Document generated on 04/05/2025 1:49 p.m.

Geoscience Canada

Book Reviews / Critiques

Volume 14, Number 4, December 1987

URI: https://id.erudit.org/iderudit/geocan14_4br01

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Publisher(s)

The Geological Association of Canada

ISSN

0315-0941 (print)
1911-4850 (digital)

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Cite this review

(1987). Review of [Book Reviews / Critiques]. *Geoscience Canada*, *14*(4), 236–240.

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Book Reviews / Critique

Book Reviews

Enhanced Oil Recovery

By M. Latil
Institut Francais du Petrole Publications
236 p., 1980; ff280, paper

Reviewed by R.N. Watson
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This volume is the fifth in a series of textbooks used for petroleum production courses at the Institut Francais du Petrole (IFP) and the Ecole National Superieure du Petrole et des Moteurs. The author has been assisted by several other staff members at the IFP for three of the eight chapters.

In examining the references at the end of each chapter, it becomes apparent that the author is fully conversant with enhanced recovery technical literature throughout the non-Communist world. It is also apparent that the translator, Paul Ellis, is familar with oilfield terminology and techniques.

Unfortunately, the most recent reference cited is from 1975, in a technological field undergoing rapid expansion. (In the introduction, the author includes a table that illustrates the increasing importance of enhanced oil recovery projects in the United States. It indicates that oil produced in the United States by enhanced recovery projects increased from 22% of total production in 1960 to 30% in 1970, and was projected to reach 40% by 1980.) With the rapid expansion of technology that this implies, is it likely that there have been no significant papers written since then [1975]?

The contents are well laid out, with chapters successively covering the basics of reservoir dynamics, water injection, gas injection in an oil reservoir, miscible drive, gas re-cycling in gas-condensate reservoirs, thermal recovery methods, and other methods of enhanced recovery. An endearing feature of the book is the way that subchapter topics are identified and numbered in the table of contents, allowing rapid location of particular topics by anyone using the book for reference purposes.

The introduction also provides a clear explanation of the principles underlying enhanced oil recovery. Natural or primary production is explained as the result of pressure being higher in the reservoir than the adjacent wellbore, and the reservoir fluids therefore moving from an environment of higher pressure toward one of lower pressure. Enhanced recovery methods are explained as those where additional energy must be provided to the reservoir to increase the pressure differential between the reservoir and the wellbore. This additional energy is usually provided by injection of a fluid that displaces the original reservoir fluids.

It is apparent that the book was originally planned as a text. In each chapter following a brief introduction of the principles, the subject is explained in full mathematical complexity, with little effort being made to guide the reader through the computations from an intuitive approach. For any equation being derived, only those terms not appearing in previous chapters are explained. This will make it difficult to follow for the person using this volume as a reference to use the formulae in a chapter without working through the preceeding chapters.

The first chapter reviews the factors common to all enhanced recovery methods. Those factors and influences are separated into reservoir characteristics, the nature of displacing and displaced fluids and the arrangement of production and injection wells.

Water injection is covered in the second chapter and is treated in more detail than any of the methods that follow. (In 1970, 80% of the oil recovered in the United States by enhanced recovery methods was from water injection projects.) An additional benefit of this process is reservoir pressure maintenance, particularly in reservoirs containing low viscosity oil.

Immiscible displacement (by gas in an oil reservoir) is discussed in the third chapter. Again, one of the side benefits is maintenance of reservoir pressure. This process is confined to those situation where gas-oil phase relationships are amenable and where there is a cheap, convenient source of gas available.

The following chapter deals with miscible displacement, where displacing and displaced fluids are miscible in all proportions. This method has the advantage of eliminating interfacial tension and the microscopic recovery efficiency approaches 100%. One major drawback is the expense associated with providing the miscible fluid in sufficient quantities.

The fifth chapter deals with gas recycling in gas-condensate reservoirs. The use by the author of the Kaybob South field in Alberta gives this chapter more interest than it otherwise would have for this relatively uncommon form of enhanced recovery.

Thermal recovery methods are covered in the sixth chapter, with discussion of both steam and *in situ* combustion processes. Both mechanisms improve sweep efficency and displacement, often through viscosity reduction of the oil.

The final chapter deals with the other enhanced recovery processes that are still considered to be experimental.

In summary, this book represents an informative treatment of a rapidly changing technological field. It is flawed, however, by being ten years out of date, and by the minimal explanations covering the derivation of the formulae in each chapter.

Cretaceous Climate (Das Klima der Kreide-Zeit)

By Edwin Kempter (with contributions by D.J. Batton, I. Harding, Li Wenben, J. Mutterlose, G. Pelzeer, R.A. Spicer, K. Wiedenroth and V. Wilde)
Geologisches Jahrbuch, Reihe A, Heft 96, Hannover
399 p., 1987, DM 168-, paper

Reviewed by Gerd E. Westermann
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This is an unusual and important book: exactly the first half is a thorough, multidisciplinary analysis of Cretaceous climates, the other a collection of original papers on diverse protistan, animal and plant fossils given supportive evidence. The main theme of Kemper is the quite revolutionary hypothesis that Cretaceous climate fluctuated greatly and that the well known Cretaceous eustatic sea-level changes were due to growing and receding polar ice caps; the cold time intervals escaped previous researchers because of strong natural bias against their detection. He then proceeds to review and discuss the diverse and seemingly overwhelming evidence from mineralogy, sedimentology, and biogeography. The book is also richly illustrated, including colour plates.

In the first half of the book, Kemper develops his mainstay for his hypothesis of recurrent near-freezing temperatures in the north-polar area, *i.e.*, the calcite pseudomorph Glendolite which he found during his extensive field work in epicontinental mudstones of the Canadian Arctic. The unstable Ikait ($CaCO_3$ hexahydrate) forms large spherical rosettes several meters below the water-sediment interface in undercooled (0 to -4%) oceans. Providing Glendolite is being discriminated from the somewhat similar Gennoishi-type mono-crystals, it is an excellent paleothermometer hitherto used only by "forgotten" Soviet authors in eastern Siberia and the North-East of USSR. The high latitudes, therefore, provide the only direct proof to Cretaceous glaciations, since glendolites and apparent drop-stones are restricted to them.

Improved biozonation permits the time-correlations from the Canadian Arctic to the well studied Lower Saxony Cretaceous Basin. Here the glendolitte levels of the Arctic are represented by terrigenous sequences bearing cool-water Boreal ammonite faunas – unless beds coeval to the Arctic glendolite levels are entirely missing in hiatuses, *i.e.*, cold-water occurred during regressive phases. Warm-water phases were consistently marked by high sea-level and, significantly, by carbonate deposits with Tethyan (southern) ammonite faunas. Other, exclusively warm-water faunas are belemnites and calcareous, mostly planktonic foraminifera which have furnished the isotope data for the previous paleotemperature curves for the Cretaceous ocean.

The climatic changes were cyclic: the megacycles approximated 2.2. Ma; mesocycles 400 Ka or 220 Ka; and dark-light bedding cycles (low-high in carbonate) with about 40 Ka. Supercycles of about 10 Ma are also indicated. This cyclicity of several orders clearly reflects Milankovich Cycles based on orbital parameters of the earth. Glacio-eustatic sea level changes are therefore the obvious explanation for the recurrent association of regression with cool water and transgression with warm water in the mid-latitudinal seas. Much of the evidence for cyclicity comes from well-log data in the thick and relatively complete basin facies. Unfortunately, the "potential" and "resistance" log-data were both simplified and cyclicity determined subjectively "by eye" only. Well known statistical methods for curve simplification (*e.g.*, "moving averages") and particularly those for determination of cyclicity (*e.g.*, Walsh Spectrum) ought to be applied.

Part 2 of the book, comprising eight "Contributions to the climate annalysis of the Cretaceous" (half of them written in English), begins with an examination of the Barremian "Blatterton" of the Lower Saxony Basin, by Mutterlose (Hannover) and Harding (Cambridge, UK). The rich phytoplankton which is concentrated in these finely laminated clays, is highly diverse in dinocycst incuding warm-water forms, contrasting with sub- and superjacent beds, and in calcareous nannofossils with warm-water affinities. These and other bituminous fine-laminated shales were deposited under relatively shallow and warm-water conditions, and the organic matter derived from periodic phytoplankton blooms.

The Lower/Upper Hauterivian boundary is duscussed by Kemper, Mutterlose and Wiedenroth (Garbsen, F.R.G.) with respect to a well marked climatic change. The shift from warm to cold water is clearly indicated by coccoliths, microfauna and ammonite taxa, as well as by lithology in outcrop and subcrop.

Palynomorphs and floral provinces are described by Batten (Aberdeen, Scotland) and Li (Nanjing, China). Global floral realms are defined, but climatic control of spore-pollen provincialism is difficult to separate from sedimentary control on a smaller scale.

The climate of the Wealden facies is reviewed by Pelzer (Gottingen, F.R.G) and Wilde (Frankfurt, F.R.G.) The diverse botanical and lithologic evidence indicates at the beginning mostly semi-arid conditions, followed by wet and warm climate with dry seasons, and ending in increasing aridity.

The truly polar Cretaceous macroflora of northern Alaska is discussed by Spicer (London, U.K.) During the Albian-Cenomanian ferns, cycads, sphenophytes, ginkgos and conifers dominated. They were probably all deciduous, however, and "actualism" cannot be strictly applied to paleoecologic inference, *i.e.*, a warm climate. Mean annual temperature was probably only approximately 10 C, and freezing winter temperatures are indicated by leaf structure. – This contradicts Kemper's conclusion in the first part of the book, that winter temperatures remained above freezing owing to the "Greenhouse-effect", and that an increase in the earth's obliquity is indicated.

Calcareous nannofossils and belemnites as indicators of warm water are discussed by Mutterlose. High diversity of the former coincide with Tethyan immigration of the latter. Microfauna supports the conclusion of warming trends.

Ammonite biogeograhy is related to ocean temperature and climate by Kemper and Wiedenroth. Repeated north- and southward ammonite migrations coincide, respectively, with increase and decrease in taxonomic diversity and of carbonate content in the sediment. Warm- and cold-water morphologic trends of ammonites are distinguished although no attempt is made to interpret these trends functionally. The trends also differ in the superfamilial clades, *i.e.*, in cold water, the Neocomitinae grew long spines and aberrant body chambers; the Ancyloceratinae thick rugose ribbing.

The book closes with a review of the climatic significance of foraminiferas and ostracods by Kemper. Many morphologic features previously considered to be of taxonomic importance are re-interpreted as ecophenotypic and used as climatic indicators. Warm and cold thermophilic or stenothermic taxa are identified. Warm-water taxa tend to be large in skeleton size and diverse. Cold-water (Boreal) associations of shallow seas closely resemble deep-water associations from more southerly (Tethyan) seas and previous confusion is clarified.

Both the author and the publisher (Schweizerbart'sche Verlagsbuchhandlung, Stuttgart), ought to be congratulated for a magnificent job in editing and production of the book. There are very few typing errors; the print and illustrations on first-class paper are excellent, and even include colour reproduction. The copy at hand is only paperbound but has a splendid cover. This volume is a must for every geological library and all students of paleoclimatology.

Recent Advances in Understanding Gold Deposits

Edited by S.E. Ho and D.I. Groves
Publication No. 11, Department of Geology & University Extension, University of Western Australia, Nedlands 6009, Australia
368 p., 1987; AUD $41.00 (surface), AUD $48.00 (air mail)

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This publication draws together 24 papers originally presented at a Geology Department and University Extension Seminar, entitled "Recent Advances in Understanding Precambrian Gold Deposits", held at the University of Western Australia in February 1987. The majority of authors are members of the Archean Gold Research Group established by D.I. Groves at the University of Western Australia, but a number of invited contributions from active workers in the field of gold deposits geology are also included.

The volume is organized into four basic subject groupings: (1) eleven papers which specifically address the geological characteristics and geochronological boundary conditions of Precambrian gold deposits, principally with reference to Western Australian deposits, and with a strong emphasis on structural environment; (2) two papers on radiogenic isotope (Pb) studies of the Yilgarn gold deposits; (3) three papers covering new stable isotope and fluid inclusion data; and (4) a miscellaneous group of articles which address diverse topics related to gold.

In the first group, both the regional tectonic framework of the Western Australian Shield (Harris) and detailed district or mine-scale structural studies are reported (Barley and Groves; Partington; Eisenor; Mueller and Harris; Skwarnecki). These papers include sophisticated structural analyses of ore deposits, and are notable for the application of kinematic indicators to deduce incremental displacement vectors. A general consensus emerges that transcurrent shear zones provide the critical tectonic environment for hosting gold deposits at the regional scale, and that second or third order dilational structures control the site of Au deposition at a mine scale, as exemplified by the Norseman-Wiluna belt. All of the studies emphasize the observations that gold introduction is late in the development of the tectonic architecture of greenstone belts, and that deposits are preferentially sited within the brittle-ductile deformation regime. Given the scope and detail of these structural studies, it is surprising that no attention is directed at hydraulic fracture mechanics, fluid pressure, and strain rate conditions, the latter two of which are the critical physical parameters which mediate the brittle-ductile transition. Geochronological studies (McNaughton and Dahl) have bracketed the timing of gold mineralization, corroborating structural evidence for late introduction of gold into the supracrustal sequence, and pointing towards a Yilgarn-wide gold mineralization event at 2.7-2.65 Ga. A key observation is that rare metal pegmatites and gold deposits share the same time framework and tectonic environment of transcurrent shear zones, but that the former are emplaced at deeper levels within the ductile deformation regime.

Alteration studies (Allen; Rames, Phillips, Groves; Groves *et al.*) document those groups of chemical elements which are introduced *versus* those which behave isochemically, the uniformly high Au to base metal ratios, and the critical importance of Fe/Fe + Mg ratios of wall rocks in mediating sulphidation reactions, which in turn are empirically associated with precipitation of gold. Groves *et al.* critically evaluate the various hypotheses for iron-formation hosted gold deposits, convincingly demonstrating that the gold enrichment is epigenetic in origin rather than exhalative. An up-to-date survey of gold deposits in the Barberton greenstone belt completes this group of papers.

A remarkably coherent set of observations emerges from new lead isotope analyses on the Western Australian gold deposits (McNaughton; Dahl, McNaughton, Groves; Barley and Groves): (1) Pb isotopic data fall on mixing lines between the end members of wall rock Pb and Pb of hydrothermal origin; (2) a radiogenic component is invariably present, implicating older sialic basement in the source regions; (3) Pb isotope data show a provinciality, signifying heterogenous source regions with respect to Th/U; and (4) Au mineralization postdates the volcanic sequences by a few tens of millions of years. These authors emphasize the requirement for detailed paragenetic characterization of the Pb-bearing sulphide minerals.

Stable isotope and fluid inclusion results attest to a distinctive, and uniform, hydrothermal regime. Oxygen isotope data are tightly constrained, and together with D analyses, implicate fluids of metamorphic or possibly magmatic origin, at temperatures of 350 ± 50°C (Golding and Wilson). A number of different populations of carbonates have been identified from carbon isotope analyses, for which carbonates paragentically associated with Au show a distinct provinciality (Golding *et al.*). The provinciality of Pb and C isotope data is directly comparable to results for the Canadian Archean gold deposits (Franklin *et al.*, Ottawa; various workers, University of Western Ontario), and these observations collectively must bear critically on the recent speculations by some other teams that felsic magmas are involved in the Archean gold deposits. Fluid inclusion data (Ho) reveals that the hydrothermal fluids were of uniformly low salinity, H_2O-CO_2-rich, neutral to slightly alkaline, and with sporadic phase separation.

The remaining miscellaneous papers address diverse topics including sulphidation of iron formations as a Au precipitation reaction (Neall); a provocative article on lamprophyres as gold exploration targets (Rock *et al.*); and a detailed and critical review of constraints on the source of auriferous fluids (Perring, Groves and Ho), in which cogent arguments are presented for metamorphic hydrothermal reservoirs rather than marine, meteoric or magmatic fluids. Sand and Ho review gold deposits of China; Barrego and Phillips describe the metamorphism of the Witwatersand succession; Palmer, Phillips and McCarthy critically evaluate geological evidence bearing on the P_{O_2} of the Precambrian atmosphere; Phillips and Myers describe the mineralogy of the Witwatersand reefs; and Monti documents a lateritic gold deposit from Western Australia.

This volume marshalls a commanding ensemble of research papers with an impressive body of new data on Precambrian gold deposits, from the most active and innovative group working on the problem. The strength of the papers lies in the quality of field observations, and in the application of geochemistry to material that has first been geologically well characterized. The editors have performed a commendable effort in ensuring a uniformly high quality of text, figure presentation, and colour photomicrographs. This volume is required reading for all geologists involved in gold deposits at the research or exploration level.

A Clarification

In a recent book review (*The Ocean of Truth*, v. 14, p. 197), I made a critical reference to unproductive scientists in the Geological Survey of Canada. Several of my former colleagues in that organization have pointed out the unfairness of my allegations, and on re-reading my own words, I admit that this paragraph was written carelessly.

While there is deadwood in the GSC, there is in most institutions, including my own. Universities are certainly no better at keeping their staff keen and productive than are governments, and I should have taken more care to balance my remarks. I offer my apologies to my friends in GSC, with whom I spent some of the most productive years of my career.

Andrew D. Miall

Controversy in Victorian Geology — The Cambrian-Silurian Dispute

By James E. Secord
Princeton University Press, New Jersey
xvii + 362 p., 1986; $49.50 US, cloth

Reviewed by W.A.S. Sarjeant
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Recently, scientific historians have been favoured with Martin Rudwick's magnificent and detailed account of *The Great Devonian Controversy* (1985); but that was an episode hither to little remembered by earth scientists. The stratigraphical confrontation about which we all learned, and which was much more regularly reported in scientific histories and geological textbooks, was that between two giants of nineteenth-century geology, Adam Sedgwick and Roderick Murchison, over the definition of the earlier systems of the Paleozoic. The story was indeed one to excite the imagination — of a geological friendship between a reclusive and ineffectual Cambridge don and a gregarious and vigorous Scottish military man that degenerated progressively into acrimony; of wholesome scientific rectitude confronting devious geopolitical manoeuvring; of bitter intellectual batting, only brought to posthumous armistice through the intervention of the mild Midland schoolmaster, Charles Lapworth.

Such confrontations are the veritable stuff of legend. Yet, of course, in legends there is a simplification to blacks and whites, in order to enhance drama, facilitate comprehension and stimulate memory. Truth, tiresomely, proves usually much more complex, albeit not necessarily less dramatic. So it is in this instance, as Secord's thorough study demonstrates.

First of all, the classic characterizations of the protagonists have been over-simple. Yes, Sedgwick did spend 69 years at Trinity College, Cambridge; but he was a sociable being, an effective teacher, long a prominent participant in Geological Society meetings in London and subsequently an effective lecturer at British Association gatherings in the provinces. Nor was he a steady advocate of a single scientific truth, persistently demonstrating the necessity for, and the integrity of, a clearly conceived Cambrian system. Instead, he changed his mind repeatedly concerning its boundaries; he made fundamental stratigraphical miscorrelations; he was eager for compromise and only precluded from it by Murchison's recalcitrance; and he was perfectly willing to rewrite scientific history, should it suit his current purposes.

As for Murchison — yes, he was glib in argument, capable of histrionics and as expert in political as in military tactics. Yes, he was a highly sociable being and quite remarkably egocentric — Secord comments acutely (p. 230) that "one searches the many volumes of Murchison's works in vain for a truly humble statement". Yet he was not nearly so Machiavellian in his attempts to maintain the Silurian as has been supposed.

Secord's account makes it clear that the adoption of the Silurian by Geological Survey mappers was much more a consequence of the factual evidence that Murchison had assembled than of any improper pressurizing. Its director, Henry de la Beche, may have had good reason to be relieved that their endeavours supported Murchison's ideas rather than provoking further hostility from that formidable gentleman, but he was quite unprepared to distort geological facts in order to make them fit the latter's theories. Indeed, both Murchison and Sedgwick came to regard the Survey's officers as scientific arbiters, whose prolonged and detailed studies in the field outvalued their own briefer investigative forays.

When Murchison succeeded to the Directorship, it is made evident that he took on the task reluctantly, as a duty to science, instead of seizing upon it as a potent tactical device in his campaign against Sedgwick (p. 257). Certainly, Murchison did wish to eliminate the Cambrian entirely from the Survey's maps; however, when two survey officers, Jukes and Ramsay protested, Murchison was swift in backing down (p. 296-297).

The fundamental difference between Sedgwick and Murchison was not between scholar and practical man, not between honesty and expediency, but between their different approaches to the business of geological mapping. Secord contrasts them thus (p. 58):

> "[Sedgwick's] remarkable facility for untangling the interrelationships of complicated rock masses was perfectly adapted for work in a region like north Wales, which provided few of the palaeontological characters or gently dipping strata favored by most contemporaries. Among the twists and turns of the Welsh rocks, geological structures could be interpreted on the grand scale, and with a few day's fieldwork Sedgwick could bring order and simplicity to thousands of feet of seemingly chaotic slate and greywacke.
>
> "Murchison, on the other hand, was above all a maker of geological maps. Known for the rapidity with which he grasped the fundamental features of a district, he excelled in inferring the distribution of the underlying formations from a quick survey of the surface. His field jottings of the 1830s reveal a scientific style considerably more deductive than that of Sedgwick, whose notebooks are crammed with thousands of discrete observations. From the beginning Murchison constructed classifications, drew tentative sections, and made correlations. Although this sometimes led to a certain carelessness in his overall structural interpretations, he pressed on and became the most productive Victorian geologist, singlehandedly putting a large portion of the Earth's crust into order."

There we have the contrast and the cause for conflict — Sedgwick, with his meticulous concentration upon detail and remarkable eye for structure, drifting into conflict with Murchison, the hasty generalizer from rapidly garnered data, the firm believer that fossils were the only key to stratigraphic correlation.

It is indeed tempting to simplify and dramatize their images. One might consider Sedgwick as the typical Dales countryman, content with his own territory and unwilling to part with a single acre of it, and Murchison as the alien empire-builder, prolific with justifications for seizing new territory and impatient with the claims of peasants driven from their lands.

Certainly it is easier to sympathize with Sedgwick's determination to ensure a posterity for his single principial attainment, the unravelling of the complex geological knot that constitutes the Lower Paleozoic of north Wales, than with Murchison for whom this was merely an additional scientific scalp to add to a mass of other adornments. One can identify with, and excuse, Sedgwick's grieved reaction when Daniel Sharpe's superficial interpretation of north Welsh geology was preferred by his friend to his own profounder study, simply because this suited Murchison's purposes (p. 163-166). It is equally easy to comprehend, but much less easy to condone, Murchison's panic at the thought of losing even the lowest part of his beloved Silurian — "if I cut off my bottom I know I should soon expire" (p. 197).

Yet, as we may perceive clearly from this objective study, both geologists behaved equally badly during this confrontation. Moreover, Murchison's belief that the positive fact of identifiable fossils outweighed any theoretical demonstration of structural possibilities remains perfectly comprehensible, whereas Sedgwick's uninterest in recognizing a distinctive Cambrian fauna — even though that might have been his easiest defence against Murchison's stratigraphical usurpations — remains puzzling.

It was, indeed, the eventual discovery of such a fauna — not in Wales, but by Joachim Barrande in Czechoslovakia (p. 276-280) — that gave scientific permanence to the Cambrian — and, by an unanticipated twist of scientific history, a greater incidental renown in that all the vast thickness of earlier strata would come to be termed the "Pre-Cambrian".

This served also as prelude to Charles Lapworth's "brilliant compromise" (p. 307) —

the distinguishing of the Ordovician system, not just as a buffer between the erstwhile stratigraphic territories of Sedgwick and Murchison, but as a unit well defined by a distinctive fossil assemblage. Even though the placement of its lower boundary was long to be disputed, this was a consequence only of differing opinion, not of any paleontological or stratigraphic ambiguity.

However, it is salutary to be reminded (p. 310) how long we geologists took to assimilate Lapworth's concept; though proposed in 1878, it was not accepted by the Geological Survey until after Archibald Geikie's retirement from the Directorship in 1901 and, even then, did not gain explicit approval from the international geological community until 1960!

This book contains several fascinating historical sidelights. We learn of the vigour and disputatious character of the early meetings of the Geological Society of London (p. 19-21) and can only regret that, as a matter of policy, no record of those debates was kept. We are made aware of the scientific impact of what Edward Forbes (p. 206) styled "that ill-paid enthusiastic band of peripatetic savants" — the first officers of the Geological Survey, whose advent marked the end of the reign of the gentleman specialist in geological mapping (p. 216). We are enabled to sympathize with Salter, the fossil collector, trapped at the heart of the Cambrian-Silurian controversy and striving desperately to please both its protagonists (p. 280).

In so wide-ranging a work, there are inevitably questionable statements and arguable opinions. The Geological Society of London was not "the first specialist society devoted to the mineral structure of the globe" (p. 14): that honour belongs in England to the British Mineralogical Society, established in 1799, and there are other claimants to it from elsewhere in Europe. The higher degree of refinement of later stratigraphical divisions, as compared with those of the Paleozoic, surely depends more on extent of outcrop, richness of fossil assemblages, and accessibility to major urban centres than to "the man-centred vision of the Victorians" (p. 35).

Moreover, the treatment of Murchison seems to me unduly kid-gloved. The author recognizes that his "social standing in science and the world at large gave him unparalleled power within the natural history community" (p. 269), but is inclined to exonerate him from any abuses of that power and to dismiss any accusations to the contrary (p. 270). One has only to read of Murchison's manipulations in the Devonian affair, and in particular of his treatment of poor de la Beche, to have this gentle judgement irrevocably vitiated.

In preparing such a work, each author must choose his own path of writing. Whilst admiring the lucid summary diagrams and careful footnotes, I would personally have preferred more direct quotations from letters and writings of Murchison and Sedgwick. The few that are presented do not serve adequately to fill out one's picture of the two principal protagonists in this memorable dispute. I would also have preferred closer paragraphing; single paragraphs that extend over more than a page (*e.g.*, p. 15-17) are a decided deterrent, to this reader at least.

In contrast, one can have nothing but praise for the masterly overview of a complex controversy presented in these pages. This work is certain, and fully deserves, to become a classic in the history, not merely of stratigraphy, but of science in general.

Sponges of the Burgess Shale (Middle Cambrian), British Columbia

By J. Keith Rigby
Palaeontographica Canadiana No. 2
Geological Association of Canada/Canadian Society of Petroleum Geologists
105 p., 1986; $25.00, paper

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There are now two landmark monographs on Cambrian sponges. The first by Charles D. Walcott was published in 1920; the second by Keith Rigby has recently appeared as *Palaeontographica Canadiana* Monograph No. 2. Both describe the sponges from the Middle Cambrian Burgess shale of British Columbia, along with a few sponges of the same age from elsewhere. Because the fauna is the same and both authors are, or were, outstanding authorities on the group, Rigby's monograph provides an excellent demonstration of just how far fossil sponge research has developed in 66 years.

Taxonomically, it is remarkable how well Walcott's species withstood Rigby's scrutiny. Excluding *Chancelloria* (which is no longer considered to be a sponge), 26 of the 27 British Columbia species described by Walcott are retained, 21 of them with the same generic name. The big change is in the much greater knowledge of early Paleozoic sponges in 1986 compared to 1920. Rigby grasps the opportunity to review reported occurrences of sponges in both the late Precambrian and the Cambrian. He then shows how the three sponge classes represented in the Burgess shale, Demospongea, Hexactinellida and Calcarea, may have evolved through the Cambrian, or for the last, through the Paleozoic. The text-figures of the evolution of the demosponges and hexactinellids are illustrated with elegant line drawings by Rigby, so are both the scientific and artistic expression of the author's expertise. They, and the other line drawings scattered through the text and taxonomic descriptions are some of the highlights of the monograph. Altogether, the review of the Precambrian and Cambrian sponges, the suggested evolution of sponges through the Cambrian and the Paleozoic, and the taxonomic descriptions are a tour de force by Rigby and present a clear picture of the state of knowledge of early Paleozoic sponges in 1986.

Regrettably, there are flaws in the monograph, and like the nursery rhyme about the little girl who had a little curl right in the middle of her forehead, when the monograph is good, it is very, very good, but when it is bad, it is horrid. The plates are strikingly bad, mostly very dark and with little contrast. Even Walcott's 1920 plates, which he routinely had touched up with ink, are better. Rigby's monograph is also comparable to Walcott's in the lack of a summary of which sponges occur in the Burgess shale (described correctly as a lentil in the first line of the abstract), and which ones occur elsewhere in the Stephen Formation. Indeed, from the title of the monograph, one would think that all of the sponges described occurred in the Burgess shale. In fact, 6 species and 4 genera described in the monograph do not occur in the Burgess shale at all; one of the them occurs in Alberta, and another occurs in a different Formation (Mt. Whyte). As a consequence, an accurate list of the sponges that occur in the Burgess shale has still to be published. And what of *Chancelloria*? This most spectacular of Walcott's sponges from the Burgess shale has disappeared into a metazoan limbo, and does not appear in Rigby's monograph, or even in the faunal list at the back of Whittington's 1985 book on *The Burgess Shale*.

In spite of these major flaws, Rigby's monograph is still the best study of Cambrian sponges ever published. It should be in the library of every institution where paleontology is taught, and in the personal library of all students of early Paleozoic life. Its reasonable price should encourage this.