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THE TECHNIQUES OF MODERN STRUCTURAL GEOLOGY: Volume 1: Strain Analysis

John G. Ramsay and Martin I. Huber

Academic Press, 1984, 360p., \$50.00 (US)

John Ramsay's first book "Folding and Fracturing of Rocks" (McGraw Hill, 1967) has served as the standard reference on stress and strain in relation to the geological sciences for the past 17 years. Its influence has been such that most of the strain studies carried out in the past 15 years were based on concepts presented in the book.

The new volume by Ramsay and Martin Huber approaches the topic from a somewhat different standpoint. Whereas the earlier book was almost entirely theoretical, with the inclusion of a few reference examples, the new one begins with practical examples. From the very first chapter where concepts of strain are presented with well designed exercises involving card deck models, to the last chapter covering progressive deformation, the initial emphasis is on worked-out examples of strain measurements.

This is a most refreshing approach to a branch of structural geology that has been neglected in the past largely because of the complex mathematical explanations with which most texts introduce the subject. The authors demonstrate that a large amount of useful information can be extracted from a variety of structural features with relatively little pain. It should produce a revolution in strain measurements similar to that started by Ramsay's first text, but this time it will be available to a larger audience.

Each chapter begins with a descriptive outline of the concept involved and the geologic features which can be used for that particular analysis. This is followed by a series of questions; some are to be answered from the reading alone, some from performing measurements on examples provided as photographs or diagrams. The answers to the questions are very conveniently given at the end of each chapter, and carefully worded and helpful explanations accompany the answers.

The questions are progressive in their search for understanding, and with each set there are some intended for those who wish to pursue the more theoretical aspects of the problems. As the authors point out, it is not necessary to complete all of these questions before proceeding. The book thus has two "tracks." One is for the student seeking a general knowledge of the way in which strain measurements can be utilized in geology. The other is for the graduate structural geologist needing a deeper understanding of the theory behind these measurements. The appendices, which offer a detailed account of strain parameters, are most useful for the latter.

The dual nature of the book means that it can be used by geologists in a wide variety of fields. It should open up to a broad spectrum of geologists the value of rigorous studies of strain history. As a teaching tool, I recommend that it form the basis of a course that everyone interested in tectonics should take. The level of study can be varied according to the background of the student; however, there are no

mathematical concepts in it that a North American student in the geological sciences will not have been introduced to. I cannot imagine a graduate program in structural geology not using this text. It is clearly written, comprehensive and beautifully illustrated. The introductory reading for each session is concise, and the questions are well defined so that they can be used as laboratory exercises. While using it in a graduate class, I found that the whole group stayed ahead of its reading assignments!

The professional geologist in a variety of disciplines should also find this book invaluable. There are many entrenched explanations of a variety of structural phenomena in the literature that have been challenged in the past 15 years. This book offers a good analytical approach, which should stir up some rethinking of old problems and encourage more comprehensive geological studies as part of routine investigations.

Ramsay and Huber draw a great deal on published strain work and bring together a wealth of ideas and results that have been introduced in the last 15 years. In addition to the excitement that this text will produce, there is the anticipation of awaiting Volume 2, on folds and fractures, and the hint of a third volume, which will cover some of the more complex three-dimensional aspects of strain studies.

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THE CARIBBEAN-SOUTH AMERICAN PLATE BOUNDARY AND REGIONAL TECTONICS

W.E. Bonini, R.B. Hargraves, and R. Shagam (eds.)

The Geological Society of America, Memoir 162, 1984, P.O. Box 9140, Boulder, Colorado 80301, U.S.A., 421p, \$47.50

Frederick Nagle wrote that, "There are enough geophysical models of the Caribbean afloat to satisfy nearly everyone; what the area needs now is critical information. . . . It falls upon those of us . . . who have tramped the terrain, collected and studied the rocks, dredged, cored, and drilled the sea bottom, looked at the structures in the field, and worked out the stratigraphy to finally do the Caribbean justice" (*Science*, 1972, v. 177, p. 782).

Although final justice is far from done, this book is another milestone of solid progress on that long journey, for most contributors did collect and study the rocks.

The three editors and nearly half of the 60 contributing authors are from Princeton University, and an appropriate subtitle might have been, "Thoughts of Princeton Geologists and Colleagues, 25 Years Later." Of the 28 papers, only two would not have filtered through a rigorous review process and only one of these could not have survived a reviewers' rerun; it is that good a book.

Almost all of the papers deal only with the geology and geophysics of Venezuela, Colombia, and the islands or marine areas adjacent to those two countries. There are four

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regional syntheses which are very different in approach. The first, an excellent review by J.E. Case, T.L. Holcombe and R.G. Martin, accompanied by an 83 x 42 cm morphotectonic map of the Caribbean, distinguishes 117 tectonic provinces and/or terranes. The R.A. Duncan and R.B. Hargraves synthesis is done mainly from the viewpoint of mantle plumes and somewhat equivocal magnetic data. Unlike the other papers of the volume, P.H. Mattson's review is strongly oriented toward the northern Caribbean and suffers from several geologic errors that should have been caught in review.

The regional synthesis by K. Burke, C. Cooper, J.F. Dewey, P. Mann, and J.L. Pindell is a sciolistic approach that tabulates highly selected data and omits many pertinent and necessary facts. It was a disappointing addition to this otherwise very informative volume. It includes 78 text errors (incorrect references, wrong dates, misspellings, transpositions and omissions of references given in the text) as well as serious omissions in fact. The latter include (1) failure to mention the documented presence of Grenville rocks in Cuba, (2) the lack of reference to many of the published radiometric dates from Cuba, although vital to any Caribbean interpretation (many of them are in the 137 to 196 Ma range), (3) the failure to mention the several major faults which cut at right angles to and offset the Cayman Trough and the Puerto Rico Trench, and (4) the lack of reference to the plateau-type shallow-marine to continental Neocomian and younger volcanic rocks of Jamaica.

With the exception of that by Case and others, the regional papers ignore three vital considerations. First, not one author knows the geology of Cuba. As Alice Boiteau and others have lamented: "In matters pertaining to Cuba, the publications cited. . . were done solely on the basis of library research; the authors never have worked in Cuba" (Transactions VII Caribbean Geological Conference, Guadeloupe 1976). Jorge Cobiella, one of Cuba's outstanding geologists, in his paper at the 1984 Moscow Congress wrote, "Since the 1950s, several papers have stressed the close geologic relations between Hispaniola and Cuba. . . . With the entry of plate tectonics onto the scene, the true nature of the relations between Hispaniola and Cuba, and between Cuba and the Bahamas, began to be overlooked by the authors working on the application of plate tectonics to northern Cuba and the Bahamas. Very few of the authors have any profound knowledge of Cuban geology. . . nor do they use the up-to-date information that is available."

The second vital fact overlooked by several authors of Memoir 162 is a most important result from DSDP Leg 67 transect of the landward slope of the Middle America Trench, that the Caribbean Plate did not come from the Pacific. "The presence of a tectonic edifice along the Pacific face of the Central American Isthmus limits the possibilities for the origin of the Caribbean Plate. The terranes of Pacific origin that are found there, starting in the late Jurassic, were 'trapped' by compressive tectonic events in their present position. The terranes of the same age in the Caribbean therefore could not have been 'captured' during episodes of the differential drift between North and South America. . . The Caribbean Plate is not of Pacific origin; all available evidence indicates its Tethys affinity" (J. Aubouin et al., DSDP Initial Reports, v. 67, p. 754-755, 1982). This statement and the unequivocal evidence on which it is based are ignored, and, as a result, the conclusions of several of the papers in the present volume are negated.

A third fact overlooked by several contributors to this volume is that cumulative offsets greater than 100-200 km are not possible either along the Northern or Southern Caribbean fault systems. T.H. Anderson and V.A. Schmidt,

among others, have demonstrated this in the onshore Guatemala extension of the Cayman fault zone (Geological Society of America Bulletin, 94, 941-966, 1983). Here, a Turonian-Santonian thrust sheet, uncut by post-Santonian faults, overlies the Polochic fault. The entire Cayman fault system either dies out westward into Chiapas, or is overlain by the allochthonous Chiapas massif. Farther east in the Puerto Rico Trench area, the absence of a pre-middle Eocene history on many of the strike-slip faults of the northeastern Caribbean has been demonstrated convincingly by Alonso and colleagues (1983, X Caribbean Geological Conference, Cartagena, Colombia) among others.

Other papers in Memoir 162 also demonstrate that lateral offsets, if any, were very small. For example, the seismic study by J.W. Ladd and others north of Venezuela and Colombia extends across the Southern Caribbean deformed belt and shows with great clarity the total absence of through-going faults. Onshore, R.C. Vierbuchen's excellent study of the El Pilar fault shows a 20-km lateral offset, possibly somewhat larger (150 to 300 km on the basis of gravity, but probably much less, as shown by the geology). The study of S.E. Munro and F.D. Smith of the Urica fault zone, which intersects the El Pilar fault, shows 35 km of right-lateral displacement. J.N. Kellogg shows that the La Oca fault has less than 100 km of lateral displacement, and he concludes that this fault is not the Southern Caribbean fault system. R. Giegengack comes to a similar conclusion regarding the Boconó fault zone (as C. Schubert did years before) and shows that reverse faulting has been more important on the Boconó fault than right-lateral movement.

This volume also includes a study of the magnetic lineations of the Venezuelan basin by N. Ghosh and colleagues, a study marred only by their belief in a Pacific insertion of the Caribbean plate. There are several papers on remanent magnetism onshore and an outstanding study by W.E. Bonini on the tectonics of western Venezuela, as deduced from aeromagnetic surveys by the petroleum companies.

An excellent paper by D.J. Beets and others reviews the magmatic and metamorphic rocks of the Venezuelan coastal ranges and the offshore Netherlands/Venezuela Antilles. R.A. Duncan and W.B. Hargraves perpetuate the idea that the Bahamas are underlain by an oceanic volcanic plateau sequence brought in from the Pacific, despite copious evidence that continental crust underlies the whole chain - evidence from subsurface penetrations in wells, refraction data, reflection-seismic data, gravity, and magnetics, published in a score or more books and papers. Muessig's second paper is a fine treatment of the tectonic history of the Falcón basin, western Venezuela. H. Duque-Caro, with his usual refreshing style, explains the sedimentary-tectonic history and multistage mud diapirism of the Sinú and San Jacinto terranes of northern coastal Colombia. C. Macellari describes the late Tertiary tectonic history of the Táchira Gap along the Venezuela-Colombia border area, in a truly stimulating paper.

Another group of papers contains new radiometric data and tectonic interpretations based on fission-track dates. An exciting paper on fission-track ages around the Maracaibo basin, R. Shagam and others who come up with a really fascinating reconstruction of that median massif's tectonic history. Other contributors summarize new radiometric data which encompass all of post-Paleozoic Venezuela and the border area of adjacent Colombia.

The several outstanding papers on stratigraphy include a fine review of the La Quinta (mainly Jurassic) of the Perijá Andes by Maze, including new data and a very good paleontologic summary. S.K. Ghosh's paper on the condensed Late Cretaceous sequence of the Mérida Andes has worldwide application. The excellent description by F.B. Van Houten and H.E. James of the late Cenozoic Guayabo delta complex of the southwestern Maracaibo basin (north of the Táchira Gap); this tantalizing study of a young delta deserved more

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space than eight pages. Finally, the paper by G. Feo-Codecido and co-workers on the unmetamorphosed, largely Cambrian, section in a graben striking from the Colombia-Venezuela border in the Barinas basin to the Orinoco delta at the eastern end of the Eastern Venezuelan basin is a "first" in Venezuelan literature; one of many firsts in research reported in this volume.

The editors deserve the thanks and respect of our profession for giving such a fine volume to geology and geophysics. This is a book that no specialist in the Caribbean or in island-arc terranes of the world can afford to be without.

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MINERAL RESOURCE APPRAISAL

DeVerle P. Harris

Clarendon Press, Oxford, 1984, 445p., \$69.00 (US)

This book is a survey and critique of quantitative methods for the estimation of mineral and energy resources. The exposition places emphasis on regional assessments of undiscovered mineral deposits. A conceptual framework is initially provided to define the field of study and to enable us to see how the highly varied appraisal methods, which form the main part of the text, may be related and integrated. From the outset Harris stresses the essentially interdisciplinary nature of the subject, combining elements of geological sciences, mineral technology, economics, and mathematical statistics.

A wide spectrum of resource appraisal methods is identified, varying from abstract to applied in terms of usefulness, and from relatively simple to complex in terms of data requirements and analytical procedures. "Resource base" and "endowment" estimates of minerals as a purely physical stock are found at the less-useful end of the spectrum. The estimation of "resources", embodying specific economic and technological conditions, occupies the middle range, comprising a matrix of known-unknown and economic-subeconomic components. Towards the applied end of the spectrum, "potential supply" estimates enable the evaluation of costs, risks, and returns associated with the possible discovery of unknown mineral deposits. Harris shows that this progression of estimates from minerals as a physical stock to minerals as an economic flow demands an increasing balance among, and a fuller array of, geological, economic, and analytical inputs.

The resource appraisal concepts, estimation procedures, and case studies are grouped into five broad categories. The first presents economic resource models based on time series of historical data on mineral production and reserves; predictions are made of future conditions. The life-cycle pattern of mineral production and various types of econometric model are included in this category. Next come quantity-quality models, which estimate the relationship between the quantity of a resource measure and its quality as defined by the cut-off grade notion, in order to predict aspects of future resource availability.

A third group of geological resource models focuses attention on the geology of the Earth as a basis for appraising the mineral endowment or resources remaining. Estimating

procedures are shown to vary from simple assessments of mineral density, to statistical correlations between geological variables and some measure of mineral occurrence.

Harris then turns to geostatistical models, which acknowledge the variable and uncertain nature of resources by probabilistically describing some indicator of mineral occurrence. These include formal probability models, the use of subjectively estimated probabilities, models that employ multiple regression analysis or multiple discriminant analysis, and tonnage-grade models that estimate distribution characteristics among mineral deposits.

The final group deals with compound models that strive for a greater balance between the physical and economic aspects of mineral resource appraisal. This type of evaluation procedure typically employs geostatistical methods to estimate unknown endowment, then applying appropriate economic and technological conditions to predict future levels of potential mineral supply.

Within these general groupings, subdivided by chapter into 14 types of models, Harris describes the underlying concept, sets out the quantitative form of the model, and then provides case studies to illustrate its application. Strengths and weaknesses of each approach are highlighted in terms of possible appraisal objectives.

The subject matter of this stimulating and important book is fundamental to long-term policy and planning in the mineral sector. While the topic addressed is of paramount concern to the formulation of government policy, there are also concepts and applications here that should be of interest for strategic planning in mining companies. The sweep of issues covered is very broad. Essential material is provided for earth scientists, resource economists, exploration geologists, statisticians, government policy analysts, mineral engineers, corporate planners, systems analysts, and mineral economists.

Harris's treatment of this wide-ranging and complex subject is comprehensive, systematic, and rigorous. At the same time, the presentation is critically focused on the more productive areas of application, stressing the dynamic nature of mineral resources, the variability and uncertainty associated with undiscovered mineral deposits, and the role of resource appraisal in the context of the mineral supply process. In the real world of mineral economics, this is precisely where the emphasis should be.

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PETROLEUM RESOURCE ASSESSMENT

Charles D. Masters (ed.)

IUGS Publication Number 17, 1984, Episodes Secretariat, 601 Booth Street, Ottawa, Ontario, Canada, K1A 0E8, 157p, \$20.00 (US)

This book consists of a series of papers presented at a symposium and workshop on resource estimating held in connection with the Circum-Pacific Energy Conference in Honolulu in 1982. It contains some material that has been published elsewhere and will be familiar to the specialist but it is useful to a wider audience to have it gathered under one cover. The volume is edited and introduced by Charles D. Masters of the U.S. Geological Survey who has been very active in the field of resource estimating both within the U.S. and world-wide.

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The volume is timely in view of the growing interest in this field and, in particular, the need not only to estimate the overall hydrocarbon potential of countries or sedimentary basins, but also to quantify the ranges of those assessments. Earth scientists are also being made aware that economists, engineers and planners need estimates of likely field sizes and other attributes of future discoveries that will effect the costs of developing these resources.

The book provides a useful "snapshot" of the state-of-the-art of resource estimating, both in mature exploration areas and also in those areas that have yet to be drilled. It contains papers on mature and immature petroleum provinces in North America and elsewhere, and the methodology is explained and illustrated with case histories. One paper deals with the relationship between field size distribution and types of sedimentary basins. The importance of resource estimating for developing countries is also discussed.

Several points emerge from the papers. First is the need for tighter definitions, and it is to be hoped that the eventual recommendations of the World Petroleum Congress's Study Group on the Classification and Nomenclature of Petroleum and Petroleum Reserves will receive widespread circulation and acceptance. As matters now stand there is much confusion, especially among lay people on the differences between recoverable and non-recoverable hydrocarbons, between original reserves and remaining reserves, and on the exact status of estimates of future discoveries. In his introduction, Masters refers to the difficulties besetting those estimating economically recoverable hydrocarbons in the years ahead who have to "second guess" future production and development practices. Add the extra complications of world oil prices and prospective demand together with political and fiscal changes, and it can be seen that this is a hazardous business.

The importance of the timing of future discoveries is perhaps insufficiently emphasized in the present book. One suspects that the numbers predicted are for the ultimate future discoveries, but other workers, especially in industry, prefer to restrict prediction to a foreseeable future. This becomes important when considering the paper by G.L. Dolton on the U.S. potential. His figure of 82 billion barrels is probably high by industry standards, and it certainly far exceeds Nehring's 1981 figure of 20 billion barrels (in the Rand Corporation's report to the USGS/DOE on significant oil and gas field discoveries in the U.S.). In view of the general expectation for the individual field sizes of future discoveries to decrease, perhaps in excess of 80,000 new field discoveries would be needed to achieve Dalton's 82 billion barrels of new oil. Considering that API statistics show that discovery rates for new field discoveries for both oil and gas are 1 in 5, it would require more than some 800,000 wildcat wells to attain this success. Currently between 6,500 to 8,200 new field wildcat wells are drilled annually in the U.S., suggesting there was a very substantial increase in exploration, already very high by world standards, it could take 100 years to attain the 82 billion barrels.

The paper by R.M. Procter and G.C. Taylor describes in detail the methodology employed in Canada and gives an informative case history of the estimation of the future potential of the unexplored basin. The paper also contains the thought-provoking observation that geologists tend to underestimate the number of prospects likely to materialize in a sedimentary basin. D.H. Root and L.J. Drew highlight the difficulties that workers in the field of resource estimation face because of the variation in data bases in great parts of the world. Even in comparatively well documented areas, statistics can be difficult to compile and use because reporting agencies themselves change or they alter their definitions

and procedures with time. In less well explored regions, or where authorities discourage the publication of well results or proven reserves estimates, it can be difficult to build up exploration histories.

H.D. Klemme brings out the interesting relationship between the distribution of reserves and the type of sedimentary basin in which they occur. It also serves to illustrate how the fit of the statistics can be affected by definitions. When the steam flood operation in the Duri oil field is completed, the reserves of the Central Sumatra Basin could be increased by up to 2.5 billion barrels, according to the Chevron Oil Co. Annual Report for 1981. With such an increase the basin would then fit Klemme's correlation even more closely.

A different approach to the assessment of poorly known basins is presented by G. Ulmishek and W. Harrison. They recognize the difficulties of equating sedimentary and tectonic basins with oil provinces and suggest the novel concept of an Independent Petroleum System (IPS). Methods for comparing a poorly explored IPS with analogous petro-liferous ones are suggested. The authors return to the point made above and strongly support the argument that resources-in-place, rather than (original) reserves, should be used since the latter are economically and technologically controlled. However, the fact remains that for most workers the best data that is available generally refers to recoverable hydrocarbons and to back track to a figure for oil-in-place adds yet another uncertainty to the equation.

All in all, Petroleum Resource Assessment is a valuable introduction to the growing science of resource estimating. In addition to providing food for thought, it should stimulate work in other areas of the world. (The reviewer acknowledges the assistance provided by his colleagues.)

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DESTRUCTIVE MASS MOVEMENTS IN HIGH MOUNTAINS: Hazard and Management.

G.H. Eisbacher and J.J. Clague

Geological Survey of Canada Paper 84-16, 1984, 230p., \$20.00 Cdn. (Canada); \$24.00 Cdn. (elsewhere).

"The high ranges of the Alps have been inhabited for thousands of years. Human experience with natural and man-induced mass movements has been profound and is well documented. This experience has contributed significantly to advances in the control of debris flows and unstable slopes. Yet no single publication, particularly in English, has attempted to bring together this Alpine experience which should be of great interest

to the development of other high mountain regions, such as those in western Canada and the United States" (from p. 69).

This substantial volume is a contribution toward the filling of this gap. It will be of interest and value to anyone, whether in Peru or Canada, Nepal or New Zealand, who lives or works in a mountainous or volcanic region, and particularly to those engaged in planning, designing, or building in such areas. Transportation facilities, dams and reservoirs, forestry, mining, agricultural developments, even housing and accommodation for tourists - all can be and frequently are affected by the phenomena described.

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The book contains a summary of 16 centuries of experience of landslides and related phenomena in the Alps. It is probably unique as a collection of case histories described by a single team, one of whom (G.H. Eisbacher, now at the Institut für Geologie, Universität Karlsruhe, F.R.G.) has visited all the sites described.

The principle value of the book (and more than two-thirds of its volume) resides in the "Appendix." This contains a brief introduction to the geology, history, and climate of the European Alps, followed by 137 brief case history descriptions of destructive mass movements in an area from France to Austria, from the year A.D. 328 to 1976. The descriptions are illustrated by sketches and photographs and in most cases some indication is given of local geological relations, volume of mobilized material, triggering event, and damage to life and property.

The order of presentation is chronological, according to the date of the most significant event in each area. There is also an alphabetical index to the Alpine localities mentioned, as well as a location map and a table listing the "key attributes" of each of the events described.

The first and shorter part of the book is a description and classification of the main types of mass movements in five major subdivisions: "debris flows from bedrock failures," "mass movements on volcanoes," "glacier-related mass movements," and "rockfalls and rock avalanches." Although many of the examples are from the case histories in the Appendix, many other areas are mentioned and illustrated, particularly from the Americas and Asia. Discussions of hazard appraisal and protective or preventive measures are scattered in several places in this part of the book.

Obviously, then, this work contains a valuable and voluminous body of information. However, few people will wish to read it from cover to cover, and, unfortunately, the authors and publishers have not made it easy to use in any other way. The chronological arrangement of case histories in the Appendix has the advantage of grouping some climate-related events, but this arrangement obscures any other relationship that may exist.

For example, it requires some effort on the part of the reader to discover that events nos. 6, 74, 75, and 127 (dated 1117, 1814, 1820, and 1963) all occurred in the drainage basin of the Piave River in northern Italy and that each probably involved initial failure of a dip slope on bedding planes in carbonate rocks. Since the last-mentioned of these events is the disastrous rock slide from Monte Toc into the Vaiont reservoir, the geological similarity is of interest. To discover it, the naive reader must find the Index Map to the case histories (which is on p. 70 and is not listed in a table of contents or index), select from it references to the descriptions of nearby events, and then find and read the selected case histories on pages 82, 160, 162, and 212. There are other examples too. Thus although the book is a valuable source of information, the reader must be prepared to expend some effort.

Civil engineers and economists will be disappointed to find relatively little quantitative treatment of the mass movements themselves and of the social and economic evaluation of hazards, such as those contained in recent treatments by O. Hungr and others in the Canadian Geotechnical Journal (Vol. 21, 1984, p. 663-677) and D.F. VanDine in the same journal (Vol. 22, 1985, p. 44-68).

The lack of an index to the many localities outside the European Alps, mentioned in the first part of the book, is a minor drawback, as are the occasional questionable word usages ("embankment" misused consistently to mean the natural bank of a river or stream; "steel-concrete," a too-

literal translation from the German, to mean reinforced concrete). However, such peculiarities do not seriously detract from the value of the book. The list of references - more than 15 double-column pages of items from 1773 to 1983 - is alone worth the price.

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THE GEOLOGY AND ORE DEPOSITS OF THE SUDBURY STRUCTURE

E.G. Pye, A.J. Naldrett, and P.E. Giblin (eds.)

Ontario Geological Survey Special Volume 1, 1984, 603p., \$30.00 (Cdn.)

The exploitation of the copper-nickel ores of Sudbury and the geological investigation of the igneous complex with which they are associated have been going on for just about a century. Fifty years ago, W.H. Collins wrote that "the Sudbury Nickel Irruptive furnishes a most interesting case of the painfully slow, caterpillar-like, yet logical way in which we grope our way to an understanding of big and intricate geological bodies." But caterpillars eventually undergo a startling metamorphosis. The flight of a butterfly, colourful, erratic but effective, may be no bad metaphor for the research reported in this volume.

Emergence from the chrysalis occurred in the mid-1960s. The impact hypothesis of R.S. Dietz (1964) for the origin of the Sudbury Basin, supported by his discovery of shatter cones, has dominated all subsequent research on the Sudbury Basin and Structure, whether it was adopted whole-heartedly, as in general by the mining community, or served to provoke a reaction, as notably by geologists in government service. The petrologic and geochemical studies, largely by A.J. Naldrett and his colleagues, that have built the present understanding of the Sudbury Igneous Complex began appearing a few years later.

The two dozen chapters of this volume present a vast amount of data on all aspects of Sudbury geology and inferences drawn from them. Data and interpretation are in general kept distinct. The chapter on the Onaping Formation, for example, is by two authors, who describe the unit jointly and part company for separate concluding statements on its origin. The amount of cross-referencing shows that the authors had the benefit of each others papers. The structure of the volume is pyramidal, building up through two syntheses, one by T.L. Muir using an endogenic model and one by W.V. Peredery and G.G. Morrison using a cosmogenic model, to an impressively clear and judicious final assessment by A.J. Naldrett. He concludes that the event, certainly catastrophic, that formed the Sudbury Basin was probably an impact (although subsequent developments could as well be accommodated by an endogenous origin). This fractured the underlying crust and triggered ascent of a magma with an initial composition similar to continental flood basalt. As this spread through the fractured ground beneath the crater, assimilation of country rock and crystallization differentiation gave rise to batches of widely varying composition. As these magmas continued to migrate, they invaded and contaminated one another, in an exceedingly complex history that has only begun to be unravelled. Precipitation of the sulphides resulted primarily from a reduction in the solubility of sulphur as the magmas became more siliceous by assimila-

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tion of country rock. The ore bodies are not, in general, the site of primary precipitation of sulphides; there is evidence that the host rocks formed from magmas that acquired sulphides during their ascent, by the invasion and disruption of other batches of magma that contained the primary sulphide cumulates.

Sudbury has almost its own dialect of geologic jargon. A glossary that defines preferred terms in local usage and also gives the synonymy to be found in older literature is thus a welcome feature. To give a trivial example, one could learn that the preferred term for "Nickel Irruptive" of the quotation in the first paragraph is "Sudbury Igneous Complex." And indeed the editors have seen to it that this and the other chosen terms were uniformly used by all contributors.

The book is handsomely produced, hard-bound, and very reasonably priced. Two-colour printing is used, on the whole quite effectively, in text layout and in illustrations. A newly compiled geologic map at 1:50,000 scale and regional geologic and geophysical maps at 1:100,000 scale are included in a pocket. Proof-reading might have been better; there are a number of typographic errors and misspelled personal names.

The final figure in the book, Naldrett's schematic cross-section of the structure, makes it clear that the direction to seek data for future major advances in understanding Sudbury (and some truly spectacular ore bodies?) is downward. In another copper-nickel district, Pechenga on the Kola Peninsula, the world's deepest drillhole is currently returning core from below 12 km. Without detracting from the achievement of the Soviet drillers, or the importance of the first look at samples from such depths in an essentially normal crustal sequence, it must be said that these are not thrilling rocks. I can think of nowhere that a deep drillhole would be more exciting and informative than at Sudbury, and nowhere that the surface and shallow-level groundwork has been better laid. May we hope that the organizing ability of the government, industry, and academic geologists of Ontario, which this volume demonstrates, will find expression in such an ambitious project?

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THE GEOLOGY OF THE ATLANTIC OCEAN

K.O. Emery and Elazar Uchupi

Springer-Verlag, New York, Berlin, Heidelberg, Tokyo, 1984, 1050p., \$98.00 (US)

K.O. Emery and Elazar Uchupi rank among the world's best known marine geologists, and it is doubtful that a team of scientists could be selected with better qualifications to produce a volume on the geology of the Atlantic Ocean. It is much to the benefit of the present and future scientific community that they have seen fit to devote the better part of the past eight years to the completion of this project. The result is a volume appropriately classed as "monumental."

The book is a broad synthesis of observed biological, chemical, geological and physical processes aimed at solving major problems associated with the shape, composition and

history of the oceans. To this end the authors review all the relevant literature for the Atlantic Ocean north to Greenland and south to the South Sandwich Islands, and for the bordering land masses; some 5,000 references are cited. Pertinent findings from other oceans and on land are frequently cited to support their arguments. The book is more than a mere compilation, because Emery and Uchupi draw on their own wide experience and knowledge to derive new insight and raise fresh questions.

The book is arranged in eight parts, the first of which traces the growth of knowledge about oceans from the earliest records to the present day. The second part is a detailed treatment of physiography, from the coastal zone on land to the deep ocean, with emphasis on accounting for the origins of physiographic features. The time element involved in the development of oceanic physiography and the formative driving forces are explained in terms of the earth's Internal Igneous Structure.

The history of the crust of the Atlantic and the nature of the continent-ocean transition zone are dealt with under the heading Syn-rift Supersequences and Crustal Boundary. The thickness, depths, ages, and structural features of sedimentary strata on the ocean floor are discussed under Drift Supersequence. Physical, chemical, and biological compositions of the sediments in the ocean, and their sources, transport and rates of deposition are treated under Sediment Provenance and Properties. All the preceding parts of the book are synthesized in Evolution of the Ocean Floor. The final section deals with all aspects of the Interfaces Between Ocean and Man.

The general format of presentation is to proceed counter-clockwise around the Atlantic, beginning off Eastern North America where, in many instances, the most extensive studies have been carried out. The literature covered includes references as recent as 1983, but the authors also review the earliest work on each topic, and thereby maintain a most interesting historical perspective throughout the entire volume.

The illustrations warrant special mention. The 12 accompanying maps (2 sheets each, folded in a separate box) cover the Atlantic Ocean and adjacent land masses from 60°N to 60°S; the projection is Mercator. The maps measure about 90 cm between these latitudes, and cover bathymetry, physiography, seismic reflection coverage, seismic refraction stations and drilling sites, depth to basement, total sediment thickness (Mesozoic and Cenozoic), isopach of Mesozoic and Paleogene, depth to base of Neogene, isopach of Neogene and Quaternary, lithofacies of deep-sea Neogene and Quaternary, tectonics, and a pre-drift map. Of the 398 figures in the text, 104 present additional maps of the 60°N to 60°S study region. Sixty-two of these are full page, 10 are about half page, and the remaining 32 figures display a total of 109 quarter page maps. A few of these illustrations are a trifle "busy," and the areal distortion introduced by the Mercator projection must be kept in mind, but they collectively represent an enormous body of compiled data. The maps are complimented by numerous cross sections and diagrams related to detailed local studies. Especially provocative among the illustrations are various graphical presentations of physical, chemical and biological parameters set against time, depth, latitude, etc. Additional statistical data are summarized in 39 tables distributed through the text.

Emery and Uchupi have produced a detailed synthesis of an enormous amount of information, and they deserve both our thanks and our praise. This work will be the primary reference on the geology of the Atlantic Ocean. It can be used with profit by the most experienced earth scientist in any discipline, and read with interest by the layman.

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