BOOK REVIEWS...

OPHIOLITES

Proceedings International Ophiolite Symposium Cyprus 1979

A. Panayiotou (ed.)

Ministry of Agriculture and Natural Resources, Geological Survey Department, Nicosia, Cyprus, 1980, 781 p., 15 Cyprus pounds, \$45.00 U.S.

This volume is the result of the Ophiolite Symposium held in Nicosia, Cyprus, April 1-8, 1979. It is a mighty compilation of 79 papers divided into five subject chapters: Troodos Ophiolite, General Aspects, Tethyan Ophiolites, Pre-Tethyan Ophiolites, and Metallogenesis associated with Ophiolites. The papers range from generalized syntheses within each category to descriptions and interpretations of individual occurrences. Seven papers are in French, the rest are in English and all have English abstracts. Missing from the book are most of the North American ophiolites, presumably because they were the subject of a separate symposium a few years ago.

The Troodos Complex, located in Cyprus, is the subject of the first chapter. In many ways, it is the focal point of the book. Because of its preserved state, and its integrity, completeness and history of investigation, it is the type-ophiolite and a standard by which other ophiolites are measured. Generalized accounts and interpretations of the Troodos Complex are given by I.G. Gass, and by D.L. Searle and A. Panayiotou, and an analysis of its tectonic setting is presented by A.H.F. Robertson and N.H. Woodcock.

The other papers in this chapter are either more specific, such as one on the significance of the sheeted dyke complex or are supplementary to the evolution of the Troodos Ophiolite. Together the articles present a coherent history of the development of this prime ophiolite; there is general agreement that Troodos represents the floor of a marginal basin underthrust from the south by the subducting margin of the African continent and subsequently uplifted.

The chapter on General Aspects is primarily concerned with problems of ophiolite genesis and emplacement. There is a consensus that most of the adequately-studied ophiolites show evidence of having been formed in marginal basins where the influence of subduction zone emanations can be seen in their geochemistry, although it is subtle enough that it is not always compelling. According to papers from R. Laurent, M. Delaloye, M. Vuagnat, and J.J. Wagner, the parent magma is of high MgO - low TiO₂ composition related to komatiites; to some degree this is strengthened by evidence from W.E. Cameron, E.G. Nisbet, and V.J. Dietrich who show that many ophiolites have affinities to the boninites (high MgO - low TiO₂ andesites) of the Marianas forearc.

Views on emplacement vary between those of W.K. Gealey, who argues that all obductions stem from the underthrusting of island arcs by buoyant continental margins, and those of N.A. Bogdanov, who favours gravitational sliding of an allochthonous sliver of oceanic crust on to a subsided continental margin. The effect of the obducted slab on the rocks on which it comes to rest is discussed by S. Karamata who proposes that the metamorphism depends on factors such as the heat content of the ultramafic mass at its point of origin, velocity of ascent, total thickness and water content of the rocks affected.

Tethyan Ophiolites is by far the longest chapter (30 papers) and covers Tethyan orogen ophiolites from the Mediterranean to the India-Burma border as well as other ophiolites of Cenozoic-Mesozoic age. Notable among the ophiolites dis-

cussed are those of the Apennines and Greece, Antalya (Turkey), Neyriz (Iran), Oman, Muslim Bagh (Pakistan), and the Himalayas of India and Tibet. The Rocas Verdas ophiolite of Chile, the Dun Mountain ophiolite belt of New Zealand, and the Marianas forearc region are included from outside the Tethyan orogen. General papers by S. Karamata, J.A. Pearce and G. Rocci, F. Baroz, J. Bebie, A. Desmet, H. Lapierre, D. Ohnenstetter, M. Ohnenstetter, and J.F. Parrot recognize two groupings in the Tethyan ophiolites: an earlier group of Lower to Middle Mesozoic age in the western Mediterranean and a later group of the late Mesozoic age in the eastern Mediterranean and further east. Several authors look at individual ophiolites that occur in the Himalayan region and are of special interest because of the lack of information from the area.

The chapter on Pre-Tethyan ophiolites includes several papers on Caledonian ophiolites in Norway and in the Canadian Appalachians. Of these, a newly-found occurrence at Karmøy along the southwestern Norwegian coast has classical ophiolite stratigraphy and is of special significance in the interpretation of other Caledonian mafic-ultramafic complexes in Norway. Other lower Paleozoic occurrences are reported from Austria, New South Wales, and Tasmania. The Tasmanian ophiolites are unique because they are present in a Cambrian sedimentary trough formed on thinned and rifted Precambrian crust. Emplacement into the thinned crust is interpreted as a function of rifting rather than of subduction as postulated for most ophiolites.

The final chapter comprises a number of papers on mineral deposits in ophiolites. The first of these is an excellent summary by G. Constantinou on mineral deposits of the Troodos Ophiolite and covers the range of deposits to be found in ophiolites; asbestos in serpentinites of the mantle assemblage, chromite at the base of the layered sequence, Fe-Cu-Ni-Co sulphide veins in the gabbros, disseminated Fe-Cu sulphides in the sheeted dyke complex, and massive Fe-Cu-Zn sulphides at the Lower Pillow Lava-Upper Pillow Lava contact.

Papers that follow deal with specific deposits in restricted parts of various ophiolitic sequences. Several excellent papers detail the occurrence and genesis of podiform chromites in the "mantle" part of a number of complexes in the eastern Mediterranean, Oman, and New Caledonia. Surprisingly, massive sulphide bodies of Cyprus-type which might be expected to be of wide interest are represented by only two papers; one on deposits in the Trondheim district of Norway by T. Grenne, G. Grammeltdt, and F.M. Vokes and in the Oman by T. Alabaster, J.A. Pearce, D.I.J. Mallick, and I.M. Elboushi. Not directly related to ophiolites but, nevertheless, of interest is one paper by W.D. Nesteroff on Fe-Mn enriched sediments found in the Stratbo trench south of Crete and related to hydrothermal activity from an active transform fault.

Viewed collectively, a reader is bound to be impressed by the similarities and differences in ophiolites around the world. Many questions come to mind: Why, for example, do ophiolites seem to be confined to a few narrow time intervals: uppermost Cretaceous-Paleocene, Jurassic-Lower Cretaceous, Permian and Cambrian-Ordovician? Moreover, although the Tethyan orogen seems to have closed over an interval of time, Upper Cretaceous-Paleocene ophiolites extend from the Mediterranean to northeastern India. Why are ophiolites limited to the Phanerozoic? The sheeted dyke complex would seem to be an essential feature of ophiolites developed at spreading centres but why is it absent in some occurrences? These and other questions that occur from the juxtaposition of such a wealth of data are indicators of the volume's value. The organizers are to be congratulated both in their conception and execution of the work of this symposium.

The book itself is undervalued at 15 Cyprus pounds (about \$45 U.S.) and is attractively printed. Figures and photographs are

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well produced. It was published in 1980, a year after the symposium, and this commendably rapid rate of publication may be responsible for the principal flaws: typographically errors are numerous and, in places, lines of type have been misplaced. These, however, do not significantly detract from the book. Anyone who is even marginally interested in ophiolites should have this book.

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EARTHQUAKE PREDICTION, AN INTERNATIONAL REVIEW

D.W. Simpson and P.G. Richards (eds.)

American Geophysical Union, Maurice Ewing Series 4, Washington, D.C., 1981, 680 p., \$29.00 (U.S.).

In May 1980, 88 scientists from 11 countries doing earthquake prediction research met in rural New York for the 3rd Ewing Symposium of Lamont-Doherty Geological Observatory of Columbia University. The product of that symposium is this impressive volume, which contains articles of current work in earthquake prediction and a discussion of future directions.

The 51 papers give a comprehensive overview of the major areas of earthquake prediction research. The flavor of the volume and the research trends can be detected by examining the distribution of the papers by topic and country of origin. There are 30 papers by authors working in the U.S.A., seven from Japan, one joint U.S.-Japan effort, five from China, one U.S.-China joint paper, two each from Canada and the U.K., and one each from Iceland, Mexico and the U.S.S.R.

The material is conveniently and logically organized by the following major themes: seismicity patterns (14 papers); evidence for recurrence times of slip along major fault zones (8); long- and intermediate-term precursors: seismic (6), non-seismic (7); short-term precursors (6); theoretical and laboratory studies (7) and reviews of national programs (3). The contents bring out the essentially empirical nature of the approach to prediction, and its weak theoretical underpinnings.

There are a few more papers on seismicity patterns and earthquake recurrence intervals than on precursors, no doubt due to the increased attention given the seismic gap concept as a reliable tool for fixing the place and approximate magnitude of future plate-boundary earthquakes. The interpretation of time-space patterns of seismicity within plates is much less certain. Although some investigators believe there are regularities in the geographical spacing of earthquakes and the migration of background epicenters toward the future great shock, the evidence for such orderly behavior is not convincing.

Long-term information about the average interval between incidents of large slip on a fault is critical to seismic hazard assessment, if not to prediction in the strict sense. Given the short history available for analysis and the large deviation from the mean expected for typical geological processes, the need to utilize all available means of pushing the history of the sequence of great earthquakes on a fault as far back as possible is obvious. Seismological data, mainly for the past 100 years and the geological evidence capable of going back tens of millennia, are presented in a series of papers on recurrence intervals. Average intervals are proposed for some major fault systems.

The search for precursors, or anomalous behavior of geophysical or geological parameters, has been a central task of

prediction research since its inception. Almost every precursor that has been proposed and tested in the past is touched on in this volume, but no single precursor or particular combination is offered as the best answer to the problem. Changes in the ratio of compressional wave and shear wave velocities and precursory changes in focal mechanisms are among the seismic precursors examined. Long-term non-seismic precursors are restricted to anomalous crustal deformation and to gravity changes. The debate about the effects of levelling errors on the detection of the Palmdale uplift also appears. No precursory gravity changes are reported. Short-term precursors may hold the key to future warnings of an imminent earthquake. Papers on this topic range from changes in ground-water chemistry to anomalous animal behavior.

The theoretical work is concerned with modelling of the processes of fault slip and the associated tectono-mechanics. The emphasis here is on the relationship of these processes to the development of premonitory phenomena. Given the rudimentary state of the theory and the consequent dependence on results from laboratory studies for the interpretation of field data on precursors, it is surprising that only one paper, on acoustic emissions during stress corrosion cracking, was presented.

The editors are to be congratulated for publishing this volume just one year after the symposium was held. The book is handsomely produced, although it contains a higher-than-normal number of typographical errors and other signs of loose copy editing. These are probably due to the use of author-prepared copy, but do not detract seriously from the readability of the text.

The over-all impression is that there is a solid base for optimism that at least in some tectonic settings earthquakes are predictable by analyzing space-time patterns of preceding activity and specific precursors. It is also clear that we are a long way from routinely reliable predictions; more hard work is needed before that goal is achieved. Access to this volume is a necessity for those working in the field of earthquake hazards reduction research and of earthquake science in general.

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ASPECTS OF MID-CRETACEOUS REGIONAL GEOLOGY

R.A. Reymont and P. Bengtson (eds.)

Academic Press, London, U.K., 1981, 327 p., \$72.00 (U.S.), 30 pounds sterling.

For some time now, it has been widely recognized that the events of the Cretaceous Period, particularly those of the mid-Cretaceous Aptian to Coniacian, may be a key to understanding the developmental history of the Earth. Never before has the stratigraphic record of a single period been the focus of such concentrated research on a world-wide basis. A natural outcome of such research has been an increasing number of international symposia, substantial volumes of proceedings, and an unprecedented number of other books and papers dealing with aspects of Cretaceous geology. Since 1974, IGCP Project No. 58, the Mid-Cretaceous Events, has been a stimulus to more than 300 scientists working on such seemingly disparate topics as biotic changes, transgressive-regressive cycles, and the evolution of ocean basins.

Aspects of Mid-Cretaceous Regional Geology is a contribution to IGCP Project 58 and a welcome complement to an earlier (1978) volume published as *Annales du Muséum d'Histoire Naturelle de Nice*, 4. Whereas the so-called 'Nice volume' deals fairly comprehensively with the mid-Creta-

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ceous stratigraphy of western Europe, North America, and parts of the Far East, the volume under review examines other parts of the world where the stratigraphy is less widely known. Taken in combination, the two volumes provide a reasonably complete, convenient, modern compendium of world-wide, mid-Cretaceous stratigraphy.

Reyment and Bengtson have arranged the contributions to the new volume so that they first deal with selected regions of the northern hemisphere and proceed, through others in the equatorial belt, to selected regions of the southern hemisphere. The regions are clearly identified on the attractive dust cover of the volume, which depicts the continents restored to their mid-Cretaceous positions.

The volume begins with an account by K.-A. Tröger of the mid-Cretaceous deposits and palaeogeographic evolution of the German Democratic Republic. This article is followed by summaries of the deposits in two vast regions of the U.S.S.R. - D.P. Naidin's on the Russian Platform and the Crimea and M.A. Pergament's on the Pacific region, which extends from the Lena River to the eastern and northern coasts.

Mid-Cretaceous sequences in Tethyan facies are represented in P. Saint-Marc's paper on the widespread carbonate rocks of Lebanon and their ammonites, rudistid bivalves, planktonic and larger benthonic foraminifera. Reyment summarizes the present state of knowledge of the mid-Cretaceous stratigraphy in a series of basins, partly related genetically, in various segments of West Africa (Gabon, Cameroun, Nigeria, Niger, Chad, Senegal, Ivory Coast, and Ghana). R. Förster does the same for two block-faulted basins along the Mozambique coast.

On the other side of the South Atlantic, Reyment also provides an account of the deposits in Colombia, and O. Renz supplements the coverage of South America with a review of the entire Cretaceous System (although with appropriate mid-Cretaceous emphasis) in Venezuela. The volume ends with a substantial synopsis of the Late Aptian to Santonian, multifaceted biostratigraphy of New Zealand by J.I. Raine, I.G. Speden, and C.P. Strong, and an intriguing account by M.R.A. Thomson of the mid-Cretaceous rocks that have been found (or whose presence may be inferred) in remote Antarctica.

The mid-Cretaceous 'epoch' spans the time of one of the greatest marine inundations of the continental masses in Phanerozoic history. This epoch is commonly described in terms of Suess' 'Cenomanian transgression', although it probably involves more than one global transgressive-regressive couplet. It is not surprising, therefore, that most contributions to the Reyment-Bengtson volume deal principally with sedimentary rocks, explaining their accumulation under broadly expanding marine conditions and commenting on local and regional controls on sedimentation.

Other kinds of rocks are not neglected, however: Pergament, for example, places appropriate emphasis on mid-Cretaceous volcanic rocks in the northeastern U.S.S.R., and Thomson on the plutonic rocks emplaced during mid-Cretaceous orogenesis in Antarctica. This volume should offer more reliable information than hitherto has been available to those workers who seek to reconstruct the magnitude of the eustatically controlled changes in sea level manifest in the great Cretaceous transgressions.

The book is well edited scientifically and technically, and its format is pleasing. Although the papers are general reviews of the current state of knowledge, they offer a wealth of detail skilfully condensed in figures and tables. Useful subject and taxonomic indices are provided, and the shortcomings of the volume are limited. The abstracts are variable in length, not necessarily proportional to the length

of the papers, and some of them are inadequate synopses that undersell the papers they represent. The texts of some of the contributions are stylistically a shade pedestrian, and a few of the text figures, although well produced, are time-consuming to read in detail because they are coded and demand excessive reference to caption and legend for explanation. The quality of the fossil plates, although on the whole good, is variable.

This volume belongs on the bookshelf of every serious student of the Cretaceous System and should be consulted by all scientists who seek to use the evidence of mid-Cretaceous stratigraphy in their concepts of global evolution.

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PHYSICS AND CHEMISTRY OF THE EARTH. VOL 10: CHEMISTRY OF THE MOON

L.H. Ahrens (ed.)

Pergamon Press, Oxford, U.K., 1980, 264p., \$97.00 (U.S.), 43 pounds sterling.

This volume contains 10 articles on topics of lunar chemistry and petrology that summarize results of photogeologic investigations, remote sensing experiments and lunar sample analyses since the first landing on the Moon in 1969. The articles, written by experts in their fields, are of high quality and not only provide general reviews on modern methods applied in lunar research and the present state of knowledge, but they also contain extensive and critical compilations of numerical data and references to the pertinent publications.

Photogeological investigations and detailed analyses of returned lunar samples revealed that the regolith which covers the lunar surface represents comminuted bedrock generated by repetitive meteoroid bombardment. F. Hörz reviews the most recent models on mechanical effects of impact cratering that resulted in conclusions on the growth of the regolith in time, the vertical mixing and lateral transport of the regolith, and the comminution of exposed rocks.

I. Adler and J.I. Trombka summarize the results of X-ray fluorescence and gamma ray measurements obtained by the Apollo 15 and 16 missions. These orbital geochemical experiments have confirmed that highlands representing the moon's initial crust consist of Al-rich feldspathic rocks whereas the mare basins are made up of Fe-rich basalts. Local occurrences of KREEP (material rich in potassium, rare earths and phosphorus) indicate processes of differentiation.

Results of mass spectrometric determinations of inert gases in lunar samples and their origin from radiogenic decay, fission, cosmic rays and primordial matter are discussed by D. Heymann. E.K. Gibson, Jr. considers the abundance of volatile elements in lunar soils, their origin and regolith processes which affect their movement and distribution. D.S. Burnett and D.S. Woolum examine the available data on the effects of particle bombardment of lunar rocks and summarize the conclusions derived from dating of impact events, residence time and erosion rates of rocks at the lunar surface.

The lunar chronology is based on Rb-Sr and K-Ar studies. L.E. Nyquist gives an extensive review of the Rb-Sr method, the ages of mare basalts and non-mare rocks, and the dating of the major episodes of lunar evolution - formation of the moon (4.6 Ga ago), intense bombardment (until 3.9 - 4.0 Ga ago) and mare volcanism (3.9 - 3.2 Ga ago). The K-Ar method is discussed by G. Turner, and all available results are reviewed on exposure ages, ages of mare basalts, highland rocks, and special rock and glass types.

The irradiation effects in the lunar soil by energetic nuclear particles from solar wind, solar flares and galactic cosmic rays are reviewed by G. Crozaz. He also presents the conclusions that can be drawn from these effects on the temporal changes in the lunar surface, especially on the layering chronology of drill cores through the regolith.

Feldspar-rich rocks of the anorthositic-noritic-troctolitic (ANT) suite of the highlands represent the oldest rocks on the lunar surface. M. Prinz and K. Keil describe their mineralogy, petrology and chemistry, present proposals for terminology and classification, discuss the difficulties in textural and compositional classification due to modifications by repeated impacts, and summarize models on the origin of the ANT suite rocks.

KREEP basalts returned from all landing sites, particularly by Apollo 14, were formed early in the evolutionary history of the Moon. They are characterized by relatively high concentrations of large-ion lithophile elements, such as K, Rb, Ba, Th, Zr, REE. C. Meyer, Jr. reviews their mineralogy, chemistry, crystallisation sequence and discusses the genesis of this highly differentiated rock type.

This review on some major topics resulting from research on lunar samples is most welcome for those who would like to know what we have learned about our satellite since the first landing on the Moon in 1969.

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PROCEEDINGS OF THE FIFTH QUADRENNIAL IAGOD SYMPOSIUM

**The International Association on the Genesis of Ore Deposits:
Volume 1**

J.D. Ridge (ed.)

E. Schweizerbart'sche Verlagsbuchhandlung (Nägele U. Obermiller), Stuttgart, F.R.G., 1980, 795 p. \$55.00 (U.S.)

This volume is one of two produced from the fifth quadrennial symposium of the International Association on the Genesis of Ore Deposits (IAGOD), held in 1980 in Snowbird, Utah, U.S.A. It contains the bulk of the reports from the conference, with the exception of studies of districts or deposits in western North America, which were published as Report No. 33 by the Nevada Bureau of Mines and Geology. This subdivision appears to have been necessary because of the high costs of publishing.

The format is pleasing and the text is remarkably free of typographical errors. As in most books of this nature, there is no index because of the extensive labour involved in preparing one. It would have been a major asset in this eclectic volume which only in the broadest sense could be said to reflect a symposium. There is no unifying theme or natural grouping of articles, except that they all deal with mineral deposits and emphasize their origins. Most of the articles, though, are well illustrated with appropriate figures, photographs and tables. In a few of the tables, the inking is so light that patterns are not completely reproduced. Although the lack of organization, indexing and introductions seriously detract from considering this volume a scholarly work, the abstracts and conclusions are nearly all informative, enabling a fairly rapid scanning of the book.

Part I, General Topics, is dominated by papers from North American and Soviet authors (11 out of 13). Many deal with a variety of deposit types and their metallogeny; others deal principally with one type - three with the origins of porphyry deposits, two with stratiform deposits, and two with deposits attributed to a metamorphic origin.

There is evidence of a great diversity of opinion regarding the tectonics of the settings and the nature and origin of ore-bearing fluids. Plate tectonics and the Wilson cycle are discussed or implied in most papers authored by North Americans, contrasting with the emphasis on vertical and geosynclinal tectonics in the Russian papers. But both sides can benefit from the articles, which contain useful concepts and information or are good reviews. For example, an article by V.P. Rakhmanov and V.K. Tchaikovsky, "Manganese Ore in Activated Platforms", may interest many North Americans concerned with strategic minerals. Similarly, R.H. Sillitoe's article, "Stratabound Ore Deposits related to Infracambrian Rifting along Northern Gondwanaland", may be particularly useful to explorers in SW Asia. In other ways, however, Part I is the least satisfactory of the three sections and several articles were very difficult to follow.

Part II, which deals with Specific Districts, appears to represent more of a consensus than Part I. This section comprises over half the volume and has a greater breadth of authorship and areas of interest. Many of the papers focus on the general metallogeny of a region, ranging from porphyry deposits (9 of 28 papers) through to precious metal veins. Again, most are written with a plate tectonic model in mind, including one Russian article on the Caucasus by A.A. Kovalev and Yu. V. Karyakin. Other articles deal with volcanogenic massive sulphides, stratiform lead-zinc (barite) deposits, karstic lead-zinc ores, magmatic deposits, unconformity uranium deposits, sedimentary iron ores, fossil placer, and granitoid tin and tungsten. Most of these are authoritative, many have good isotopic and temperature data and interpretations and all consider the origins of the deposits in detail.

Part III, Specific Deposits, has the greatest homogeneity, but one gathers this is accidental. Of the 13 papers, 11 deal with stratiform deposits - volcanogenic or sedimentary. The other two papers concern a vanadiferous titaniferous iron magmatic deposit in western Australia and a precious metal vein deposit in New Zealand. In all papers, the principal concern is the origin of the deposits. Six of the papers that describe stratiform deposits wrestle with the problems of interpreting the origins through high-grade metamorphic overprinting. Most of the deposit descriptions and interpretations are interesting, and the gradients in massive sulphides between volcanogenic and sedimentary are well documented. The unusual deposits of particular interest include R. Key's, "Stratiform Manganese Mineralizations in the Palapye Group, Central-Eastern Botswana," S.F. Squiller and C.B. Sclar's, "Genesis of the Sterling Hill Zinc Deposit, Sussex County, New Jersey," and M.K. and A. de Brodtkorb's "La Helvicia - A Stratabound Pb-Zn-Barite Deposit, Argentina."

The omission of regional or deposit descriptions from Western North America may be viewed as irritating to some or pleasing to others. Moreover, the authors of this volume consistently quote references from their own backyard. This volume testifies to the need for more international meetings and resulting publications in the field of metallogeny.

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