Book Reviews ...

or slow sedimentation; it may also be a product of increased volcanism. The high concentration of Ir at the base of coal deposits found in terrestrial sections is easy to explain, because coals are known to concentrate platinum-group metals.

It seems worthwhile to consider terrestrial processes as the main factors in the latest Cretaceous environmental changes. The biotic crisis at the K/T boundary might thus be explained by tectonic processes associated with intense volcanism, or marked regression of the sea together with climatic changes. Variations in ocean chemistry and rapid upward migration of the carbonate compensation depth close to the surface might also be responsible. As regards the biological effects of extraterrestrial impact, it is interesting to note that, with the possible exception of one crater, there are no known connections between large land impact events and global or local extinctions.

If biotic extinctions can be shown to be related to impacts of major extraterrestrial objects, then these may have had a major influence on the evolution of life. Therefore, the search continues for signatures of such impacts during other periods of drastic geological changes and biotic disturbances such as the Frasnian/Famennian, the Permian/Triassic, and the Eocene/Oligocene boundary.

The reader will find much detail on the complex bolide problem in this book, an immense source of information for all concerned with Earth history and the evolution of life.

A. Vogel

Free University of Berlin, F.R.G.

AFRIQUE DE L'OUEST: INTRODUCTION GEOLOGIQUE ET TERMES STRATIGRAPHIQUES. WEST AFRICA: GEOLOGICAL INTRODUCTION AND STRATIGRAPHIC TERMS

J. Fabre (ed.)

Pergamon Press, London, New York, 1984, 396p, £36.00/\$65.00 (US)

A comparison of the new International Stratigraphic Lexicon on West Africa with the original published in 1956 under the editorship of Raymond Furon illustrates the enormous advances that have occurred to the understanding of the geology of the region. These changes have occurred, not so much for the Phanerozoic sediments, but for the rocks in and bordering the late-Proterozoic to early Paleozoic Pan-African metamorphic belts. For these rocks a comparison of the two accounts is like comparing two very different cultures which share little in the way of common images and language. The older "stratigraphic" view of metamorphic rocks, in which age is a function of metamorphic grade, has been replaced in the new edition by a quite different understanding, based on considerations of the timing of the superposed rock-forming and metamorphic events in the Pan-African belts. The contemporary synthesis also takes into account the metamorphic and structural transitions and discontinuities across

the margins of these belts into the crystalline rocks of the West African Craton and its mid- to late-Proterozoic sedimentary cover.

These changes reflect the contributions of both the field geologists and the geochronologists who provided isotopic ages needed to chronologically calibrate the rock sequences recognized in the field. Many people have played key roles in initiating the changes, some contributing perceptive generalizations, others vast arrays of field and other observations. For example, W.Q. Kennedy showed in 1964 how the undisturbed cratons are embedded between Pan-African belts which wrap round them, and that the thermal structure of these belts has influenced the geological history of Africa down to present times.

Basic information on the Pan-African rocks came largely from French geologists such as J.-M. Bertrand, R. Black, R. Caby, J. Sougy and R. Trompette working in Mauritania, Senegal, the Ahaggar of Algeria, Mali, Upper Volta, Togo and Benin. These and many other geologists from different countries contributed to the intensely fruitful twenty years that culminated the early 1970s. Among these papers were the articles that set out much of what we know now of the Pan-African belts, information which was later used to recast the crustal evolution of West Africa in the image of plate tectonics.

It is no accident that the French contributions to West African geology have been substantial. The political and geographic continuity of French West Africa allowed French geologists to produce regional syntheses of the geology through ready access to a vast region extending from the Atlantic coast to the border of the Sudan, and from the Mediterranean to the Gulf of Guinea. The coastal British colonies were like isolated islands in a sea of French West Africa, and in some early French maps synthesizing West African geology, these islands appeared as empty spaces conveniently filled with map legends. It was not that the English speaking geologists were inactive, only that they worked on a local scale and neither dreamed of regional syntheses, nor had access to the political and administrative structures which would have made such syntheses possible.

The present volume is based upon the experience of many individuals who made important contributions to the geology of West Africa. The Lexicon is divided into four sections. The first contains 21 chapters (two in English, the rest in French) describing the geology of West Africa, from the Archean to the Quaternary deposits of Mauritania and Saharan Algeria, but omitting the geology of the West African continental margins. The quality of these chapters vary; some of the shortest describe the Paleozoic and Mesozoic sediments, and seven of these lack maps.

There are excellent chapters on the Precambrian rocks in the Pan-African belts, and on the crystalline rocks of the West African Craton and its late Proterozoic cover. They draw together published information from both well- and less well-known sources together with less formal information of the kind to which investigators working on shared problems are privy.

The second section is a detailed listing of West African stratigraphic names, including a description of the rock units, the location of the type sections, and citation of the literature in which the unit was first defined. The third section is a chronological index of the stratigraphic names, and the fourth a West African bibliography containing some 1,300 entries covering the period 1870-1983 from African surveys, government reports, and national and international journals.

The Lexicon is in a sense a landmark, containing indications of the changing social and political conditions in West Africa. This is most evident in the bibliography, which shows that the number of publications on West African geology

Book Reviews ...

Figure 1: Date of publication of the 1,300 items cited in the Lexicon.

grew rapidly from 1950 until 1970-73 when 50 to 60 articles on geology appeared each year (see Fig. 1). The decline since then has been even more rapid, falling to eighteen papers in 1982 and thirteen in 1983, for which the bibliography may be incomplete.

Within this decline there is an increasing contribution from African geologists, but these figures reflect the end of the era when colonial governments provided access and logistics for field work in West Africa, and when European geologists forged strong and often passionate links with the continent and its geology. Territorial consciousness and the natural decay of colonial connections have changed the motivations and opportunities for work on the scale of the recent past. Much of the future now lies in African hands. The Lexicon is an indispensable source book on West African geology. In welcoming its appearance, one is led to speculate who will write the next Lexicon some 20 years or so in the future. For it to succeed, as Fabre's has, will require the emergence of a new cadre of elite geologists with the same passion for the geology of West Africa as most of the present authors possess.

N.K. Grant
Oxford, Ohio, U.S.A.

gories, which few outside the ranks of the trace fossil specialist will readily remember or even want to remember. Why is it necessary to have *Fodinichnia* for a feeding burrow or *Cubichnia* for a resting trace, or now *Agrichnia* for "patterned burrow systems of uncertain behavioural significance"? These are descriptive terms rather than a true method of classification. Much better surely to use "feeding burrow" or "resting trace" which all can understand? However this first section also contains a very useful chapter on the techniques of studying modern biogenic structures.

The strength of the book lies in the sections on sedimentologic and stratigraphic applications and on paleoenvironment. These may be biased a little towards Mesozoic to modern sediments, but this is where the bulk of trace fossil work in the last 10 years has been concentrated. The whole treatment is up-to-date and presented in a very readable form. The chapter on the limiting factors of bioturbation and trace fossil distribution is a most interesting discussion of such topics as subaerial vs subaqueous trace fossils, sediment composition, texture, stability and consistency, as well as salinity, oxygenation and bathymetry. Another chapter is an excellent summary of continental and subaerial environments, a subject that has only recently received significant attention. The sections on fluvial, lacustrine and marginal marine environments are also excellent and up-to-date. The book closes with an extensive reference list and helpful glossary of terms.

There is a liberal sprinkling of photographs and line diagrams. The quality of the photographs is variable, while some of the line diagrams have either been reproduced without sufficient reduction or, in the case of some small drawings, placed alone on a complete page, so they are lost in a vast space. One drawing for example, occupies less than 1% of the page!

Notwithstanding these minor criticisms, the book is well written, and in places very thought provoking. It will prove valuable for advanced students and research workers alike.

T.P. Crimes
University of Liverpool, U.K.

NOBLE GAS GEOCHEMISTRY

Minoru Ozima and Frank A. Podosek

Cambridge University Press, New York, Cambridge and London, U.K., 1983, 367p., \$79.50 (US)

A seemingly novel and complex discipline called noble gas geochemistry has recently emerged from the shadows of geological science. In reality, this has been used extensively for the past two decades to decipher some of the mysteries of meteorites and the cosmos. The recent emergence of noble gas geochemistry really applies only to systematic studies of terrestrial samples. These have prospered mainly because of the significant advances made in our understanding of the geochemistry of both meteorites and the Earth, and the realization that the solution to significant problems requires geoscientists to become multidisciplinary even in fields that seem as esoteric as noble gas geochemistry.

ICHTHOLOGY: TRACE FOSSILS IN SEDIMENTOLOGY AND STRATIGRAPHY

A.A. Ekdale, R.G. Bromley and S.G. Pemberton

SEPM Short Course No. 15, 1984, 317p., \$16 (US) members, \$20 (US) non-members

The authors of this book, written to accompany an SEPM short course, have produced a very readable and interesting summary.

The first section on the study of trace fossils is perhaps the least useful because the history of trace fossil research and the classification of trace fossils have been thoroughly reviewed in quite a number of recent texts. The treatment of the behavioural classification of trace fossils follows most other texts in using latinized cate-

Book Reviews ...

The authors present summaries of noble gas studies on everything from earthquakes to meteorites to the Earth's mantle, crust, oceans and atmosphere. The text devoted to meteorites is, by far, the strength of the book, even though some of the discussion is biased. Researchers who have always wondered why entire sessions of meetings are devoted to noble gas cosmochemistry will find these sections particularly enlightening. Included, for example, are discussions of the compositions of planetary and solar type rare gases and the mechanisms by which the former can be derived from the latter.

There is a superb discussion of the complex and often emotional neon and xenon "alphabet games" played by most noble gas cosmochemists and witnessed by amused or confused novices at national meetings. How the composition of the Earth's atmosphere is related to solar and planetary noble gas components is also discussed, and the extreme depletion of both xenon and the light isotopes of xenon in the atmosphere relative to planetary gases in meteorites is emphasized. Possible explanations for the marked differences between the atmospheric and planetary xenon contents and isotopic compositions are recurring themes in this book.

The book begins with a very thorough discussion of the nuclear and physical chemistry of the noble gases. The figures and references contained in the nuclear chemistry section have most of the basic information needed by a noble gas geochemist. However, despite its appeal to most chemists, the detail included in the chemistry section is not very beneficial to most geologists who often find that such detail does not generally apply to the multivariance of natural systems. Nevertheless, the qualitative aspects of adsorption, diffusion and solution that are presented are important, because these are the mechanisms that are reflected by noble gas contents of a sample.

The book also reviews several discoveries that stimulated research on the noble gas geochemistry of terrestrial samples. The search for the xenon missing from the Earth's atmosphere and for possible records of atmospheric evolution led researchers to study the noble gases adsorbed on and trapped in sedimentary rocks. These do contain substantial quantities of adsorbed xenon, though the authors argue that the amount cannot account for the depletion of xenon in the atmosphere relative to meteorites.

The isotopic composition of the noble gases in ancient sedimentary rocks is identical to that of the modern atmosphere. This implies either that the isotopic composition of noble gases in the atmosphere has remained constant throughout time or that all of the sedimentary rocks studied have equilibrated with modern atmospheric noble gases. This quandary has yet to be resolved and further work is needed.

Some of the other important discoveries discussed in this book include the detection in the deep ocean of juvenile helium from the mantle and the presence of excess ^{129}Xe in CO_2 well gas. These discoveries provide the impetus for much of the current research on lavas and nodules from the mantle.

In addition to the significant advances, examples of the limitations and over-interpretations of noble gas data are evident in this book. The conflicting results of numerous studies on the noble gas composition of Josephinite indicate a great dependency on experimental technique and the prejudices of the researcher. The section of the book on atmospheric degassing and evolution models exemplifies the futility of such exercises without better constraints.

The authors briefly discuss the substantial effects that degassing and alteration can have on the isotopic composition and abundance pattern of the noble gases in igneous rocks.

However, like many other workers, much of their text is devoted to the presentation and use of abundance patterns in lavas and nodules and their comparison with solar, planetary and atmospheric noble gases. Finally, the extensive discussion about the existence of undepleted and depleted portions of the mantle could have been more succinct and conclusive if certain studies and definitive conclusions had not been overlooked by the authors.

It is evident upon reading this book that the vulnerability of noble gas geochemistry is associated with the choice of samples. It is also evident that noble gas studies can be very powerful in constraining the origin and evolution of meteorites and of the planets. Since this book has been published there have been significant advances that attest to the importance of this discipline. Nevertheless those unfamiliar with noble gas geochemistry will find this timely book to be an excellent synopsis, and researchers in the field will find it to be a superb reference book.

T.K. Kyser
Saskatoon, Canada

PYROCLASTIC ROCKS

R.V. Fisher and H.-U. Schmincke

Springer-Verlag, Berlin, 1984, 472 p., \$49.00 (US)

This well-presented book by two of the world's leading volcanologists is a very welcome and timely addition to the sparse group of modern volcanology texts. As the first book dedicated to the topic of fragmental products of explosive volcanism, it fills a gaping hole in the literature. The result of ten years of collaboration, the book is remarkably up-to-date, covering advances made in this field up to 1983.

As the authors state in their preface, "Pyroclastic Rocks is somewhat of a misnomer for the title of this book. Strictly speaking, pyroclastic refers to clastic materials ejected from volcanic vents, whereas we include discussions of rocks ranging from lahars remobilized from loose surficial volcanic fragments to pillow lavas." The book could indeed equally well be entitled *Volcaniclastic Rocks*, for most types of clastic deposits associated with volcanoes are discussed in some detail. By including opening Chapters (2 to 4) on volcanoes, volcanic rocks, physical and chemical properties of magmas, magma chamber processes and eruptive mechanisms, the authors have produced the best volcanology text to appear to date.

The introduction to the book is somewhat weak, because it does not properly set the scene for this exciting group of rocks. It does, however, convey the importance of volcaniclastic rocks in the geological record, something sadly neglected in the past. Eruption types are realistically grouped into pyroclastic systems, those eruptions driven by internal (magmatic) volatile behaviour, and hydroclastic systems, those in which external (meteoric) water plays a role. One small problem here is the tacit assumption that vulcanian eruptions are phreatomagmatic (due to the explosive interaction of magma and groundwater), whereas this opinion is not shared by the volcanological community in general.

Book Reviews ...

Chapter 5 deals with the constituent fragments of pyroclastic deposits, concentrating on character and texture, and with the bed structures that occur. Chapters 6 to 10 cover each major pyroclastic deposit type, largely according to depositional processes. Fallout deposits that accumulate from atmospherically transported ash clouds are very well discussed. A separate chapter is devoted to submarine fallout deposits, a much needed summary on the important topic of deep-sea ashes. Pyroclastic flow deposits are divided into those produced from dense, largely laminar flows (pyroclastic flow deposits), and those produced from lower density, turbulent flows (pyroclastic surge deposits). The formation of flows, historical concepts leading to the understanding of flow deposition, grain size relationships and bedding structures are well described, as are the depositional facies produced by the various types of pyroclastic flows. Ignimbrites (ash flow tuffs), a rock type important throughout the geologic record, are rather under-represented, especially with respect to internal structures and post-depositional processes. Possibly the strongest point of the book is the discussion of the deposits and mechanisms of hydroclastic eruptions and submarine volcanic activity. The realization that explosive interaction of external water and magma plays a vital role in most types of volcanic eruptions and strongly influences the characteristics of the deposits is, perhaps for the first time, adequately discussed in a volcanology text book. Volcanic debris flows (lahars) are succinctly treated in Chapter 11, and the importance of their deposits in many volcanic areas is well stated.

Other topics such as the alteration of volcanic glass (Chapter 12) and tephrochronology and stratigraphic problems (Chapter 13) are dealt with thoroughly. Especially useful are the authors' ideas on volcanoclastic depositional facies around various types of volcanoes. This is an important topic which has only been marginally addressed in other volcanological texts. The final chapter places pyroclastic rocks into various depositional environments according to their plate tectonic setting. This section will possibly have the widest appeal to geologists in general, and it adequately summarizes the available literature on this topic. The authors do not discuss ancient sequences in any detail, and the book could have benefited from a more thorough discussion of the importance of volcanoclastic sequences in the evolution of sedimentary basins.

This reviewer has few criticisms to make of the book as a whole. One is use of the imprecise term "cinder" as an equivalent of the more correct term "scoria." Also, "agglutinate" is used ambiguously with respect to welded airfall deposits (not all welded airfall deposits are formed by agglutination). A rather limited number of field locations are used to illustrate all the types of pyroclastic deposits, and many of these are from alkaline volcanic centers, such as Atlantic islands and the Eifel volcanic field in Germany.

The book has a detailed table of contents, good indices and a very complete reference list. There is, however, no glossary, which may be a disadvantage to those unfamiliar with the subject or to beginning students. The abundant illustrations, including both line and half tone diagrams, are of high quality throughout. A significant proportion of the diagrams are original, and thus make this a very valuable source book for research in this field. Of particular interest and use are "process" diagrams, which summarize various factors involved in eruptive and depositional processes of many types. Overall, this book should become the standard reference for researchers, students and teachers in volcanology.

S. Self
University of Texas,
Arlington, U.S.A.

GLACIAL GEOLOGY - AN INTRODUCTION FOR ENGINEERS AND EARTH SCIENTISTS

N. Eyles (ed.)

Pergamon Press, New York, 1983, 409p, \$17.95 (US)

This is a portmanteau volume, a collection of studies on the extent, properties and implications of the engineering soils and sediments represented by glacial deposits. Fifteen authors are involved, nine from Britain and six from Canada. Throughout the book the terms "engineering soil" and "sediment" are used more or less interchangeably - a quite acceptable usage.

A basic premise of the approach followed in the book, as set out in the introductory chapter on the landsystems approach to glacial geology, is that if the landsystem can be identified from surface landforms, then it is possible to identify in turn, the subsurface conditions. The landsystem, once identified, provides a model not only for planning and the interpretation of the results of site investigation and laboratory testing but also focusses attention on those features that should be looked for in making a geological assessment of any location.

Within the fifteen chapters a rough division into four topics can be discerned: studies of materials (e.g. R.M. Quigley on clays), studies of landforms (e.g. N. Eyles and M.A. Paul on periglacial landforms), studies of construction problems (e.g. by M.S. Money on dam and reservoir construction in glaciated terrain), and studies on mapping, distribution and site investigation (e.g. A. Strachan and W.R. Dearman on mapping in glaciated terrain). The practical emphasis is very marked, perhaps more so than the title indicates, and chapters 12 to 15 dealing with foundations, roads, dams and hydrogeology provide a good overview of engineering problems encountered in glacial materials.

The materials considered range from tills and other boundary aggregates through variously consolidated clays, silts, sands and gravels to peats and organic soils. Peats actually are somewhat neglected, and there are no entries for peat, muskeg or organic soil in the index, a rather surprising situation in a book with a high Canadian content. Some other problem soils, however, receive quite good coverage. Quigley's discussion of sensitive clays is detailed and well illustrated, and loess, "by far the most important periglacial accumulation" according to J.K. Charlesworth, both in Europe and North America, receives the attention it deserves from Eyles and Paul in their periglacial section. They reproduce the old Grahmann map of loess distribution in Europe (using R.F. Flint's 1971 version). This is still a useful map, but the widespread cover and complexity that it reveals make the need for the new INQUA Loess Commission map very apparent.

"Drumlin" has nine index entries and must obviously still be regarded as an important phenomenon of glacial geology. As S. Baranowski once stated, "until the mechanism responsible for drumlin formation is fully understood, some of the key glaciological problems related to the glacier bed will remain obscure," and this may be the reason for the large amount of investigative effort devoted to this problem. This reviewer looks forward to the publication of the comprehensive drumlin bibliography compiled by J. Menzies (co-author of Chapter 2). The problem of drumlin formation may be the

Book Reviews ...

most taxing physical question related to till materials, but there is also an aggravating semantic problem which needs to be addressed. The chapter by J.A. Sladen and W. Wrigley is about lodgement till, which they describe as being invariably a "well-graded" material, i.e. completely unsorted and having a wide range of particle size. It still seems strange that "well-graded" and "poorly-sorted" should be more or less synonymous, and there is always the chance of dangerous confusion arising here as geologists and engineers try to communicate important matters to each other.

The illustrations are striking, and some of the pictures are very stylish and informative. The paper binding is solid and the print - direct reproduction from typescript - is clear and acceptable. There is a good list of references and a modest index. In all a very satisfactory book.

Ian Smalley
University of Waterloo, Ontario

THE TRIAS AND ITS AMMONOIDS: THE EVOLUTION OF A TIME SCALE

E.T. Tozer

Geological Survey of Canada Miscellaneous Report 35, 1984, 171p., Cdn\$8.00/Cdn\$9.60 (outside Canada)

E.T. Tozer has been publishing on Triassic ammonoids for some 30 years. He has been instrumental in unravelling many of the problems inherited from generations of European geologists who tried to set up a definitive series of Standard Ammonoid Zones on successions that are incomplete, difficult to correlate, and complicated tectonically and sedimentologically. The resultant mistakes have taken a lot of sorting out, and it is with the aid of careful collecting from successions in various parts of the world that many of the major problems have been resolved. This book is Tozer's historical review of the development of Triassic biostratigraphy.

The subject is introduced in a way that will be comprehensible to the non-stratigrapher. Indeed the first succinct and meaty chapter can be readily understood by the non-geologist. Some of his remarks may seem obvious to those well versed in the workings of Mesozoic stratigraphy, but the author has experienced, no doubt, that what he takes for granted other stratigraphers are unaware of. He has erred on the side of caution - and I believe he was right to do so.

One word "biochronology," which the author uses may raise eyebrows among purist stratigraphical theoreticians. By this he means the same as the 'standard' chronology of British Jurassic stratigraphers, myself included. Working with Mesozoic ammonoids he and I speak the same language - that there is effectively no practical difference between carefully chosen ammonoid biostratigraphy and chronostratigraphy.

It is in the second chapter that we first begin to find evidence of the statement in the Preface that "this report has not been submitted to the usual editorial procedures." For in a short chapter on Trias divisions and boundaries

comes the statement that "Buckman was okay." I do not dissent from this statement, but it certainly makes one aware that this is not one of the usual Geological Survey of Canada reports.

The third chapter on ammonoids traces the development of their names from the sixteenth century to the present day. Included is a plate of 74 different ammonoids from the Canadian Triassic - a taste of the enormous variety of the group at this time. This review is followed by a discussion of the history of Triassic stratigraphy from its beginnings in Germany until marine Triassic faunas were identified in the Arctic, the Himalayas and British Columbia.

In chapters 7 and 8, Tozer deals with a period of the development of Triassic stratigraphy that depended much more upon personalities. First Mojsisovics, then his controversy with Bittner over the Norian, which split the Austrian geological community at the turn of the century. Back then to more discoveries in the Salt Range of Pakistan and the Himalayas, and on again to finds in the western U.S.A. and Canada and the work of A. Hyatt and J.P. Smith.

The account of the discovery of rich Triassic faunas in Timor shows to the non-stratigrapher the importance of detailed observation and records when collecting. It records that 9 different faunas were obtained from one block 1m thick, occurring in an olistostrome. This chapter is less than one full page of text, but, as a stratigrapher, I would dearly love all my non-stratigraphic colleagues and those students who come back from the field with sloppily collected material to read it. The lesson is there - collect and record with care!

The twentieth century progress of Triassic stratigraphy continues through a list of famous names - but one is never aware that this is a list. Interesting sidelights are thrown upon many of the characters. Although I have worked on Upper Jurassic ammonites for many years and frequently used the works of L.F. Spath, I learnt more about Spath the man from Tozer's comments than I had previously known.

The narrative chapters conclude with a section showing how the Triassic timescale for North America evolved in its final form over the past decades, and how the biostratigraphy was married into the successions obtained from study in other parts of the world including Europe - where it all started. It is also here that one of the outstanding problems remains to be resolved - the correlation of the Muschelkalk faunas with those of the Tethys.

A useful reference list, an appendix of almost 100 stage names that have been applied to the Triassic, and a comprehensive index conclude a most unusual book. Refreshing and interesting to read, this is a work all who read will benefit from. The style throughout is very informal and easy to read, concessions are made to the non-stratigrapher - but I feel the author is mistaken in his apparent belief that the book will be read by non-geologists. What has been gained by figuring a *Pinacoceras* and describing it by saying "the edge was sharp?" To have said the venter was sharp would have sacrificed little or nothing to lucidity.

The book is singularly free of printing errors and is abundantly illustrated by photographs and diagrams. The former are mostly clear and useful, but the maps vary considerably. The Pangaeon Triassic globe appears to have been drawn around a mis-shapen teacup and the standard of draughtsmanship is variable. But these are carping criticisms of a most interesting and entertaining book. The author is uniquely qualified to write on this subject, the result is authoritative, and I can recommend it wholeheartedly.

J.C.W. Cope
Swansea, U.K.

Book Reviews ...

GEOCHEMICAL ASPECTS OF RADIOACTIVE WASTE DISPOSAL

Douglas G. Brookins

Springer Verlag, New York, 1984, 347p, \$44.50 (US)

During the last thirty years, the safe and effective disposal of radioactive wastes has been a matter of public concern in many countries. Shallow or deep burial is considered a potentially satisfactory means of disposal. Yet proof is required that radioactive wastes can be effectively isolated over the long time spans needed before all the radionuclides will have decayed to innocuous levels. To demonstrate this is no easy task, particularly when a multidisciplinary force of scientists and engineers must work together to achieve a realistic design and show that it will function effectively for thousands of years.

The most important consideration in all forms of radioactive waste disposal, and especially those involving waste from commercial nuclear power reactors and defense operations, is the chemical processes that can lead to migration of radionuclides and their escape to the accessible environment. There is a vital need for comprehensive review of this subject for all concerned, in order to educate, provide a focus and stimulate efforts to resolve critical issues.

The reviewer was already aware of four geochemists who were planning to take up this challenge when Douglas Brookins effectively beat them all to the punch with his own perspective on the subject. In the preface he makes it clear that this book is an attempt to correct deficiencies in the training of nuclear scientists and geoscientists in the area of waste isolation chemistry. The intent is to emphasize the importance of analogous natural systems and to show that rocks are likely to retain radioactive waste safely. Unfortunately, the result is not altogether satisfactory, although the author is to be commended on making the attempt.

In preparing the book, the author has drawn heavily on recent, albeit already dated U.S. government reports and on his own extensive experience of the geochronology and geochemistry of natural systems. Seven chapters in the book relate to the high level and transuranic wastes and the siting and design of repositories for their disposal. The overwhelming emphasis is on the domestic U.S. program, especially in Chapter 2, which deals with the history and organization of the National Terminal Waste Storage Program. Unfortunately, no mention is made to passage of the Nuclear Waste Policy Act of 1982, which makes obsolete much of what is written in this chapter. There is also a brief discussion of foreign programs. One chapter each discusses low-level waste disposal and uranium mill tailings in the United States. Three chapters are devoted respectively to natural radiation, geochronology and natural analogues, one discusses concepts in toxicity, and two brief chapters provide an introduction and conclusions.

The organization of the book is chaotic. One would expect the introduction to explain what the book covers, perhaps also including a discussion on the nature and sources of radioactive wastes and why they must be disposed of properly. Instead we are treated to a detailed tabulation of radionuclides and their speciation in solution, a listing of the composition of deep groundwater, and discussions on modelling and on the regulations of the Nuclear Regulatory Commission. The need for modelling is not, however, explained, although the author does state his intention to stress the problem of input data and limits for models rather than the models themselves, and to draw on natural analogues in order to provide information on the predicted behaviour of buried radioactive waste.

Much of the text shows a lack of continuity or organization. For example, Chapters 12 and 13 review "Waste Forms" and "Engineered Backfill and Canisters," respectively, but are separated by 180 pages from Chapter 4 on "Types of Radioactive Waste and the Multibarrier System."

On a more detailed level we find abbreviations, units of measurement, and technical terms introduced without explanation, or only after many pages have been read. The implication that the reader is expected to be intimately familiar with the subject being addressed is particularly challenging for those unfamiliar with the U.S. waste isolation program. A glossary of terms would have been a useful addition to the text.

Much information is included that neither supports nor is subject to geochemical analysis. Such material detracts from the subject of the book and could, in my opinion, have been omitted, especially in the case of the chapter on alternative methods of waste disposal. I found 40 typographical errors, altogether too many for an international publishing house like Springer Verlag.

Several problems of geochemical significance have been treated either very cursorily or not at all. These include sorption-desorption phenomena, the quantitative prediction of solubility controls on radionuclides, and the effect of interactions between waste canisters and host rock in the thermal region around the former.

On the other hand, geochronology and its application to natural systems and particularly natural analogues such as the Oklo fossil reactor are treated at length. Even so, the reader will not find it easy to extract input data and limits for models from these situations. There is little discussion supporting the selection of natural analogues in order to validate predictive models of radioactive waste migration. This is a pity because the author could surely contribute much of value to the debate on this subject.

In spite these reservations, there is food for thought in this book, particularly when Douglas Brookins reviews the toxicity of commercial nuclear power wastes in relation to natural ore bodies of uranium, lead or mercury, or when he discusses his geochronological findings relating to the behaviour of clay minerals as closed systems over geologic time. Indirectly, he provides a strong justification for exploring the development of a waste form composed of synthetic hydrothermal silicate minerals as radioelement hosts, as suggested by Rustunn Roy of Pennsylvania State University. Also, Brookins' views on the use of poisoned lands for low-level waste disposal are novel and worth further discussion.

Brookins has extracted useful tabulations from otherwise difficult-to-secure reports, and his book is a valuable source for such material. On balance, I am glad to have his book on my bookshelf and would recommend other workers in the field also to have access to a copy.

John A. Apps
Berkeley, California, U.S.A.

The many strata of Springer earth sciences

K. O. Emery, E. Uchupi

Geology of the Atlantic Ocean

1984. 399 figures. XIX, 1029 pages
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