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See table of contents

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Book Reviews / Critique

Reviews

Old Bones and Serpent Stones. A Guide to Interpreted Fossil Localities in Canada and the United States. Vol. 2: Western Sites.

By T. Skwara
Illustrations by Ignatius Fay
Blacksburg, Virginia: McDonald and Woodward Publishing Co.
vii + 301 p., US $14.95

Reviewed by William A.S. Sarjeant
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Geological travellers are becoming increasingly well served by guides to the rocks and fossils to be seen on their wanderings. In the United States, in particular, there are excellent "roadlogs" reporting on the rocks, structures and geological vistas to be seen by the wayside. Though similar works are not yet widely available for travellers in Canada, their production is beginning. The Geological Survey of Canada has produced some truly splendid guides to rock and mineral localities (*e.g.*, Sabina, 1992) and similar works, though generally of lesser quality, are available for various regions of the United States.

The work here under review — its companion volume has not yet been published — represents a further step forward in the provision of guidebooks for the geological traveller. It consists of two parts: a general introduction to paleontology and a guide to 45 selected sites in western North America south of the Laurentian Shield (and exclusive of Alaska).

The introductory section, "The Many Faces of Paleontology", is excellently conceived, lucid and highly readable. It treats successively the processes of fossilization and the procedures of classification (the latter being especially well set forth), the history of life through geologic time and, briefly, the geological evolution of North America.

My principal problem with this section is the author's uncritical acceptance of the concept of mass extinctions. Yes, these do add drama to the history of life, but, as I have striven to demonstrate elsewhere (Sarjeant, 1990) and as has been clearly shown by others (*e.g.*, Kauffman, 1984; Sullivan, 1987; Hoffman, 1989), they have no objective reality. It is regrettable that a work designed for a mass readership should so wholeheartedly propagate this particular myth.

I have problems also with a number of points of detail. Humboldt's inadvertant erection of the earliest-recognized geological system was based on his study of the Jura Mountains of France, not Switzerland (p. 21). As Retallack and Feakes (1987) have demonstrated, there is good geological evidence for life on land before the Silurian, in contradiction to the statement on page 43. We are told on page 45 that the "early amphibians were large animals" and that they could not have fed merely on arthropods; yet, there is an extensive Carboniferous record of small amphibians. Also on page 45, we are informed that there were "no reef-building organisms in the Carboniferous", a statement astonishing to a reader like me who grew up close to the Carboniferous reef-knolls of the English Pennines!

On page 52, we are informed that the ammonites appeared in the Triassic; well, that might be a matter of semantics, but most invertebrate paleontologists distinguish the Triassic ceratites, with their essentially quadrilobate sutures, from the true ammonites with their quinquelobate sutures, whose first appearance defines the beginning of the Jurassic. That same page tells us that the mesosaurs were marine and implies that they were present in the Mesozoic; not so, they were Permian reptiles of terrestrial waters. Moreover, the placodonts, so prominent in the Triassic, are oddly excluded from the list of six principal marine reptilian groups, as also are the marine crocodiles which, contrary to the statement on page 56, did not survive even to the end of the Cretaceous, let alone into the Tertiary! Despite the statement on page 53, the dinosaurs did *not* appear in the Early Triassic; their entry onto the world stage did not happen until the Late Triassic (Thulborn and Sarjeant, in press). In contrast, there is now good evidence for ankylosaurs in the Jurassic, much earlier than the Cretaceous entry mentioned on page 54. In the Cenozoic, yes, South America had a unique fauna (the prominence of marsupials in which escapes mention) and that fauna was indeed largely eliminated when the land connection to North America was re-established (p. 57); but surely it cannot be claimed that the *African* fauna (exclusive of that of early-isolated Madagascar) was ever similarly unique?

There are also omissions that may inadvertently mislead or confuse the uninformed reader. Large terrestrial amphibians disappear from the geological record in the Late Permian when, indeed, the amphibians ceased to be prominent (p. 50). It is, however, not mentioned that amphibians of even larger size — the stereospondyls — were present in the marine waters of the Triassic world-wide and persisted in the Australian region, at least, as late as the Early Cretaceous. Nor does the Mesozoic appearance of the modern types of amphibians — and, for that matter, of the turtles — gain mention.

All in all, this first section of the book arouses mixed emotions; enthusiasm for its readability and dismay at the number of minor flaws. The second and more important section, however, arouses only admiration. It is an intelligent selection, from the numerous paleontological localities in western North America, of the ones that are most significant, accessible and best displayed. Their locations are clearly indicated, their importance well encapsulated, and the restrictions upon access or collecting very clearly set forth. The listing of the sites in stratigraphic order (p. 76-77) is helpful. This is a guide that will be of great value to all intelligent geological tourists, whether professional or amateur. I regret, however, that, of the 45 sites listed, only four are in Canada and none are in Saskatchewan.

The text is enhanced throughout by Ignatius Fay's neat, clear drawings and excellent maps. The numerous photographs have suffered in reproduction (*e.g.*, Fig. 9). This is a pity, for they were well chosen and, if the publishers had done a better job with them, would also have served as enhancement to the text.

This book, then, has its flaws, but its modest price and generally attractive presentation make it well worth acquiring by all western paleontologists who like to view their fossils at the outcrop.

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The Sternberg Fossil Hunters. A Dinosaur Dynasty

By Katherine Rogers
Mountain Press Publishing Co.
Missoula, Montana
xiii + 288 p., 1991, US $12.00 paper

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Charles Hazelius Sternberg and his three sons George Fryer, Charles Mortram and Levi, together with the wives and children of those sons who were called upon for aid from time to time, were indeed a unique family. Their achievements in the collecting of fossils — not just dinosaurs, but vertebrates of all ages from Permian to present, and not just vertebrates, but also fossil invertebrates and plants in profusion — not only are, but are likely to remain, unparalleled. Charles Hazelius Sternberg wrote two books recounting his adventures (*The Life of a Fossil Hunter*, 1909, and *Hunting Dinosaurs in the Badlands of the Red Deer River*, 1917) and both George and Charles M. Sternberg wrote shorter accounts of their adventures while fossil-hunting. In addition, David A.E. Spalding provided a percipient account of the family and its achievements in his "Introduction" to a recent reprinting of *Hunting Dinosaurs* (1985). The work here reviewed, however, constitutes the first extended account of the Sternberg family and, as such, it is important.

For the writing of this book, the author was especially well situated. She had known George Fryer Sternberg for 40 years and was able also to interview on numerous occasions Myrl Walker, George's assistant in what became the Sternberg Museum at Fort Hays State University, Hays, Kansas. After Walker's death, she was given access to a large collection of documents and letters concerning the Sternbergs, including eight photo albums containing some 2500 photographs taken by George on fossil-hunting expeditions between 1906 and 1965. She notes (p. x) that:

> ... hundreds of the pictures have no captions and have been almost useless as research materials...

Nevertheless, enough of the photographs could be recognized to furnish illustrations for her book; these are of great historic interest.

Equipped with such personal knowledge of the Sternbergs and such a mass of data, Ms. Rogers might well have produced a definitive account of the Sternbergs and their achievements. That, however, did not happen.

Ms. Rogers is not a paleontologist and that is fair enough. Unfortunately, she seems not to have called upon paleontological assistance to any extent. Several of the generic names for fossils that she quotes are junior synonyms, though not recognized here as such: examples are *Macrophalangia* (p. 170), properly *Chirotenotes*, and the many mentions of a great teleost fish consistently called *Portheus* (*e.g.*, p. 33 and 89), though it is properly *Xiphactinus*. George's early misidentification of a pachycephalosaur skull as *Troodon* (p. 160) is quoted without comment; probably it was a skull of *Pachycephalosaurus* or *Stegoceras*. There are mis-spellings of generic and specific names — *Hesperornis* (p. 168), *Araucaria* (p. 210), *Lambeosaurus lambei* (p. 156) — and of the first names and surnames of distinguished palaeontologists: "Marcelin Boule" (p. 120), properly Mercellin; "Handle T. Martin" (p. 193), properly Handel; the "Ameghine" brothers (p. 193), properly Ameghino. Darwin's classic work of 1859 was not called *Origin of the Species* as page 8 indicates; and, despite page 154, a "holotype" is not merely "a single specimen". *Oreodon* was not "an extinct porcine animal" (p. 60), but a primitive camel-like mammal. We are not told to what groups several genera belong; it would have been helpful to know that *Adinotherium* (p. 204) was a toxodont; *Prototherium* (p.205), a sirenian and *Parastrapotherium* (p. 209), a representative of that quite extraordinary South American group, the astrapotheres. When we are merely informed, for example, that George's party collected in Patagonia "a rare specimen of fossil bird" (p. 208), the vagueness is truly frustrating!

There are some statements that are outright misleading. We are told (p. 36) that Charles Hazelius Sternberg "had no confrontation of any consequence" with Indians during his fossil-hunting career, but this is surely contradicted by the episodes recounted on pages 43, 54 and 62! John Bell Hatcher's career was scarcely "long and successful", as page 76 tells us; rather, it was tempestuous and ended prematurely with his death at the age of 43. How did the Sternbergs contrive to see "the majestic Rocky Mountains" (p. 138) on a railway journey between Wyoming and southeastern Alberta? Moreover, my many Scottish and Canadian friends who are curling enthusiasts will not like to see it dismissed (p. 178) as merely "a game similar to shuffleboard"!

The biggest problem encountered by the reader is Ms. Rogers's awkward writing style. It is made manifest in the book's very title, which, taken literally, refers to persons hunting fossil Sternbergs! There are, however, many other obscurities or ambiguities. Some are amusing: for example, "This summer's expedition to the chalk beds living in a tent" (p. 3); "The cook let them have one-fourth of a mutton" (p. 208); and "There stood Dr. George Sternberg waiting for them. What a wonderful sight!" (p. 16). There are strange word usages, as for example when young Charles H. Sternberg was "somewhat incapacitated" (only somewhat, when it took him three months to recover in hospital?), or when George M. contributed "... somewhat regularly to scientific journals" (p. 168). The word "enormity" is consistently employed (*e.g.*, p. 144 and 182), not in its modern sense of "a great crime; outrage; iniquity", but in its archaic meaning, "hugeness". Edward Drinker Cope "... became self-righteous, narrow-minded and intolerant", we are told on page 30; but in the next sentence this is contradicted, for we are informed that "... he became increasingly generous and indulgent ..."! All in all, this text needed, but did not received, careful editing. For this the publishers, rather than the author, must be held blameworthy.

On the positive side, the illustrations are always interesting and the maps recording the Sternbergs' travels are clear and easily understood. The annotation is careful and the indexing thorough. The "References", however, will cause problems to persons wishing to obtain works cited on interlibrary loan, since they lack pagination. No attempt is made to list all the Sternbergs' writings, and such a listing would have been extremely useful.

This book brings together a great deal of information — especially on George Sternberg's activities — that hitherto was unavailable. Given better editing (textual and scientific), it could have been a classic work on the history of paleontology. As it stands, it must be considered only to serve as a valuable source for the definitive account of the Sternberg family which, I trust, someone else will write some day.

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Georges Cuvier. An Annotated Bibliography of His Published Works.

Compiled by Jean Chandler Smith
Introduction by Stephen Jay Gould
Smithsonian Institution Press
Washington, D.C.
xx + 251 p., 1993, US $48.00

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Jean Léopold Nicolas Fréderic, Baron Cuvier (1768-1832) — remembered as Georges, a name transferred to him by his parents upon the death of a thus-named elder brother — was not only the first great comparative anatomist and vertebrate paleontologist, but also a stratigrapher of distinction and an early historian of the earth sciences. His concept of successive "revolutions of the globe", during which a large part of the animal life of the world was destroyed and replaced by a new creation, is now discredited (although it is shadowed in the still-prevalent nightmares of mass extinctions that continue to plague our science). However, it helped to make geology acceptable to the theologians and politicians of the early 19th century, and thus had a long-term positive, as well as a short-term negative, influence upon the development of the earth sciences.

This comprehensive and clearly presented bibliography fairly indicates the breadth of Cuvier's concerns, and surveys admirably the daunting plethora of republications in various languages, whole or partial, of his original contributions. They include not only the extensive scientific writings that are his principal legacy, but also the products of his 30-year labour as Perpetual Secretary (Classe des sciences physiques) to the Paris Academy of Sciences and his posthumously published letters. (Biographical works and other secondary sources on Cuvier are not considered.) This work deserves to be on the shelves of all serious historians of the biological, medical and earth sciences.

After the Ice Age. The Return of Life to Glaciated North America

By E.C. Pielou
University of Chicago Press
ix + 366 p., 1992, US $24.95, paper

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Even during the initial "mixers" and certainly afterward, participants at many geological meetings swiftly divide into two groups: the "real" geologists who are concerned with strata no later than Tertiary in age — good, solid rocks usually, whether igneous, sedimentary or spoiled (*i.e.*, metamorphic) — and the "superficial" geologists concerned with essentially unconsolidated sediments of Quaternary date. Like ice from a tributary glacier alongside a stronger glacial stream, the latter follow a parallel course to the rest of us, but normally our streams do not mix.

In my own palynological studies, I have crossed the boundary a few times and have found the experience disconcerting. Instead of dealing with assemblages dated only vaguely within a five to ten million year span, suddenly one finds they can be accurately dated within ten, or even five years. The precision ought to be pleasing; instead, it is somehow trivializing. If they're so new, how *can* they be important or even interesting? How *can* people devote a lifetime of research to questions so minor, mere marginal brushstrokes in the great geological picture? Well, if you read this book, you will discover the answer.

The first chapter on "The Physical Setting" is pedestrian: one feels that the author wrote it dutifully, since it *had* to be there, but without real interest and certainly without passion. After that, however, matters change. With this tedious business safely behind, Dr. Pielou can start instructing us on the matters that truly interest her, that excite her; as we read, we come to share her excitement. The text is lively and absorbing. The maps that depict ice advances or retreats are helpful, as are the sketches of sections through Quaternary sediments. The many drawings of animals and plants are quite delightful and truly enhance an already very attractive book.

There are a few problems and carelessnesses. Palynology is *not* synonymous with pollen analysis (p. 41), not even in the Quaternary (a word often — three times on p. 13 alone — misspelled "Quarternary"). Dinoflagellates (p. 43) are flagellate, yes, but they are not properly protozoans; rather, they are protophytes (plants) or, better still, protists. Yet, after such errors, Dr. Pielou writes so admirably on procedures in Quaternay palynology (p. 53-56), and in particular on the difficulties in properly interpreting pollen spectra (p. 64-68), that I am sure to be quoting her in future palynology classes.

On page 109 we have the note "mastodons (sometimes written mastodonts)", but this is not so. The word "mastodont" embraces a very much wider range of proboscideans, including all the genera with long, sometimes shovel-like or down-curving tusks, whereas "mastodon" refers to a much more limited, shorter-tusked group of extinct elephants. "Jon" Terasmae (p. 97) is properly Jan and there are other minor misprints (*e.g.*, "indentical" p. 84) which need to be tidied up. More serious is the failure (p. 30 and accompanying maps) to identify the high Arctic refugium in which, as Paul S. Martin (1967) has shown, the musk-ox survived the Pleistocene.

Dr. Pielou's very interesting assessment of the causes of the wave of Late Pleistocene extinctions of terrestrial mammals properly considers the role of early man, Martin's (1967) hypothesis of Pleistocene overkill being fairly presented. However, she seems unaware of the amplification of this hypothesis by Owen—Smith (1987), who demonstrated how a mere reduction or extinction of the biggest herbivores could result in habitat destruction and indirectly generate a wave of secondary extinctions. For my part, I believe with Martin that early man's activities marked the beginning to the only *real* great extinction in geological history: the one that we have caused and, alas, are still causing each day and each hour.

Such matters require attention in subsequent editions of this book; for there should, indeed there must, be future editions of so excellent and stimulating a work. If you find these "superficial" earth scientists hard to understand and respect, read it and perhaps your prejudices against them will vanish. If you're one of them, ready it anyway; you're sure to enjoy it!

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High Resolution Stratigraphy

By E.A. Hailwood and R.B. Kidd
Geological Society, London
Special Publication 70
357 p., 1993, US $97.00/£58

Reviewed by Andrew D. Miall
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Stratigraphy has undergone two revolutions during my career. The first was the explosion in facies analysis and facies modelling in the 1960s and 1070s. The second revolution, which is still underway, is that surrounding the development of sequence stratigraphy. There are two quite separate aspects to the second revolution. The first of these is that sequence stratigraphy provides a framework for the evaluation of stratigraphic successions, by postulating that basin architecture is controlled by absolute or relative sea-level change. Essentially, this is a new approach to facies analysis and facies modelling that is having a powerful effect on the sophistication of modern stratigraphic basin analyses. The changes it has wrought in our discipline can readily be assessed by careful comparison between the second (1984) and third (1992) editions of the Geological Association of Canada's *Facies Models* volume, edited by Roger Walker and Noel James.

The second aspect of the sequence stratigraphy revolution takes us back to some much older concerns of the stratigrapher, and is currently a far more controversial topic. Peter Vail and his former colleagues at Exxon claim that the sea-level changes that control basin stratigraphy are all of global, "eustatic" origin, and that, therefore, the framework of stratigraphic sequences is essentially identical around the world. This major assumption permitted the Exxon group to develop a "global cycle chart", which was offered as a template for global stratigraphic correlation. This proposal has stimulated a considerable amount of research into the details of the stratigraphic record and into mechanisms for global sea-level change. The major test of eustatic control is global correlation of the sequence record; the demonstration of simultaneous sea-level changes in tectonically separate basins in different parts of the world, which can only mean eustatic control. The key here is the word "simultaneous". Methods of dating and correlation of the stratigraphic record, which were among the major preoccupations of 19th century stratigrapher, have once again become of central importance. It is this subject that the book *High Resolution Stratigraphy* addresses.

The book represents the results of two research conferences hosted by the Marine Studies Group of the Geological Society, held in London in October 1990 and January 1991. The book is not focussed on sequence stratigraphy, but consists of a set of 21 research papers which together constitute a lengthy and detailed snapshot of the "state of the art" of dating and correlation methods. The papers deal mainly with British data, but correlations in Europe and North America also receive considerable attention; the technical approaches and kinds of analysis and discussion are of universal relevance. Those concerned with the controversy over the Exxon global cycle chart should examine this book, as it provides much food for thought, demonstrating, in fact, that we have a very long way to go before any realistic assessment of short-term global eustasy is possible.

Age dating, once a matter of assigning relative ages through the meticulous examination of fossils, and considered the domain of aged specialists doddering about in musty museums, has become an advanced science using the very highest technology. Fossils are still of central importance, but their examination now forms part of a broad and complex subject that makes use of many other important physical and chemical properties of the earth that have undergone gradual and measureable change with time. Conventional radiometric dating methods are, of course, the oldest complement to biostratigraphy. To these two primary techniques are now added magnetostratigraphy and several types of high-resolution chemical stratigraphy. Integration of all these data, a subject pioneered by such workers as William Berggren in the 1970s, has resulted in a global time scale of increasing accuracy and precision. It is clear from reading these papers that biostratigraphy is still of critical importance. Indeed, J.C.W. Cope makes the claim in a review paper in this book that for pre-Cenozoic rocks it still provides by far the most accurate method of correlation, and that for much of the Phanerozoic, nektonic and planktonic forms permit zonal subdivision into time slices of 0.5 m.y. or less. Of course, such precision is commonly only obtainable in stratotypes and reference sections, and cannot be relied upon for routine correlations. Also, the assignment of radiometric ages to biozones remains a subject fraught with error and uncertainty, with residual errors of several millions of years remaining for many important boundaries in the chronostratigraphic framework.

The book is divided into four sections, following an introductory review by the editors. This review provides a useful summary of the historical development of stratigraphic techniques that accompanied technical improvements in the methods of marine drilling and core recovery, and included the application of advanced physical and chemical sampling methods to core and outcrop sections. The first section is entitled "Techniques: chronology and correlation", and includes three papers. A.G. Smith provides a review of the method of constructing chronograms in order to deal systematically with error and imprecision in quantitative age assessment. A.E. Mussett and A.G. McCormack describe a new test for assessing the precision of magnetic reversal correlations, and R. Thompson and R.M. Clark describe a technique for using oxygen isotope data to perform pattern-matching tests for correlating DSDP cores. The next section, the longest in the book, consists of nine papers focussing on the Cenozoic record. Subjects covered include the use of molecular stratigraphy, magnetic susceptibility and magnetic reversal stratigraphy, physical and chemical fingerprinting of tephras, and several papers dealing with various biostratigraphic topics. The papers include both regional correlation studies and attempts to improve the global time scale. The first is important, of course, because of the improved data base from which global correlations can be attempted.

One of the most interesting papers in the Cenozoic section of the book, to this reader, is that by D.G. Jenkins and P. Gamson examining a single biostratigraphic datum plane of Pliocene age.

One of the major foundations of chronostratigraphy is the assumption that biological evolution is geologicallly rapid. It has long been assumed that new species spread throughout their particular faunal or floral province at an essentially instantaneous rate (on geological time scales). This justifies the use of the term "first-appearance *datum*" (my italics) for the records of such appearances. Much attention has been paid to the recognition of such datum planes for pelagic marine organisms and for palynomorphs which blow in the wind, because of their value in providing regional or global correlation planes. The short paper by Jenkins and Gamson casts some doubt on this fundamental assumption by arguing that the foraminifera *Globorotalia truncatulinoides* took 0.6 m.y. to spread from the South Pacific Ocean, where it first evolved in the late Pliocene, to the North Atlantic Ocean. The proposal is based on careful magnetostratigraphic correlation of fossil records in several DSDP cores, and is an example of the very high chronostratigraphic resolution that can now be obtained for Quaternary and some late Cenozoic sections. A possible error of 0.6 m.y. in first-appearance ages is very significant for the evaluation of the Cenozoic and Mesozoic record, for much of which a dating error of ±0.5 m.y. is now claimed. It suggests that such high-precision correlations should be viewed with caution, and it casts doubt on our ability to erect a global sequence framework for cycles of less than a few million years duration.

The third section is entitled "Mesozoic", but consists of four papers dealing mainly with the Upper Cretaceous and one, the paper by Cope referred to above, that is a general review of the Phanerozoic record. The first paper in the section, by J.M. McArthur and six co-workers, sets out to establish a strontium isotope curve for part of the Late Cretaceous, based on samples taken from the British Chalk. A correlation error of ±0.8 m.y. is claimed, which is very promising. Use of the technique depends on the presence of suitable fossil material and absence of diagenesis. Next, D.S. Wray and A.S. Gale report on the geochemical fingerprinting and correlation of marl bands in Turonian chalks of southern Britain and northwest France, and demonstrate the ability to carry out regional correlation of these bands, which are spaced only a few metres apart. The data may be used to construct detailed isopach maps that throw light on local subsidence patterns and fault movements. M.B. Hart examines foraminiferal "events" in the British mid-Upper Cretaceous, and develops a British eustatic curve that shows little relationship to the Exxon "global" curve. J.M. Hancock updates his trans-Atlantic correlations, building on earlier work which he carried out in co-operation with E.G. Kauffman. He discusses the apparent simultaneity, or lack thereof, in various transgressions and regressions in northwest Europe, Montana, the Atlantic coastal plain of New Jersey and Delaware, Texas-Arkansas, and the Gulf Coast, and concludes that these cannot be correlated very readily to those in the Exxon global cycle chart.

The Paleozoic section of the book is the least useful, in that it consists of four specialized papers that do not permit the drawing of any generalized conclusions. Two of the papers are by M.R. House and his co-workers describing goniatite biostratigraphy and regional facies shifts in the Catskill delta, New York, and the Canning Basin, Australia. D.K. Lydel examines worldwide correlation of Upper Llandoverian graptolites, an exercise that has suffered from, among other problems, the destruction of important Chinese collections during the Cultural Revolution in the 1970s. Finally, M.D. Brasier discusses the emergence of a carbon isotope stratigraphy for the Cambrian System.

It is clear that, despite the increasing sophistication of chronostratigraphic work, it will be many years before real tests of global eustasy on a frequency of less than a few million years can be attempted. While extremely detailed correlation frameworks are now available for certain successions in certain regions, two old and serious problems remain: the problem of faunal provincialism, and the problem of finding enough useable samples to provide accurate and precise radiometric tie points for the biostratigraphic time scale. Hancock and Cope both comment on the difficulty of correlating Tethyan and Boreal Jurassic ammonoids, while several writers discuss differences in radiometric age assignments for critical stage boundaries. Chronostratigraphic precision of a few thousands of years can now be obtained for many Cenozoic sections and a few older ones, permitting very detailed studies of local subsidence and regional changes in sea level. However, until these two old problems are surmounted and a reliable, practical, global chronostratigraphic framework suitable for routine correlation at a precision level of at least ±0.5 m.y. is available, proposals for a global framework of short-term cycles (frequently of less than a few millions of years), such as constitutes the Exxon global cycle chart, are simply not sustainable.

Advances in Reservoir Geology

Edited by M. Ashton
Geological Society, London
Special Publication 69
240 p., 1992, US $84.00/£50

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The days of large-scale frontier exploration might be past in North America and Europe (but probably not in Asia, including the former communist countries, where exploration techniques stagnated over the years), but this has not removed the need for skilled reservoir geologists. Quite the contrary, in fact. The vast expense of installing production facilities for frontier fields, such as those in the North Sea, means that the very best geological information must be made available to bring production efficiencies to a peak. Initially, production drilling must be planned in the absence of detailed subsurface information on reservoir geometries, a conundrum familiar to production geologists in the petroleum industry. Once primary production peaks, however, the skills of the production geologist are really brought into play, as the anatomy of the reservoir is carefully examined in order to maximize secondary production. By this time, subsurface stratigraphic data will be more abundant, and production data on the fluid flow history can also be brought to bear on the problem of analyzing reservoir architecture and its porosity-permeability patterns. Among the techniques used are statistical methods for evaluating stratigraphic and production data, and analog methods for studying modern environments or outcrop examples of geological units considered to be comparable to those producing from the subsurface.

Advances in Reservoir Geology is a collection of these research studies, mainly by British and Norwegian geologists interested in improving production from various North Sea oilfields. Most of the papers focus on Jurassic fluvial-deltaic production from the northern North Sea Basin, some by reference to outcrop analogs in Britain and North America. There is also one paper dealing with the Rotliegende Sandstone, an eolian unit of Permian age.

The first paper is a multi-authored study by K. Gibbons and co-workers, mostly Norwegian industry geologists, and examines the effects of carbonate cementation on production from Middle-Upper Jurassic sandstones in the Troll field, offshore Norway. Application of sequence concepts to the stratigraphy indicated that most of the carbonate cementation is associated with maximum flooding surfaces and sequence boundaries, and this led to an intensive study of subsurface stratigraphy and correlation, the results of which are reported in this paper. Correlations with the Exxon global cycle chart are suggested. Mapping of carbonate-cemented horizons was facilitated by this study and is of considerable importance to production planning because of the barriers to flow caused by the cementation.

The second paper, by R.W. Lahann and co-workers uses detailed core and thin-section studies of facies, petrology and diagenesis to explain variations in production performance of a mixed fluvial-eolian suite of sediments. The study examines the Rotliegende Sandstone in the gas-producing Vanguard Field of the southern North Sea. The best production is from the foresets of large-scale eolian crossbedded sandstones, which exhibit high porosities and have good interconnectivity.

The use of image-analysis techniques to explore porosity-permeability patterns forms the focus of the next paper by W.D. Clelland and co-workers. Samples were taken from an Upper Jurassic unit in the central North Sea. Manipulation of digitized images by computer enabled connectivity of the pores through small pore throats to be examined rapidly for many thin sections, resulting in a vastly increased data base for formation evaluation than that obtainable by normal optical thin-section examination.

There follow three papers using North American outcrop studies to throw light on North Sea petroleum production. The first is by P. Lowry and T. Jacobsen, who carried out an outcrop study of the Ferron Sandstone in Utah, with the aim of relating permeability to facies architecture. The outcrops provide a well-known example of river-dominated delta front, as documented several years ago by T. Ryer. The present researchers collected approximately 850 permeability measurements from the outcrop faces by using portable permeameters while suspended in front of the cliff face on ropes. The data were then employed in a series of production simulations, varying facies characteristics and production pressures in each run. No detailed comparisons with actual producing fields were attempted.

Ø. Høimyr and co-workers compared permeability distribution in the Statfjord Formation, Snorre Field, in the North Viking Graben, and in outcrops of the Pennsylvanian-Permian Maroon Formation of Colorado. Both are interpreted as braided fluvial systems. The facies architecture of large outcrops of the latter was used to develop a set of heterogeneity models for running a water injection simulation program, by varying the sandstone permeability characteristics and the density of shale breaks, and running a flow algorithm for each model. The use of outcrop facies data was found to provide useful reality checks on such models.

The last of the three outcrop papers is by T. Dreyer, who presents a study of the Miocene fan-delta sediments of the Ridge Basin, California, and the Tilje Formation, a Jurassic producing sandstone on the Norwegian shelf. Flow units were defined from the Ridge Basin data, and were found to be laterally very extensive, indicating the need for good subsurface mapping of the reservoir so that injection and production perforations can be appropriately placed for each unit.

The next paper is a think-piece by J. Alexander that probably should have been offered as an introductory or concluding article. It provides a thoughtful review of the successes and problems with the use of analogs in studying subsurface reservoirs (*e.g.*, the problem of correct comparison of scales of facies units). Many examples are quoted, but the author did not draw on the studies reported in this book, which would have made this a much more useful review.

The last two papers examine logging techniques. G.I.F. Cameron and co-workers developed simulated dipmeter logs by taking nearly 1600 dip readings on a large outcrop of a Carboniferous deltaic complex in central England. The intent was to test the usefulness of dipmeters for investigating sedimentary structures and paleocurrents in the subsurface. The outcrops themselves had been subjected to a detailed sedimentological analysis by earlier workers. The authors criticize some of the older, simplistic ideas about dipmeter interpretation, such as the usefulness of upward decreasing and increasing dip values (the so-called red and green patterns). However, separation of dip readings according to their magnitude, made it possible to isolate those relating to foreset dips, and therby obtain reasonable estimates of paleocurrent directions.

Lastly, L.T. Bourke and co-workers described the use of a nitrogen probe permemameter to build permeability images of borehole surfaces, and discussed the uses of the results in interpreting petrology and sedimentary structures.

In conclusion, this is a useful book for those interested in keeping abreast of the latest sophistications in reservoir analysis. In particular, the book throws considerable light on the types of problems encountered and methods used in the development of clastic reservoirs in the North Sea. Specialist studies of this type are likely to be of increasing usefulness in North America, as the petroleum industry is forced, by low oil prices, to postpone expensive frontier exploration and focus on increasing the production efficiency of existing fields by the careful use of sedimentological data to explore reservoir heterogeneity.

Tectonic Assemblages of Ontario. Maps 2575-2583

Ontario Geological Survey
Queen's Printer for Ontario
1992, $4.50 each, set of 5 maps $16.50, set of 4 charts $13.20, complete set $29.70

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Most geologists are familiar with the approach of mapping tectonic assemblages in the Cordillera, where the knowledge of faunal assemblages, geochronological and paleomagnetic data and lithostratigraphy have been combined to help define contrasting geological terranes. Although some of these tools are not available to the Precambrian, geologist Greg Stott and a team of "compilers and interpreters" have attempted to synthesize what is known about the tectonic assemblages and plutonic suites of Ontario into five maps (1:1,000,000) and four charts produced by the Ontario Geological Survey (OGS) as part of its centenary map series. For the purpose of this exercise, a *tectonic assemblage* consists of "stratified rock units built during a discrete interval of time in a common depositional or volcanic setting and is typically bounded by faults, unconformities and intrusions", whereas a *plutonic suite* is "a set of spatially associated plutons of common age, composition and probably common origin".

These maps contain a wealth of information, but most users will need to study the legends carefully to get maximum value from them. At first glance, the shorthand notation used for classification looks rather complex, but, once mastered, allows a user to extract the name, probable age range, composition and, locally, aspects of petrogenesis of assemblages and suites. For example, one can, from the map, identify the well-known Blake River (BR) "assemblage" in the Abitibi subprovince as belonging to the 2690-2710 Ma age range and, from the accompanying charts, learn that it is composed of mafic to felsic calc-alkalic volcanic rocks and minor units of iron formation and interflow turbidite, and further, that it is of similar age and composition to the Tisdale, Gauthier and Dismal Lake assemblages. One can also gain an appreciation of major reversals of way-up in the BR assemblage, as well as identify the locations of sampling sites for U-Pb age determinations, which in turn are keyed to tables that cite the precise ages, error limits, and sources of information. This use of the existing geochronological data base for Ontario implicitly acknowledges that, without age constraints, the task of producing these maps would likely have proven impossible.

The maps should be of some interest to economic geologists even though mineral deposits are not plotted on them. The positions of interpreted centres of volcanism, commonly favourable for the occurrence of base metals, are prominently marked. In addition, in light of the current interest in diamond exploration, users will readily find localities where lamprophyre, kimberlitic dikes and diatremes, fenitic rocks and alkalic rocks are known, both in exposed regions and beneath Paleozoic cover.

Definition of the assemblages and suites within the metamorphosed and deformed rocks of the granite-greenstone and gneissic terranes of the Superior and Grenville Provinces leads to considerable illumination of the geology of Ontario, but the extension of the approach to autochthonous, non-metamorphosed and little-deformed Proterozoic sequences leads to some surprising results. For example, in the Lake Superior area, the Sibley Group becomes the Sibley "assemblage", whereas the well-known Logan diabase sills are so-designated where they intrude Animikie strata, but are termed Nipigon sills to the northeast where they reside mainly in Archean basement or the Sibley Group. Both of these examples illustrate that there is little apparent advantage in extending the assemblage and plutonic suite terminology into areas where there is a well-founded existing conventional nomenclature.

I suspect that the tectonic assemblages maps for Ontario will meet with mixed reviews, mainly because of the unfamiliarity of this approach to Precambrian workers. There is also a likelihood that some of the current divisions will change with time, given that the geochronological data base for Ontario, although exceptional, is uneven in areal coverage, and many educated guesses were undoubtedly necessary in extrapolating assemblages into areas lacking age determinations. This is to be expected, however, based on the Cordilleran experience, where terrane boundaries seem to shift as frequently as the aluminosilicate triple point once did. These potential difficulties in no way detract from the fact that these maps efficiently portray a wealth of information at a manageable scale. As always, the benefit/cost ratio of these maps from the OGS is exceptionally high.

Instructional Videos: Analogue Modelling

Tape 1. Extensional Fault Structures
Tape 2. Inversion Fault Structures

By British Petroleum
Distributed by Geofilms Limited
12 Thame Lane
Culham, Oxford OX14 3DS UK
1990, VHS or PAL format, 32 min. each, 2 tapes, US $275.00 + US $20.00 S&H for each tape

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The video format is ideal for certain instructional purposes, as these two tapes illustrate. Unfortunately, the high cost of these videos is likely to discourage their use in the classroom and restrict the potential audience for these otherwise excellent films.

The two tapes detail the experimental methods and results of a series of two-dimensional sandbox models on fault systems. Dr. Ken McClay of the Geology Department, Royal Holloway and Bedford New College, University of London performs the experiments, and discusses their interpretation with various experts, as well as showing examples of similar structures to those seen in the models on reflection seismic sections. This three-fold approach to the models is particularly useful. First, the models are filmed during the experiment using time-lapse photography, so the evolution of the fault systems can be seen as the parameters of the model are changed. Being able to pause and rewind the tapes through these sections greatly enhances their utility. Second, the models are compared with seismic sections that show analogous structures. The value and pitfalls of such comparisons are clearly discussed. Third, Dr. McClay and other experts discuss the models and the sections, especially aspects that may contradict or support modern structural geology theory. Having access to the time-lapse photography itself is wonderful; having access to informed discussion is even more beneficial.

Tape 1 deals with five models of extensional faults, progressing from simple to more complex models. In addition, Tape 1 explains in great detail the methodology used in the modelling, which is particularly useful to any instructor of a structural geology or tectonics course. The models emphasize sedimentary basins developed in rift environments. These basins have a pre-rift sedimentary fill and, in all cases, syn-rift sediments are added so that sedimentation keeps pace with basin subsidence. All five models assume a fixed footwall configuration. Each model is shown in time-lapse view, an analogous seismic section is shown, and then both are discussed.

The first model on Tape 1 is of a listric fault that becomes horizontal at depth, and is subjected to 50% extension. The model clearly shows the development of a crestal-collapse graben and development of synthetic and antithetic faults. Model 2 is a listric fault that dips 10° at depth, and 100% extension occurs. Model 3 is a listric fault with a ramp flat extended to 50%. The addition of the ramp fault results in considerable changes in the faulting pattern from the previous models. Model 4 represents asymmetric, 50% regional extension. A rubber sheet is used to produce the fault pattern, with the rubber sheet simulating a midcrustal decollement. This type of extension produces domino-type fault blocks. This reviewer notes that the resulting structure mimics the basin and range province of the western United States. In the ensuing discussion, it is suggested that this type of extension pattern is anomalous. This is a noteworthy conclusion, given how many researchers in North America use the basin-and-range area as a model for regional extension. The final model on Tape 1 is similar to Model 4, except that extension is symmetric (pulled from both sides) and continued to 100% extension. The resulting pattern, however, is not symmetric, and results in two graben of unequal size forming with a central horst.

Tape 2 presents four models of inversion structures, which can be regarded as compressional structures developing after a period of extension. The tape starts with a discussion of the meaning of the term inversion and how the term has evolved. In these tapes, inversion describes the reactivation of extensional half-graben systems by subsequent compression (positive inversion) and the reactivation of compressional structures by subsequent extension (negative inversion). The tape focusses only on examples of positive inversion because of its application to petroleum exploration, particularly in environments such as the North Sea basin. The section explaining the methodology of the modelling, however, is not as detailed as in Tape 1.

In Tape 2, the models consist of prerift basins which are extended as in Tape 1, filled with syn-rift sediments, buried by post-rift sediments, then compressed. The first model represents extension as shown in Model 1, Tape 1, which is then compressed. Particularly interesting is that compression does not always reactivate the faults developed during extension. In addition, in this model and in the others, the faults do not necessarily assume shapes or angles that most interpreters of seismic sections would normally assume could occur. Model 2 is similar to Model 1, but involves a planar fault. Model 3 involves extending then compressing a series of domino fault blocks. Model 4 involves a listric fault with a ramp flat, similar to Model 3, except that mica is added to some sand layers in order to enhance shearing. The last model is probably the most interesting, as it involves the development of thrusts, nappe-like folds, and back thrusts. It is unfortunate that the series does not go one step further, and examine thrust systems and negative inversion in greater detail, as these latter systems would be of great relevance to Precambrian terranes and interpretation of seismic sections in shields.

Although the two tapes can be used separately, they are better viewed as a package, particularly as many of the models used in Tape 2 represent compression of models developed in Tape 1, and because the details of the modelling experiments are only explained on Tape 1. Tape 1 can be used in conjunction with two articles by Ken McClay which outline the results of the models (McClay and Ellis, 1987; Ellis and McClay, 1988). Tape 2 can be used in conjunction with two articles on inversion tectonics, one by Bally (1983) showing seismic expressions of various structures, the other by Cooper and Williams (1989). These tapes could also be used in conjunction with another video package dealing with the sedimentological evolution of the East Greenland Rift (reviewed in Geoscience Canada, v. 19, p. 182-183), particularly if the videos were being used in tectonics or sedimentology classes.

Although there are always problems involved in adapting the results of geological modelling to the explanation of full-scale, more complex geologic phenomena, the tapes illustrate the strengths and weakness of such approaches, and encourage the viewer to think about the structures involved and how they develop. They are a valuable aid in assisting students to visualize regional tectonics and structure.

Although these tapes were designed to give petroleum explorationists a better understanding of structural geology processes in order to assist in seismic section interpretation, they can be used by a much broader audience. They could be used in any undergraduate level structural course to illustrate how fault systems develop, and how slight changes in the initial conditions can cause significant changes in the final geologic system. They are obviously of great use to those involved in seismic interpretation, particularly Canadian geoscientists involved in interpreting LITHOPROBE seismic lines. Sedimentologists studying rift basins would also find the series of considerable interest, especially Tape 2 where inversion processes result in tectonically forming a section that seismically resembles an aggradation-progradation sedimentary section.

With such a broad potential audience, it is unfortunate that the producers could not have teamed up with a group like the American Association of Petroleum Geologists so that these tapes could have been distributed at a lower price. Even US $275 for the two tapes would have been better than the current price of US $590 with shipping. As a result of this high cost, many who could benefit from viewing these tapes will never have the opportunity to do so.

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