. Brower (U.S.A.) gave introduction to a handy computerized method for seriation of an original data matrix as applied to biostratigraphy. G. Bossi (Argentina) presented a new program for palaeocurrent analysis, and U. Th. Mello (Brazil) presented an algorithm for synthetic stratigraphy.

In a series of papers, Brazilian participants discussed other aspects of data handling; E. Lewis reviewed an extensive program of lineament analysis developed by the Brazilian oil company PETROBRAS, and A.A.R. Oliveira discussed theoretical considerations in estimating the presence of faults by means of triangulation. Various interpolation methods used in automated contouring of geological data were compared by J.K. Yamamoto, and R.C.M. Periano described MICROMAP, an interactive contour mapping system. A versatile package called GEOQUANT adapted to an IBM PC, compiled by the Brazilian geological survey company CPRM, was demonstrated by P.C.A. Branco. This is a fully integrated, interactive, modular statistical and mathematical system for analyzing geochemical and petro-

Figure 1: Some of the COGEODATA participants in Ouro Preto. G. Gaál (2nd from left), H. Chaves (front row with briefcase), H. Roeser (on Chaves' right).

logical data. Finally, M.C. Pacino (Brazil) analyzed possibilities of using finite and two-dimensional convolutions operators in handling gravimetric data.

The fifth South American COGEODATA Symposium will be convened in Venezuela in February 1989, by N.G. Munoz J. (P.O. Box 50447, Caracas 1050-A, Venezuela). Computer applications in oil geology, mineral resources and geochemistry will be reviewed.

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IGCP Begins Work on Metalliferous Black Shales

Jesenik, Czechoslovakia, 6 - 11 October 1987

Black shales of Precambrian to Recent origin are distributed on all the continents. The most economically significant occur in Europe, Asia, North America and Australia, where important ore deposits and promising metal accumulations have been found recently. Black shales are known to host a wide range of materials including Au, Ag, platinum group elements, U, Mo, V, Pb, Zn, barite, Sn, W, Hg, Sb, Fe, Mn and graphite.

It is not surprising, therefore, that scientists in many regions have shown considerable interest in comparing and correlating their studies of black shales and related ore deposits. In Czechoslovakia last October, representatives from 13 countries met to establish the organizational structure of new IGCP Project 254 and to review the state-of-the-art of studies on these rocks. The meeting was supported by the Geological Survey of Czechoslovakia, the Czechoslovak Commission for Cooperation with Unesco, Unesco and IUGS.

The meeting established eight working groups divided with respect to mineralization types, as follows:

- Au, Ag (Coordinator J. Aichler - Czechoslovakia),
- Platinum group elements (I.R. Plimer - Australia),
- U, Mo, V (J.S. Leventhal - U.S.A.),
- Pb, Zn, Cu and barite (I.R. Jonasson - Canada),
- Cu and accompanied elements (E.C. Jowett - Canada),
- Sn, W, Hg, Sb (B. Moine - France),
- Fe, Mn (Fan Delian - P.R. China),
- International standards and correlation of analytical measurements (B. Arbogast - U.S.A.).

V.A. Burjak (U.S.S.R.) focussed attention on the behaviour of gold during lithification and metamorphism of the black shale formations of East Siberia, the Far East and the north-east part of the Soviet Union. Some 10 to 20 t/km³ of Au

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are expected to be released during lithification, 2.5 to 6.0 t/km³ during metamorphism and 3 to 6 t/km³ during granitization.

Fan Delian (China) presented the results of studies on ore mineralization on the Yangtze platform where several anoxic periods, closely related to mineral ore deposits, have been established. Sinian black shales contain Mn-carbonate and Mn-sulphide-carbonate, pyrite, phosphorite-rhodochrosite and silver-vanadium ore deposits. Barite, phosphorite, V, U, and Ni-Mo poly-element deposits are located in Cambrian black shales, together with stratabound Pb, Zn, Hg ore deposits, which are also closely related to these black shale formations. Middle Ordovician black shales are associated with Mn carbonate deposits, and the important role of clay minerals and micro-organisms during ore forming processes has been proved.

Several papers dealt with the role of organic matter in mineralization processes. Leventhal emphasized the importance of organic matter in concentrating metals (Chattanooga shales, Alum shales, and Grants uranium deposits) and in reducing sulphate to sulphide either by biological or nonbiogenic means, as in the case of the uranium deposits of the Wyoming basins, south Texas coastal plain, and Pine Point Pb-Zn deposit. Chemically or biologically reduced sulphide is the active agent that reduces and precipitates the metals. It seems that carbon and sulphur data from Nevada-disseminated gold deposits are useful in interpreting the relationship between organic matter and mineralization.

I.R. Grauch (U.S.A.) and his co-authors stated that the organic matter at the Cluff Lake U-deposit is related to a migrated radiation-damaged bitumen. The uranium occurs as micron-sized mineral particles in the organic matter along with other exotic minerals, but there is no evidence that the organic matter concentrated oxidized uranium atoms from solution. The main role of this organic matter has been to contain and protect U from oxidation during the last 1,000 Ma.

A summary of geochemical studies on metalliferous shales in the midwestern U.S.A. was given by N.R. Shaffer (U.S.A.). Anomalously high concentrations of Zn, Cu, Cr, V, Ni, Mo, P and other elements have been found in the upper part of the New Albany Shales, where $\delta^{34}\text{S}$ values in pyrites are as low as -42.4%. Anaerobic sulphate-reducing bacteria probably generated the sulphides in a system open to sea-water sulphates during periods of low detrital sedimentation.

A review of investigations of the Marsberg Cu deposit of the Rhenish Massif was presented by B. Stribny (F.R.G.). He showed that low-grade, stratabound sulphide mineralization is situated in folded Lower Carboniferous black shales and lutites as well as in bituminous limestones and marls of the Permian cover. Parts of these ore accumulations were mobilized and reprecipitated in fracture zones and along surfaces of unconformity. In addition, oxidation and cementation processes caused an intensive migration of metals, resulting in the formation of high-grade ores, with up to 16% Cu in these zones.

The geochemical characteristics of carbonaceous meta-sediments (including black shales) from six Proterozoic schist belts in Finland were presented by K. Ruskeenieni (Finland). There is no clear correlation between the contents of carbon and sulphur or between C and U, V or Mo in these rocks, but the contents of some metals increase in black schists near mineralization and ore deposits.

B. Kribek (Czechoslovakia) discussed carbon-rich rocks in the Bohemian Massif as a source of metal in the Variscan uranium deposits of zonal type in the highest grade Precambrian metamorphics of the Moldanubicum. Metamorpho-

genic gold mineralization has been found in black phyllites in the Jeseniky mountains, a part of the Central European Variscides. The most valuable result of the study of the West Carpathian pre-Alpide units is the finding that black shales were the source of metals and sulphur during epigenetic Sb-mineralization in the Little Carpathians.

The contribution of Z. Kukal (Czechoslovakia) concerned the development and genesis of black shales in the Bohemian Massif, their wide stratigraphic distribution from upper Proterozoic to Tertiary rocks, and the conditions of their formation on single stratigraphic levels (euxinic versus anoxic). B. Buchardt (Denmark) discussed the Alum Shale formations in Scandinavia especially from the organic geochemistry point of view. The Polish group, M. Banas, W. Mayer and A. Piestrzynski, presented an overview of economically significant black shale formations in Poland emphasizing the "Kupferschiefer" type, which is one of the largest potential reserves of copper ores in the world.

The role of hydrocarbons in the formation of "Kupferschiefer" type deposits was also pointed out by Jowett. Jonasson and M. Polgari (Hungary) outlined the distribution of metalliferous black shales and related ore deposits in their countries. Also discussed was the role of volcanic additions in Archean sediments as potential sources of metals for the early Proterozoic silver-sulfoarsenide veins in the Cobalt area of Canada.

Considerable time was devoted to a discussion of sampling and analytical procedures in geology. To ensure satisfactory correlation in analytical work, Leventhal will distribute samples of Chattanooga shales as a USGS standard. All the papers presented at this inaugural meeting of IGCP Project 254 will be published in due course. The next meeting will be held in Beijing, China, July 30th to August 4th, 1988, within the framework of the IAS International Symposium on Sedimentology Related to Mineral Deposits. We would like to appeal to all scientists dealing with black shales to join our Project.

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IUGS TIE, SCARF AND PINS

To celebrate the 25th anniversary of the International Union of Geological Sciences, the IUGS Secretariat has designed a silk tie of dark blue, with white and yellow stripes and bearing a yellow IUGS logo.

A ladies' scarf (28 x 30") is also available with a design based on a photomicrograph of metachromite in metadunite from Hordaland, Norway. The main colours are blues with some white and red. An IUGS lapel pin is also available.

Prices including postage and handling:

Tie	\$12US
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Order from: the IUGS Secretariat, Geological Survey of Norway, P.O. Box 3006, N-7002 Trondheim, Norway.

Minerals and Geology of Pakistan Reviewed

Quetta, Pakistan, 20 - 28 October 1987

The National Centre of Excellence in Mineralogy located at Quetta, Baluchistan, organized late last year a symposium on the Mineral Resources and Geology of Pakistan. This reviewed recent work by Pakistani scientists on a wide range of topics including the following:

As regards oil and gas, A. Malik pointed out that three out of five gas fields of the Marri Bugti Agency possess reserves of 6.5. trillion cubic feet in Upper Cretaceous to lower Tertiary clastics and carbonates. These are likely to be revised upwards as work progresses. The Baluchistan Province is divisible into five plate-tectonic units, according to A. Farah. These are the Chagai volcano-plutonic arc, the arc-trench system of the Kharan-Makran region, the Chaman strike-slip zone, an ophiolitic zone, and the continental shelf of the Pakistani plate.

M. Ali and colleagues reported that although gravity, magnetic and resistivity surveys over lead-zinc deposits of the Besham area yielded low geophysical signals, they were useful in demarcating ore zones occurring in places of low gravity and magnetic relief around structurally weaker zones. A new occurrence of pink zoisite (thulite) was reported by T. Khan and others in calc-silicate pockets in quartz veins cutting granodiorite from Nomal. And R.H. Siddiqui and co-workers argued that the phyllic alteration sequence in tonalite porphyry at the Deshte Kain Cu-Mo prospect is due to Siand K-metasomatism. I. Ali relates sulphide mineralization at the Saindak polymetallic deposits to hydrothermal alteration, with K-silicate alteration correlating with high Cu content.

A review of the geology of Kala Chitta Range was given by A.A. Butt who showed that the Mesozoic-Cenozoic evolution prior to the Miocene was broadly similar to that of adjacent regions. The major Late Cretaceous (Cenomanian-Turonian) regression, and the Coniacian-Campanian transgression in the north led to epidiagenetic changes in Cretaceous rocks and secondary porosity in sandstone. Another Late Cretaceous regression formed residual deposits over the micritic

Figure 1: Field excursion participants at the barite quarry at Gunga, Khuzdar District, Pakistan.

Kawagarh Formation, and a transgression during Thanetian (Late Palaeocene) time deposited shallow shelf carbonates. Marine deposition in the Kala Chitta Range ceased between Late Eocene and Oligocene time, and the Range formed a Miocene hinterland to the adjacent Potwar basin. Butt also highlighted the significance for Palaeogene stratigraphic correlation of the nummulitid genus *Ranikothalia* from Late Palaeocene rocks of Pakistan.

Exploration for chromite ore bodies in the Muslimbagh ophiolite emplaced in the Palaeocene or Early Eocene would be aided, it was suggested by S.G. Abbas, by concentrating along the hinges of isoclinal folds within dunites. Z. Ahmed demonstrated that the Sakhakot-Qila ophiolite has strongly magnesian ultramafites with certain unique features in its pyroxenes and its pyroxenites.

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Paleontology and Evolution: Extinction Events

Leioa (Biskay), Spain, 20 - 23 October 1987

The Leioa Campus of the Universidad del País Vasco (Euskal Herriko Unibertsitatea) in this old region of the Iberian Peninsula was the recent site of an international conference sponsored jointly by the university, the Sociedad Española de Paleontología, and IGCP Projects No. 199 (Rare Events in Geology) and 216 (Global Biological Events in Earth History). Some 60 papers were presented to the 140 participants from 18 countries around the world.

A.J. Boucot (U.S.A.) opened the Conference by stressing the similarities among Phanerozoic extinctions. The differences were exposed at a hierarchical order, which makes it difficult to determine the causes. His call was to analyse carefully each case of biotic crisis! As regards extra-terrestrial events in extinctions, D.M. Raup (U.S.A.), using the Cretaceous-Tertiary (K/T) boundary case as his central point, expanded on the general effects of cosmic events on

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Earth life. His approach suggests a strong link between cause (impacts) and effect (extinctions), and he emphasized that organisms live not only on Earth but also within a cosmic scenario.

Up-to-date results on the K/T boundary in western North America were presented by G.A. Izett and C.L. Pillmore (U.S.A.). Their finds of shocked quartz are one of the stronger arguments in support of a large meteoritic impact at the end of the Cretaceous Period. Y. Rosenfeld and colleagues (Israel) also favoured a meteoritic impact but a multiple one, as indicated by several Ir anomalies and extinctions recorded around the K/T boundary in southern Israel. On the other hand H.J. Hansen (Denmark) reported careful analyses that support an earthly source for Ir concentrations.

The correlation of terrestrial data on extinctions with better known marine events was discussed by M.T. Alberdi (Spain) and F.P. Bonadona (Italy), J. Agustí and S. Moya (Spain) and M.A. Alvarez and co-workers (Spain). E. Aguirre (Spain) drew a detailed picture of the non-catastrophic Plio-Pleistocene macro-mammal successions in Central and Western Europe. His work shows a strong coincidence between faunal crises, extinctions and the last record of normal magnetic polarity and, to a lesser degree, geographic or climatic changes.

Other speakers explained extinctions by genetic, ecological, or morpho-functional causes. J.A. Kitchell (U.S.A.) gave a general review of the biological selectivity of extinctions, showing that the difference between mass and background extinctions is not a simple quantitative rate, as suggested by the stratigraphic record. Survivals can be related to normal characteristics of life, as for example in the case of the meroplanktonic centric diatoms of Late Cretaceous age, which survived the K/T boundary extinction thanks to their resting spores. A. Monclova (Spain) approached the Late Cretaceous dinosaur extinction as a break of the trophic web caused by the change in the Cretaceous flora, preceded by an inversion of the prey/predator ratio, according to his results, along the Jurassic-Cretaceous transition and into the Early Cretaceous Period. O.H. Walliser (F.R.G.) reviewed the different causes of bioevents, and drew attention to the need for detailed studies both stratigraphical and geochemical.

Many papers used the K/T boundary, mainly from the biostratigraphic point of view, to explain causes and patterns. One scenario for the extinction at this level was outlined by A. Hallam (U.K.) who pointed out its biological selectivity. He is now of the opinion that two different causes were involved, one involving long-term climatic changes accentuated by fall in sea levels and the other catastrophic, to explain the crises in marine plankton and terrestrial plants around this boundary. Similarities and differences between several well-known K/T boundary localities were discussed by J. Wiedmann (F.R.G.) who also pointed out the consequence of evolutionary patterns on marine macrofauna and plankton.

Detailed biostratigraphic studies on new and old K/T boundary sections were presented by P.D. Ward (U.S.A. for the Basque Country), A. Smit and others (The Netherlands for Spain), and for sections in the northeastern Apennines by A. Montanari and W. Alvarez (U.S.A.) and R. Cocioni (Italy). K. Perch-Nielsen (Switzerland) reviewed nannoplankton biostratigraphy across the K/T and Eocene/Oligocene boundaries. In her opinion, survivors of a calcareous nannoplankton mass-mortality at the K/T boundary became extinct during the earliest Paleocene.

Figure 1: Penetrating the K/T boundary bed at Zumaya, Spain, during the conference field trip.

As regards dynamics, M.J. Benton (U.K.) contrasted the study of extinction on the basis of tetrapods with that based on marine invertebrates. The former have the great advantage of their monophyletic taxonomy whereas the latter have a paraphyletic one. He raised the question of possible changes in extinction times and patterns when marine invertebrates have a monophyletic taxonomy. G.E. Boyajian (U.S.A.) analyzed the variation in the rate of background extinctions. This was higher during times with a large proportion of young genera than during periods when old genera increased their proportion of the total population. G.R. McGhee (U.S.A.) selected the role of low speciation rate in the Frasnian/Famennian crisis, in addition to the rate of extinction, as a trigger mechanism.

M. Bagge-Johansen (Denmark) presented an extinction pattern of brachiopods (micromorphs) in the K/T transition of NW Europe. In her opinion, the sudden extinction of 70% of species was more related to a perturbation by external forces than a change of long period in the faunal system. M.C. Rhodes and C.W. Thayer (U.S.A.) analyzed the K/T boundary and Permian/Triassic boundary bio-events. They found different patterns in those two major crises that did not fit with a cyclic cause for extinction events. W. Browicz-Lewinski and co-workers (Poland and Spain) reported a rich occurrence of possible shocked quartz and plagioclase at the Middle-Upper Jurassic boundary, in addition to Ir anomalies. The role of possible meteoritic impact is enhanced with their results.

Finally, papers by E.G. Kauffman, T.A. Hansen, Y. Herman and others (from U.S.A., India, Switzerland, and U.S.S.R.) favoured the stepwise model of extinction. The latter reported new data in the Mangyshlak K/T boundary section that favoured large-scale volcanism as the trigger mechanism for this bioevent. Kauffman used effectively the ecological graduation of extinction in a stepwise fashion to explain the depletion of ecosystems over 3 to 4 Ma, with several larger fluctuations in ^{18}O , ^{13}C , etc. commonly associated with those extinction steps.

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