Book Reviews / Critique

Book Reviews

Dinosaur Extinction: Sudden or Slow, Cataclysmic or Climatic?

[Essay Review of
Dinosaur Extinction and the End of an Era. What the Fossils Say]

By David Archibald
Critical Moments in Paleobiology & Earth History Series, New York Columbia University Press 1996, xviii + 237 p.

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There was a time when scientists, seeking to explain the Earth and its features, erected vast edifices of theory upon the most insubstantial of factual foundations. The chisels of Lyellian common sense have long been chipping away at the bases of those speculative edifices undermining most of them and replacing them with more solidly based scientific structures. It is only for the public at large that the wild concepts of such persons as Immanuel Velikovsky and Erich von Däniken, or the determinedly limited visions of such scripturally blinkered Creationists as Duane Gish, retain any strong appeal: moreover, the appeal is made to their imaginations, not to their sense of logic. We scientists nowadays refrain from such imaginings, don't we?

In general, the answer is "Yes," but there remains one scientific topic which, it seems, causes us to cast aside logical analysis and allow our imaginations to take flight. That topic is the extinction of the dinosaurs. The literature on this theme is becoming enormous; the most comprehensive survey, by Tokaryk *et al.* (1992), already requires a very sizeable supplementation.

It is a theme that has evoked strong feelings and much misunderstanding. On an early page of the book that stimulated this essay, Archibald describes the present situation very clearly:

> Misinformation abounds concerning the disappearance of dinosaurs. A partial explanation for this abundance of confusion is that many people have offered their opinions with little or no knowledge of dinosaurs. I am not sure why this is the case, but much of the ad hoc theorizing seems to come from the widespread perception that no great knowledge of these creatures, their environment, or their contemporaries is necessary to proffer a hypothesis for their demise.
>
> Physicists would no doubt cast a jaundiced eye upon the newest theories of quantum physics published by biologists. Yet expert opinion about the demise of the dinosaurs is apparently off-limits to no one. I know of no other area of science that engenders such a plethora of published speculation. Consider: in one year two of the most prominent semipopular journals in science, *American Scientist* and *Scientific American*, published three articles purportedly about dinosaur extinction. All three articles included the word "dinosaur" in the title, or at least mentioned them in the first and last paragraphs. But none offered more than passing treatment (if that) of dinosaur biology or their extinction. It is even more telling that vertebrate paleontologists wrote none of these articles. No wonder there is considerable confusion in the scientific and popular literature on dinosaur extinction. (p. 12)

The consequence has been a ballooning of extinction theories, many having only the most meagre of attachments to any stratum of facts. In an entertainingly wry analysis, Alan Charig (1993) identified some 90 such theories, yet he concluded:

> I have gradually come round to the opinion that the abundant extinctions near the Cretaceous–Tertiary boundary are no different in kind from the countless other extinctions that have been taking place on the planet since the beginnings of life and throughout evolutionary history... They seem to represent nothing more than a high concentration of events which, in other respects, conform to the normal pattern; they are largely due to the selection pressure produced by the continual changes in every aspect of the total environment. (p. 314)

I quote Charig at length since Archibald seems unaware of his paper, or of the earlier works by Hoffman (1989) and myself (1990), which arrived at comparable conclusions. Yet, had Archibald known of our writings, they would surely have pleased him, since our conclusions so largely mirror his own.

The first basic question to be addressed must be: are the dinosaurs truly extinct? To that matter, Charig (1993, p. 300-302) gave fullest consideration, examining at length the claims that dinosaurs have been observed in various areas of the globe during the present century. However, he indicated a proper distrust of all of them. Although we contemporary scientists may disagree on many matters concerning dinosaurs, we do at least all agree that, yes, they are indeed extinct.

It is on the other questions that there is disagreement. First of all, when did the dinosaurs actually *become* extinct? This is not so easy a question to answer, for the available evidence is so limited. There is, of course, an excellent series of outcrops in eastern Montana that has been very carefully examined, and with good reason since, as Archibald writes:

> It is without question the most important region for the study of vertebrates at the K/T boundary. It holds that honor, however, only because there are no contend-

> ers. The Hell Creek Formation is the *only* place in the world where we have a reasonable sense of what happened to vertebrates through the K/T boundary. (p. 8)

This is not altogether true, for there are outcrops traversing the boundary in Alberta (Srivastava, 1994) and Saskatchewan. However, all fall within a geographically quite tightly circumscribed area of North America. Other terrestrial sections traversing the boundary may be discovered in the future (quite probably in central or eastern Asia) but, for the moment, we are afforded only a very limited peephole into that period of the past.

Archibald indicates (p. 17) his justified distrust of supposedly Early Tertiary records of dinosaurs. As matters stand, the latest reliable record of dinosaurs we have is from the late Maastrichtian; that is, for the latter part of the latest stage of the Cretaceous System. Moreover, both in Montana and in western Canada, the latest dinosaur bones are found significantly *below* the Cretaceous–Paleocene boundary (Archibald, *op. cit.*, p. 42-45; Lerbekmo *et al.*, 1979; Srivastava, 1994). However, evidence from one single region does not justify the conclusion that the dinosaurs suffered a synchronous worldwide extinction. If we used only North American evidence, we would surely conclude that the marsupials became extinct worldwide during the earliest Tertiary, but, of course, they flourished long afterward in South America, even spreading northward in the Neogene as far as southern Canada. Moreover, they remain highly varied in Australia, despite the ecological disaster caused by white settlement. Might the dinosaurs likewise have lingered much longer, in isolated situations or in especially favourable environments: the Amazon or Congo basins, for example? Such meagre geological evidence as we have does not enable us to answer that question. However, it is certainly insufficient to justify the assumption that the dinosaurs faded out worldwide during a single, brief interlude of time.

Another common belief is that the dinosaurs were a flourishing group until brutally and brusquely eliminated, while still in their prime, by some extraterrestrial catastrophe. That is a concept almost universally accepted by the public at large and beloved of journalists. It has been embraced so enthusiastically by some scientists as to become an article of faith. The gathering in Houston in February 1994, billed as a "conference on New Developments Regarding the K/T Event and Other Catastrophes in Earth History," was so evidently slanted in view that doubters like myself did not attend, knowing that we would be as welcome as militant atheists at one of Billy Graham's crusades. The few dissenters who did bravely attend, and dared to raise their voices in opposition, were referred to scornfully by one "convert," Peter Ward (1995), as a "dream team of Charles Officer, Gerta Keller, Norm McLeod and a cast of foreign *eminences grises*." Quite clearly, he considered the opinions of "foreigners" to be much less acceptable than those of good red-blooded Americans! Like (I would suspect) other attendees, Ward confused their rejection of impact by an extraterrestrial body as a cause of extinction with a rejection of impact as an event. Yet, of course, the two questions are quite separate and will be discussed separately in the paragraphs which follow.

Did the dinosaurs indeed plunge from abundance, numerically and taxonomically, to entire extinction within a short space of time (days, weeks, a decade, or a few decades)? Not so. As Archibald carefully and judiciously demonstrates (*op. cit.*, p. 33, 110, 112; Hurlbert and Archibald, 1995) and as Sloan (1985), Williams (1994) and others have independently demonstrated, evidence from earlier Cretaceous strata indicates that the dinosaurs were in progressive decline. Their paleontological record shows them to have been a group becoming ever more ripe for extinction.

A third point, and surely the most cogent argument against any cataclysmic event as cause for dinosaur extinction, is the fashion in which most other terrestrial and marine groups crossed the K–T boundary virtually unscathed. The crocodiles and birds — the two groups closest to the dinosaurs — were vigorously evolving right across the boundary and, in the Hell Creek Area, show no faunistic changes (Bryant, 1989). The champsosaurs, although an archaic group, not only suffer no extinctions (Archibald, p. 104, 106) but even become larger and more numerous (Bryant, 1989). Of seven families of Late Cretaceous lizards, six continued to flourish in the Tertiary (p. 102), while modern groups of turtles were already appearing below the boundary (p. 100). The fossil records of freshwater fishes, whether elasmobranchs or actinopterygians, show no significant extinctions (p. 86-91), nor do those of the amphibians (p. 92, 94; see also Bryant, 1989). Pterodactyls do indeed fade from the fossil record at the end of the Cretaceous, but then, as Wellnhofer (1991) has shown and Archibald notes (p. 114-115), they were already in deep decline. Dale Russell's suggestion (1976), that no terrestrial vertebrates larger than 25 kg survived into the Paleocene, has been explicitly contradicted by Bryant's analysis (1989, p. 88), which demonstrates that crocodiles of larger size certainly did survive!

The question of plant extinctions, at or about the K–T boundary, is somewhat harder to resolve and is discussed at length by Archibald (p. 175-176, 196-197). Yes, there were changes, as Sweet and Braman (1992) and as Srivastava (1994) have shown, but these merely mirror the environmental shifts caused by a marine regression and consequent climatic deterioration. Moreover, those changes are essentially confined to middle latitudes; in the southern hemisphere and in high latitudes, no significant shifts in floras have been observed. Sweet and Braman (1992) also concluded that the Early Paleocene floras were still in a transitional state from those of the Maastrichtian, observing that:

> It is not until after an interval from 3 to 14 m above the K-T boundary, which may represent a duration of at least 100,000 years... that a final shift occurs to a palynoflora typical of the remainder of the early Paleocene. [The] single impact scenario hypothesis cannot be correct. (p. 73)

Archibald does not discuss the insects, but they can give little comfort to the believers in a catastrophic extinction. All the major living orders had come into existence by the end of the Cretaceous, even the Lepidoptera (Sarjeant, 1990, p. 104). Such frail creatures should surely have been ready victims to any such terrestrial disaster, yet they survived unscathed!

In the marine realm, three principal extinctions have been traditionally advanced as evidence for a cataclysm: those of the ammonites, the belemnites, and the marine reptiles. The ammonites were certainly in decline during the later Cretaceous, as Taquet has demonstrated graphically (1993, fig. 9), yet, as Peter Ward has pointed out (quoted by Archibald, p. 183), they may well have survived into the Paleocene, a conclusion endorsed by W.J. Zinsmeister and R.M.

Feldmann (1994). The belemnites gain no mention from Archibald, however, W.A. Cobban (quoted in Sarjeant, 1990, p. 103) has indicated that only one family still survived in the late Maastrichtian, and may well have continued to survive into the Eocene! The marine turtles passed the boundary unscathed; the other marine reptiles of the Late Cretaceous (mosasaurs and elasmosaurs) were dependent on cephalopod food and were suffering from increasing competition from the sharks, so their decline to extinction was predictable. Its exact date, though, is again unclear.

The principal groups of marine fishes — actinopterygians and elasmobranchs — show no changes at the K–T boundary (Archibald, p. 90) and even the coelacanths, although fading from the fossil record at this time, certainly survived it. Of the bivalves, the characteristically Cretaceous inoceramids were gone before the Maastrichtian and the rudistids were in deep decline during that time. In general, though, bivalve extinction patterns about the boundary were, according to Jablonski and Raup (1995), quite normal and did not differ in the various depth zones. Archibald discusses these (p. 184), but his analysis of the other marine groups is less thorough; interested readers should instead consult Hoffman (1989) or my own earlier paper (1990, p. 104). However, it seems that although there were indeed extinctions among brachiopods, arthropods and echinoderms around the time of the K–T boundary, these were not of so abnormal a magnitute as to require explanation by some catastrophic event.

Among microfossils, the foraminifera have been given greatest attention in the extinction debate. It has been suggested by Smit (1982) and others that the planktonic foraminifera, at least, suffered a sudden mass wipe out. Archibald discusses this at length (p. 186-190), but considers the evidence they present to be too equivocal to give any clear-cut support for a mass extinction An equally prominent group of zooplankton, the radiolarians, show no changes at the boundary (Archibald, p. 195). Neither do the dinoflagellates, as I have noted earlier (1990, p. 104-105); indeed, as was apparent from several papers presented at the International Palynological Congress in Houston, Texas, during June 1996, Late Cretaceous dinoflagellate cysts are virtually indistinguishable — especially at high latitudes — from Paleocene asemblages. It has been claimed that the calcareous nannoplankton may furnish evidence of serious decimation (Smit and Hertogen, 1980), but do they? Archibald gives them only passing mention, while Hoffman (1989, p. 28) presents good reasons for concluding that the coccolith and planktonic foraminiferal extinctions were not synchronous. All in all, the evidence from marine microfossils is, at best, highly contradictory and does not support the concept of a cataclysmic cause.

Well then, we have seen the extreme geographic circumscription of data concerning the timing of dinosaur extinction and we have also seen how meagre were the reflections of this so-called "great extinction event" among the numerous other groups of organisms, represented as fossils around the K–T boundary. The remaining question is: was there indeed an "extraterrestrial event" at that time — the impact upon Earth of an asteroid or a large meteorite — as Alvarez and his associates proposed (Alvarez *et al.*, 1980), or a succession of comet showers, as Hut *et al.* (1987) hypothesized?

Nowadays, the iridium layer is so well documented that it has been tacitly accepted internationally as marking the actual Cretaceous–Tertiary boundary. However, as Hoffman has shown (1989, p. 29), it is not an unequivocal indication of extraterrestrial impact. First of all, there is not always a precise iridium "spike," but quite often, instead, a broad iridium-enriched zone. Second, both phenomena can be explained by terrestrial causes: in particular, the so-called "Deccan traps" volcanic episode of the late Maastrichtian. This episode has been discussed at length by McLean (1982; 1985b), who suggested that it may have produced effects sufficient to account for the elimination of the calcareous microplankton (McLean, 1985a, c) and to adversely affect terrestrial fauna worldwide (McLean, 1988). Certainly such a volcanic episode is likelier to have produced long-term effects than any impact.

Another problem with the concept of an extraterrestrially induced cataclysm, as case for a mass extinction, is the gap (most notably in the Hell Creek section) between the last evidences of dinosaurs and the iridium "spike." Although, in his discussion of the problem it presents, Archibald generously points out (p. 47) that the intervening strata are low in fossils, this gap needs to be explained by the neocatastrophists. While the time duration it represents is hard to quantify, it is likely to have been longer than, let us say, the interval between the dying of the last mammoth and that comparable happening, the dropping of the atomic bombs on Japan. Indeed, for my part, I consider that any extraterrestrial impact is quite as unlikely a cause of dinosaur extinction as is nuclear attack for the extinction of the mammoths!

In his final assessment of that hypothesis, Archibald is somewhat more generous (p. 204-206). He believes the proximate cause of dinosaur extinction to have been environmental change, triggered (in North America, at least) by the dwindling and drying-up of the midcontinental Cretaceous seaway, with its consequent effects on terrestrial habitats. This concept is supported by the work of Sweet and Braman (1992) and Srivastava (1994), as cited earlier. Moreover, both Taquet (1993) and Barrera (1994) have presented evidence of major changes in terrestrial climate and in ocean temperature and chemistry during the early to late Maastrichtian, with the latest Cretaceous coolest. This work firmly contradicts the neocatastrophists' concept of an environment that was stable right up to the boundary.

An accessory cause that Archibald cites, and which was earlier advanced by Sloan (1976), Van Valen and Sloan (1977), and Sloan *et al.* (1986), may have been the growing competition, in this changing environment, of the early ungulates. Van Valen and Sloan (*op. cit.*) indeed demonstrated the presence of bones of *Protungulatum* in strata only a few metres above the last dinosaur remains: almost as close as that iridium layer!

Nevertheless, in his final assessment, Archibald veers toward the catastrophists, accepting the evidence for meteorite impact at Chicxulub in the Yucatán Peninsula of Mexico and hypothesizing that:

> Material ejected into the upper atmosphere formed a cover of darkness, screening out the sun to the point that photosynthesis ceased or diminished for many weeks, depending upon location. The effects were especially acute at lower latitudes and closer to the impact, such as in North America. Low-latitude plants, unaccustomed to lower light regimes caused by seasonal changes in sunlight, were especially hard hit. Higher

> latitude plants, accustomed as they were to seasonally lower light regimes, survived much better — as did the animals that fed upon them. (p. 206)

Well, maybe such an impact might indeed have wiped out the local North American dinosaur fauna (although not, it seems, seriously affecting most other terrestrial organisms), but is there any good cause for supposing that it had truly world-wide effects? Archibald discusses the possible global consequences — tsunamis (p. 132), acid rain (p. 140), and wild fire (p. 141) — but gives excellent reasons for rejecting them all. Moreover, as he notes (p. 190) and as subsequent researches have emphasized, we have no evidence of high-latitude extinctions.

Certainly the present evidence is too meagre, even for us to be sure when the dinosaurs became extinct in North America, let alone elsewhere in the world. Data obtained only from a limited area of North America is much too insubstantial a basis for deciding the date of the event. It is altogether inadequate for the sweeping conclusions drawn by other scientists — most often, be it said, physicists and geophysicists — that there was a universal cataclysm at the end of the Cretaceous. We can only trust that new localities will be discovered, from which fresh evidence will be forthcoming.

In the meantime, I urge you to read this book as the most thorough delineation so far of this particular arena of scientific speculation. I urge you also to ignore the protestations of the neocatastrophists and to maintain a healthy scepticism concerning not only the causes, but even the eventual date, of dinosaur extinction.

REFERENCES

Alvarez, L.W., Alzarez, W., Asaro, F. and Michel, H., 1980, Extraterrestrial cause for the Cretaceous-Tertiary extinction: Science, v. 208, p. 1095-1108.

Barrera, E., 1994, Global environmental changes preceding the Cretaceous-Tertiary boundary: early-late Maastrichtian transition: Geology, v. 22, p. 877-880.

Bryant, L.J., 1989, Non-dinosaurian lower vertegrates across the Cretaceous-Tertiary boundary in northeastern Montana: University of California Publications in Geological Sciences, Berkeley, Los Angeles, Oxford, v. 134, xii + 98 p.

Charig, A.J., 1993, Disaster theories of dinosaur extinction: Modern Geology, v. 18, p. 299-318. [Republ., *in* Sarjeant, W.A.S., ed., Vertebrate Fossils and the Evolution of Scientific Concepts: Gordon & Breach, Reading, England, p. 309-328.]

Hoffman, A., 1989, Mass extinctions: the view of a sceptic: Geological Society of London, Journal, v. 146, p. 21-36.

Hurlbert, S.H. and Archibald, J.D., 1995, No statistical support for sudden (or gradual) extinction of dinosaurs: Geology, v. 23, n. 10, p. 881-884.

Hut, P.W., Alvarez, W., Elder, W., Hansen, T., Kauffman, E.G., Keller, G., Shoemaker, E.M. and Weiserman, P., 1987, Comet showers as a cause of mass extinctions: Nature, v. 329, p. 118-126.

Jablonski, D. and Raup, D.M., 1995, Selectivity of end-of-Cretaceous marine bivalve extinctions: Science, v. 268, p. 389-391.

Lerbekmo, J.F., Singh, C., Jarzen, D.M. and Russell, D.A., 1979, The Cretaceous-Tertiary boundary in south-central Alberta — a revision based on additonal dinosaurian and micro-floral evidence: Canadian Journal of Earth Sciences, v. 16, p. 1866-1869.

McLean, D.M., 1982, Deccan volcanism and the Cretaceous-Tertiary transition scenario: a unifying causal mechanism, *in* Cretaceous-Tertiary extinctions and possible terrestrial and extraterrestrial causes II: National Museum of Natural Sciences, Syllogeus, v. 39, p. 143-144.

McLean, D.M., 1985a, Mantel degassing unification of the trans- K–T geobiological record: Evolutionary Biology, v. 19, p. 287-313.

McLean, 1985b, Deccan Traps mantle degassing in the terminal Cretaceous marine extinctions, Cretaceous Research, v. 6, p. 235-259.

McLean, D.M., 1985c, Mantle degassing induced dead ocean in the Cretaceous–Tertiary transition, *in* Sundquist, E.T. and Broecker, W.S., eds., Carbon cycle and atmospheric CO_2: natural variations Archean to Present: Geophysical Monograph, v. 32, p. 493-503.

McLean, D.M., 1988, K–T transition into chaos: Journal of Geological Education, v. 36, p. 237-242.

Russell, D.A., 1976, Mass extinctions of dinosaurs and mammals: Nature Canada, v. 5, p. 18-24.

Sarjeant, W.A.S., 1990, Astrogeological events and mass extinctions: global crises or geological chimaerae?: Modern Geology, v. 15, p. 101-112.

Sloan, R.E., 1976, The ecology of dinosaur extinction: Athlon, Life Sciences Miscellaneous Publications, Royal Ontario Museum, p. 134-154.

Sloan, R.E., 1985, Gradual extinction of latest Cretaceous dinosaurs in the Hell Creek Formation, McCone County, Montana: Geological Society of America and Associated Societies, Rocky Mountain Section, Boise, Idaho, Paper 72269, 2 p.

Sloan, R.E., Rigby, J.K., Jr., Van Valen, L.M. and Gabriel, D., 1986, Bradual dinosaur extinction and simultaneous ungulate radiation in the Hell Creek Formation: Science, v. 232, p. 629-633.

Smit, J., 1982, Extinction and evolution of planktonic Foraminifera at the Cretaceous/Tertiary boundary after a major impact, *in* Silver, L.T. and Schultz, P.H., eds., Geological Implications of Impacts of Large Asteroids and Comets on the Earth: Geological Society of America, Special Paper, n. 190, p. 329-352.

Smit, J. and Hertogen, J., 1980, An extraterrestrial event at the Cretaceous–Tertiary boundary: Nature, v. 285, p. 198-200.

Srivastava, S.K., 1994, Palynology of the Cretaceous–Tertiary boundary in the Scollard Formation of Alberta, Canada, and global KTB events: Review of Palaeobotany and Palynology, v. 83, p. 137-158.

Sweet, A.R. and Braman, D.R., 1992, the K–T boundary and contiguous strata in western Canaa; interactions between paleoenvironments and palynological assemblages: Cretaceous Research, v. 13, p. 31-79.

Taquet, P., 1993, Les dinosaures, grandeur et décadence: La Vie des Sciences, C. r. Acad. Scie., Paris, sér. gen., v. 10, n. 4, p. 265-284.

Tokaryk, T.T., Storer, J.E. and Nambudiri, E.M.V., 1992, Selected bibliography of the Cretaceous–Tertiary boundary event, through 1989: Saskatchewan Museum of Natural History, Regina, Canada, Contributions Series, n. 11, 140 p.

Van Valen, L. and Sloan, R.E., eds., 1977, Ecology and the extinction of the dinosaurs: Evolutionary Theory, v. 2, p. 37-64.

Ward, P., 1995, The K/T trial: Paleobiology, v. 21, p. 245-247.

Wellnhofer, P., 1991, The illustrated encyclopedia of Pterosaurs: Salamander Books, London, 192 p.

Williams, M.E., 1994, Catastrophic versus noncatastrophic extinction of the dinosaurs: testing, falsifiability, and the burden of proof: Journal of Paleontology, v. 68, n. 2, p. 183-190.

Zinsmeister, W.J. and Feldman, R.M., 1994, Antarctica, the forgotten stepchild: a view of the KT extinction from the high southern latitudes: Lunar & Planetary Institute, contribution n. 825, p. 134-135.

Géologie de la réserve faunique de Papineau-Labelle- Si la Terre m'était contée...

par Pierrette Tremblay, Louise Corriveau et Robert-André Daigneault,
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Je me souviens avec beaucoup de plaisir des premiers affleurements visités sur le terrain lors de ma première année d'étude au département de géologie de l'Université de Montréal; la visite de l'intrusion du Mont-Royal, les dépôts sédimentaires de la mer de Champlain, et les calcaires de l'Utica parmi d'autres. Ayant atterri en géologie un peu par hasard, j'avais la vocation un peu vacillante au départ et c'est sans doute ces visites et les premiers emplois d'été sur le terrain qui contribuèrent le plus à me faire persévérer dans cette voie. Une des plus mémorable de ces visites fut certainement la collecte de minéraux aux pourtours d'un des rares gisements miniers de la Province géologique de Grenville, la mine d'or de Montauban. Cette localité riche en pegmatites et autres roches de haut grade métamorphique, recelle de superbes spécimen minéraux. Je me souviens de l'excitation de toute la classe, certains ramenant des cristaux de phlogopite de 10 cm de dia-mètre, ou d'autres ayant trouvé de fins cristaux de quartz ou de sphalérite, et que dire des semaines suivantes passées à identifier les échantillons les plus difficiles. Peu d'autres sciences que la géologie peuvent susciter une vocation scientifique avec des outils aussi simples qu'une loupe, un marteau et une carte. Le malheur, c'est que bien que les roches intéressantes ne manquent pas au Canada, peu de cartes et livrets d'excursions sont orientés vers le grand public. La carte et le livret décrits ici sont de ce type et ils portent justement sur des roches de la Province de Grenville.

Quelques intéressants livrets et cartes-guides géologiques pour le grand public sont apparus ces dernières années, en langue française. Ces ouvrages-guides ont l'avantage d'amener le lecteur sur des sites intéressants du point de vue géologique où il pourra observer directement des phénomènes géologiques à différentes échelles, des affleurements montrant des fossiles, des minéraux attrayants, etc... L'ouvrage de Tremblay *et al.* poursuit dans la même veine, en s'attardant sur la région de la réserve faunique de Papineau-Labelle, située dans la région de l'Outaouais du Québec, où on observe des roches metamorphiques et ignées vielles de plus d'un milliard d'années. C'est là un excellent prétexte pour faire apprécier la grande diversité de la science géologique aux personnes qui en sont peu familières.

La carte-guide et le livret d'accompagnement montrent une présentation graphique stylisée et soignée, qui saura attirer l'attention des jeunes lecteurs car riche en photographies (affleurements, roches, minéraux, géologues au travail) et diagrammes. La carte-guide contient toute l'information nécessaire pour prendre part à des excursions de la géologie de la réserve faunique Papineau-Labelle, à partir de circuits au noms évocateurs (Circuits des collectionneurs, de la muraille, du chevreuil, des voyageurs et autres).

Le livret est une série de courtes présentations visant à initier le lecteur au concepts fondamentaux de la géologie (minéralogie, pétrologie ignée, metamorphique et sédimentaire, géologie historique, géochronologie, télédétection, techniques d'observation sur le terrain, tectonique des plaques, etc...). Ces présentations occupent près des 2/3 du livret, ce qui ne laisse que peu de place pour des descriptions portant strictement sur la géologie de la réserve faunique de Papineau-Labelle. Ces descriptions sont toutefois bien documentées et intéressantes, par exemple celle de la Brèche de Rivard, un diatrème découvert pendant les récents travaux d'une des auteurs.

En résumé, il s'agit là d'un des rares ouvrages de vulgarisation de la géologie disponible en langue française, qui sait informer de façon intéressante les jeunes et moins jeunes même sans visiter le terrain. Mais comme c'est l'intention des auteurs, il faut toutefois espérer que cet ouvrage saura aussi inspirer les parents et éducateurs férus de science et les inviter au plein-air en compagnie de quelques jeunes. Comme tout géologue le sait bien, rien ne vaut une bonne journée sur le terrain pour attiser l'excitation scientifique et faire de belles découvertes.

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I remember with much pleasure my first visit to outcrops in the field, while enrolled in my first year at the Department of Geology of Université de Montréal: the Mont-Royal intrusive, the sedimentary deposits of the Champlain sea, and the Utica limestones amongst others. Having landed in geology a bit by accident, my calling was a bit unsteady to begin with and it is without doubt these visits and the first student summer jobs doing field geology that contributed most to keeping me going on this path. One of the more noteworthy of these visits was surely the mineral hunt on the periphery of one of the rare mines of the Grenville

geological Province, the Montauban gold mine. This locality, rich with pegmatites and other rocks of high-grade metamorphism, harbours superb mineral specimens. I recall the excitement of all my classmates, some bringing back phlogopite crystals 10 cm across, or others having found fine quartz or sphalerite crystals, not to forget the following weeks spent identifying the more difficult samples. Few other sciences but geology can give rise to a scientific vocation with tools as simple as a handlens, a hammer and a map. Unfortunately, although interesting rocks abound in Canada, too few maps and field guidebooks are targetted toward the general public. The map and booklet described here belong to this type of work and pertain precisely to some rocks of the Grenville Province.

A few interesting guidebooks and related maps for the general public have appeared in recent years in the French language. These guides have the advantage of bringing the reader to interesting sites, where he can observe directly geological phenomena at different scales, some outcrops showing fossils or minerals. The guide of Tremblay *et al.* carries on this path, and centres on the Papineau-Labelle wildlife reserve area, situated in the Outaouais area of Quebec, where are exposed metamorphic and igneous rocks more than a billion years old. Here lies an excellent pretext to make the great variety of geosciences appreciated by people unfamiliar with the field.

The booklet and accompagnying map show a stylish and polished graphic presentation that will attract the attention of young readers, being rich in photographs (outcrops, minerals, geologists at work) and diagrams. The guiding map contains all the information necessary to participate in geological excursions in the Papineau-Labelle wildlife reserve, starting from circuits with evocating names (Collector's, Barrier, Deer, Voyageurs and other circuits).

The booklet is a series of short presentations aiming to introduce the reader to fundamental concepts of geology (mineralogy, igneous, metamorphic and sedimentary petrology, historical geology, geochronology, remote sensing, field observation techniques, plate tectonics). These presentations make up 2/3 of the booklet, which leaves little room for descriptions dealing strictly with the geology of the Papineau-Labelle reserve. Nonetheless, these descriptions are well documented and interesting, for example the one dealing with the Rivard Breccia, a diatreme discovered during the recent studies of one of the authors.

In summary, this is one of the few popular works about geology available in the French language, that will inform in interesting ways, young and not so young, even without going to the field. However, as is the intention of the authors, we shall hope that this small guide will give some inspiration to parents and teachers interested in science and will invite them outdoors in the company of youngsters. As every geologist knows so well, there is nothing like a good day in the field to stir up scientific excitement and make beautiful discoveries.

Salt Tectonics: A Global Perspective

Edited by M. P. A. Jackson, D. G. Roberts and S. Snelson
American Association of Petroleum Geologists, Memoir 65
1996, 454 pages, US$119.00

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If you work in the oil industry and need an up-to-date overview of salt tectonics you cannot afford to overlook AAPG Memoir 65 and its transatlantic namesake referred to below. The volume reviewed here was spawned by papers presented at the 1993 Hedberg Conference on Salt Tectonics, held in Bath, UK. It is lavishly illustrated with many colour figures and several fold-outs, is excellently edited (salt is black in many cross sections) and is unusually well cross-referenced.

The emphasis is on the large scale aspects of salt tectonics, as documented by reflection seismic data in areas of active hydrocarbon exploration within the orbit of US-based oil companies. There are no papers dealing with the internal fabrics of salt bodies, nor any that provide detailed information about classic regions such as England, Germany, Romania, the Alps, North Africa and Iran, where many of the early halokinetic concepts were generated. Moreover, the volume contains only limited discussions of modelling. However, by a happy coincidence, most these deficiencies are more than adequately addressed in another 1996 publication, also entitled "Salt Tectonics," issued by the Geological Society of London (Special Publication 100) and edited by G.I. Alsop, D.J. Blundell and I. Davison (£66.00). There is essentially no overlap and, between them, the two books provide an authoritative overview of our current understanding of halokinetic phenomena.

AAPG Memoir 65 opens with a fascinating historical overview (M.P.A. Jackson) documenting how ideas of the mechanisms and controls of subsurface salt deformation have evolved over the last 140 years. Jake Hossack emphasises how the geomechanical behaviour of salt bodies complicates section balancing, since salt can flow in and out of the plane of a section. This affects extensional regimes and is a particular problem in compressional situations, as kinematic modelling makes clear (J. Letouzey *et al.*). C.J. Talbot introduces the term "molding" to describe how the stiffness of the overburden affects the shape of a salt diapir and he develops a behavioural grid involving burial history and the ratio R/A (salt rise minus dissolution/deposition minus compaction). R.C. Fletcher *et al.* develop theoretical constraints for the emplacement of salt glaciers and present some marvellous 3-D seismic projections of the Mickey sheet offshore of the Mississippi Delta. The Cenozoic structural evolution of the Gulf Coast Margin is colourfully diagnosed by modern backstripping software (F.A. Deigel *et al.*). Implicit in the reconstructions are areally continuous basal salt sequences, sheets and canopies that diminish in volume through time, and widespread salt welds (contacts between strata originally separated by now vanished salt). F.J. Peel *et al.* discuss the intrusion of high level salt canopies and include a 3-D seismic image showing 100 square miles of near-seabed sediments that have been displaced laterally above such an allochthonous salt sheet. They, D.C. Schuster and M.G. Rowan discuss the structural style of Gulf Coast salt bodies and the kinematics of growth and deformation in chapters full of regional seismic profiles and reconstructed sections.

In the southern North Sea, east of the UK, Permian salt forms the key detachment interval underlying younger beds which are interpreted as deforming by gravity sliding (M. Coward and S. Stewart). A relationship between fold wavelength and post-salt thickness is documented. Further south, the opposite case can be made (G. Remmelts). North of the Netherlands, sub-salt basement faults appear to control the diapiric geometry. Downdip slumping and folding of sediments overlying Aptian salt characterise the Cabo Frio region offshore of Brazil in the South Atlantic (W.U. Mohriak *et al.*). Extensive horizontal shortening of the post-Aptian section occurs in the adjacent Santos Basin (P.R. Cobbold *et al.*), where syntectonic sedimentation has clearly shaped salt-cored structures. Similar basal gliding on Aptian salt is present offshore of southern Gabon on the opposite side of the Atlantic Ocean (L.M. Liro and R. Coen), but here the overlying section has extended by breaking into a series of half grablens separated by landward facing listric normal faults.

Middle Miocene salt underlies extensionally deformed sediments offshore of Yemen where it has sourced several spectacular salt canopies (R.C. Heaton *et al.*). Extensional diapirism also characterises the Prebetic foldbelt of southeastern Spain, where the control is dominantly tectonic since most of the Triassic salt bodies are associated with faults (M.J. de Ruig). In the southeastern foreland of the Pyrenees, detachment occurs above upper Eocene salt which has lubricated overthrusting (M. Sans and J. Vergés), but the structures are small compared to those of the Parry Islands foldbelt in Arctic Canada (J.C. Harrison). There, a Paleozoic succession more than 10 kilometres thick is buckled between ductile Ordovician evaporites and Devonian shales. Salt has migrated to anticlinal welts during buckling, and it is suggested that a passive roof duplex (essentially a massive triangle zone) may extend across the entire 200 km width of the foldbelt. The volume ends with two papers on halokinesis in the Nordkapp Basin of the Barents Sea (K.T. Nilsen *et al.*, H. Koyi *et al.*) for which the data sources are primarily reflection seismic profiles.

So Memoir 65 leads its readers through many spectacularly documented salt-cored structures and tectonic provinces where a major control of deformation has been the mechanical properties of salt-rich intervals. Apart from Chapters 2-5, the treatment is not heavily theoretical. Future research avenues are not explored, nor is the question of why certain buried salt sequences, such as the Prairie Evaporites in western Canada, have not become involved in halokinesis. Sadly, there is no discussion of the spectacular salt tectonics of eastern Canada. Nevertheless, the beautifully illustrated case histories contained herein are an invaluable addition to the literature and M.P.A. Jackson's elegant review of salt tectonic concepts is the best available. Even if you can't afford to buy AAPG Memoir 65, you should peruse it and also examine the Geological Society of London's complementary volume!

Principles of Precambrian Geology

By Alan M. Goodwin
Academic Press
Harcourt Brace and Company
London, San Diego, New York,
Boston, Sydney, Tokyo, Toronto
1996, 327 pages, US$54.95

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Precambrian geology has advanced rapidly over the past two decades, fuelled primarily by developments in U-Pb geochronology which provides precise age control from Precambrian sequences around the world. This explosion of knowledge has paved the way for *Principles of Precambrian Geology*, which actually contains only a few principles but is a treasurehouse of information on Precambrian rocks from all of Earth's cratons. This work represents an update and abridgement of Goodwin's 1991 book *Precambrian Geology: The Dynamic Evolution of the Continental Crust.* Both the update and abridgement are significant, including addition of the substance of 642 new references, and reduction of volume from 666 to 327 pages.

The book purposely steers clear of tectonic models in its systematic description of major rock packages that constitute Earth's nine cratons (exposed Precambrian plus buried extensions): Cathaysian, Siberian, East European, North American (with Greenland), South American, African, Indian, Australian and Antarctic. This approach produces a level playing field on which to unfold the fabric of Precambrian geology. Individual chapters on the major time divisions of the Precambrian — Archean (70 p.), Early Proterozoic (53 p.), mid-Proterozoic (41 p.), and Late Proterozoic (40 p.) — form the main substance of the book. The rock record from each time window is reviewed for every craton, providing "snapshots" in the geological evolution. Navigation through the book (and Precambrian time) is facilitated by this hierarchical structure; a disadvantage of such a time-space matrix is that correlations between sequences in apparently isolated cratons may not be obvious. This represents a missed opportunity afforded by the synthesis: not drawing out the threads that link rock sequences of similar age in isolated cratons. But the author's stated intent is to provide an inventory, not break new research ground. The book succeeds admirably in presenting information on out-of-the-way places ferreted out from both well-known and obscure literature sources; the 37-page reference list alone is a valuable resource.

The book is not exclusively descriptive. The final chapter (Evolution of the Continental Crust) delivers an overview of changes in global dynamics as recorded in geological history. Interestingly, Goodwin's views on the topic of the operation of plate tectonic processes in the Archean appear to have been swayed by Hamilton's influential 1993 DNAG paper. Contrast his 1972 "Variations in Tectonic Styles in Canada" paper on the Superior Province

> ...Archean volcanic rocks closely resemble modern island arc assemblages, particularly the more primitive ones..... A similar pattern of events operating in Archean time may have produced the volcanic-rich belts of the Superior Province. (p. 608)

with his 1996 remarks

> ...much of Archean magmatism-tectonism may be better explained by models of voluminous magmatism, such as expressed by plume-generated phenomena, including great upwellings in the form of lava lakes and magma oceans. (p. 276)

In Goodwin's view, the Archean-Proterozoic boundary marks the most profound change in Earth's evolution, from rapid crust-forming events in the late Archean (whatever their cause), to voluminous accumulations of banded iron formation in the Early Proterozoic, reflecting an increasingly oxygenic atmosphere and hydrosphere. Although some elements of the Early Proterozoic record resemble the products of modern processes, it is not until the Late Proterozoic that Goodwin finds sufficient evidence to conclude that plate tectonics, as we know it, was active. Discerning style changes in the Precambrian rock record through time and interpreting their underlying thermal and dynamic causes are currently active areas of research in early Earth evolution.

It is hardly worth mentioning the few curious features of the book. One is adherence to Stockwell's time division of the Proterozoic (Aphebian, Helikian, Hadrynian) in description of the Precambrian of Canada. Although entrenched in the literature, these local terms have equivalents in the early, mid and late (Paleo-, Meso-, Neo-) Proterozoic designations and appear unnecessary, particularly in light of the quantity of precise geochronology available for units throughout this craton.

Overall, I found the book to be an informative, well organized distillation of the substance of Precambrian geology. It is relatively free of typographical errors and easy to read, including all of the line drawings and tables. A challenging goal in undertaking a review of the scope of *Principles of Precambrian Geology* is to achieve an even treatment of individual cratons and time windows, as well as between supracrustal and plutonic rock types. In assembling observations and interpretations from thousands of sources, Goodwin has presented a balanced global overview of Precambrian rocks and processes. I wish this book had been around at the time I studied for my Ph.D. comprehensive exams!

1995 Canadian Minerals Yearbook Review and Outlook

Published August 1996 by
Minerals and Metals Sector, Natural Resources Canada
softcover, 40 chapters, individually paginated
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Perhaps you know that Canada is the world's largest exporter of minerals. Did you also know that in Canada in 1995 mineral production provided 2.5% of total national employment, 4.25% of Gross Domestic Product, and 16.3% of total domestic exports, totalling over $41 billion for minerals? Or that for the past 26 years, 1970-1995 inclusive, Canada was the top destination of mineral exploration capital from worldwide sources in 14 of these years, Australia in eight years, and the United States in four years? These fascinating facts and literally thousands of others are to be found in this year's annual review of the Canadian mineral industry, compiled by staff of the Minerals and Metals Sector of Natural Resources Canada. This massive annual compendium of mineral exploration and production activity is packed with information of interest to anyone in the minerals business in Canada or abroad; in fact, to anyone interested in one of the fundamental industries underlying the growth, development and continued success of Canada as a nation. When it becomes available each August, the book provides a very complete annual snapshot of the Canadian mineral industry for the previous year. The focus is on the non-fuel mineral industry, but coal and uranium are included.

Despite the mass of information presented, the format is friendly, having evolved over a number of years. Eight introductory chapters set the stage, covering: general and regional review, Canadian reserves of selected major metals, Canadian mineral exploration activity and discovery analysis, Canadian mine openings and closings, the international scene, and a new chapter on Canada's global mining presence. This chapter is highly informative and a welcome addition, answering such questions as who is exploring elsewhere in the world, what are they looking for, how much money is being spent, who is collaborating, etc. Although many authors are involved, the writing is lucid, well-organized and illustrated, and supported by instructive tabular data. Indeed, this observation is true for the whole volume, not just the introductory chapters.

Following these eight introductory chapters, some 31 chapters deal with 37 mineral commodities, from Aluminum to Zinc. Some commodities such as antimony, bismuth, cesium, lithium, *etc.*, are combined in a specialty non-ferrous metals chapter. Non-metals covered include cement, lime, mineral aggregates, peat, coal and stone. Not all commodities are covered each year: in this volume, 18 are not covered. These are noted as being covered in earlier volumes of this series. A useful addition for future volumes would be to list the last volume in which a specific commodity not covered in this volume was covered (1993 edition, etc.). Copper, diamonds, gold, iron ore, lead, nickel, sulphur, uranium and zinc are included in this 1995 edition.

The format for each commodity varies, but generally includes an introduction, Canadian developments (by province or region where appropriate), world developments by region, consumption and uses, and outlook. The outlook sections seem to me to be particularly useful - for some commodities, opportunities virtually leap off the page to greet the reader! Commodity information is presented in narrative form with lots of sub-headings and again supported by many figures, tables and graphs, making the material easily and quickly comprehended or assessed. The last three chapters cover principal Canadian non-ferrous precious metal mine production in 1994, a broadly based statistical report, and definitions and valuation in mineral production, shipments and trade.

The mineral commodity information itself, the manner in which it is presented, and the fact that it is timely (including 1995 data, and in some cases data to April 1996), is the major achievement of the volume. Clearly, this is not a book that most people would want to read from cover to cover, but it is the quickest and easiest means I know of to obtain an understanding of the current Canadian mineral industry. Because the information is up-to-date, Voisey's Bay is here, as is diamond exploration in the Northwest Territories, new gold exploration, and the challenges to Canada's mineral industry from developments elsewhere in the world. Many countries with good mineral potential are striving to develop increasingly attractive environments for foreign investors. Although this is resulting in fierce global competition for mineral investment, the up-side for the Canadian mining industry is that opportunities are now truly global. Because the Canadian mining industry has an enviable track record, Canadian companies are well-positioned to take advantage of new global opportunities. The two chapters on the international scene and Canadian global mining presence give us a snapshot of activities and success in the global arena.

All of the information in the volume, as well as new related information on minerals, is also available by fax using the Mining FactsLine (dial 613-947-6767 from your fax phone). The information obtained in this manner is still paper copy, however. As useful as the 1995 Canadian Minerals Yearbook is, I can't help thinking what an excellent CD-ROM this material would make! The statistical data in particular are ideal for a digital format; indeed, all of the information in CD-ROM format would be even easier to access and use. This is not to criticize the volume, for it is a major achievement in its present hardcopy form. Some of these topics and more information on the Canadian minerals and metals industry are also available through the Minerals and Metals Sector's web-site home page at http://www.nrcan.gc.ca/mms/ms-home.htm.

The 1995 Canadian Minerals Yearbook is available in many libraries across Canada. It deserves to be on the desk of everyone who has any interest in Canada's mineral industry, its activities, challenges, and successes, and its prospects for the future.

Physics and Chemistry of Minerals

By Alexandra Navrotsky
No. 6 in Cambridge Topics in Mineral Physics and Chemistry
Cambridge University Press
40 West 20th Street
New York, NY 100111-4211
1994, 417 p., US$79.95 (hard cover)

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Geology departments everywhere are engaged in sometimes fierce debates over what should be taught as "mineralogy" in the undergraduate curriculum. Traditionalists urge an emphasis on hand specimen identification using macroscopic mineral properties, while revisionists (including this reviewer) believe that earth scientists of the 21st century will need to apply principles of thermodynamics, crystal chemistry, solid state physics, and surface chemistry to increasingly complex and very practical geological problems. Examples include the technology of extracting hydrocarbon from the immense reservoir of methane hydrate clathrates, the understanding of inorganic reactions controlling reservoir permeability, and the influence of mineral surface reactions on the dispersion of pollutants in the near surface environment.

Professor Navrotsky's book addresses the needs of the second group of teacher-learners. It is based on a one semester course taught to senior undergraduates and graduate students at Arizona State University and Princeton University. It is aimed at an audience with one year each of college chemistry and physics and mathematics through calculus. Rather than an exhaustive treatise on specific topics in mineral physics and solid-state chemistry, it is a introductory survey of the modern tools available to researchers in mineral science.

The introduction outlines the philosophy and organization of the text. Chapter 2 introduces the crystal chemistry concepts needed to understand the symmetry and arrangement of atoms in crystals. A substantial part of the chapter deals with the crystal structure of common rock-forming silicates. Chapter 3 deals with experimental methods for studying the microscopic structure of matter and introduces the main concepts underlying diffraction and spectroscopic techniques. The mathematical content is kept to a minimum and the practical applications of the various methods are emphasized. Methods for studying thermodynamic properties are covered in Chapter 4 and include calorimetric techniques, phase equilibrium studies, and P-V-T determinations. A return to microscopic phenomena in Chapter 5 introduces concepts from solid state physics, molecular orbital theory and Pauling's approach to chemical bonding. A glossary of quantum mechanical terminology is a boon to the beginner faced with deciphering the titles of journal papers in these fields. Chapter 6 provides a link between the microscopic and macroscopic properties of crystals with an emphasis on heat capacities and phase transitions. Solid solutions and order-disorder phenomena in crystals are discussed in Chapter 7, while melts, glasses, and amorphous materials form the subject material of chapter 8. The book concludes with a chapter on the interface between mineral physics and materials science. This chapter, at least, should be required reading for all those academics agonizing over the place of mineral chemistry and physics in a modern earth science curriculum.

The qualitative, yet thorough and rigorous approach taken in this text, together with the emphasis on earth science applications make it an enjoyable introduction to modern mineral physics and chemistry for senior undergraduate and graduate geologists. The references are extensive and up-to-date. A particularly useful touch is the separation of "General Reference and Bibliography" from "Specific References" which makes the text particularly valuable for self-education and as a guide to advanced material in the many sub-fields it addresses. As the author notes, the Reviews in Mineralogy series of the Mineralogical Society of America and the Short Course Handbook series of the Mineralogical Association of Canada represent the next level of detail on many of these topics.

This is a very worthwhile volume for both those in the midst of their geological educations and for those who seek an introductory update on the modern

theory and techniques used in the study of solid earth materials. My own copy is within an arms-length of my desk.

Raphael Pumpelly, Gentleman Geologist of the Gilded Age

By Peggy Champlin
Tuscaloosa and London
University of Alabama Press
1994, xiii + 273 p., $49.95

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One hears often of golden ages, always in the past, always impossible to place exactly into a time-frame. In the United States at least, the "Gilded Age" has in contrast a clear definition: "the post-Civil War years, when westward expansion, railroad building, and industrial growth were accompanied by almost unrestricted speculation in mines and land" (p. xii). To be sure, there had been earlier practical pioneers — in particular, from Abraham Gottlob Werner's school at the Freiberg Mining Academy in Germany — but it was during this time that geology was transformed in North America from a gentlemanly pursuit, affording only incidental opportunity for profit, into a career in which one might certainly earn a living and, given good fortune, even hope to gain real wealth. At the beginning of the century, geology had remained essentially a hobby, for persons with ample spare time and intellectual horizons extending beyond eating, drinking, sex and hunting. By its end, geology was an established scientific discipline, figuring increasingly prominently in university courses, spawning societies at whose meetings serious papers might be presented to an increasingly knowledgeable and critical audience, and having its own journals in which, if they passed muster, those papers might be published. At the beginning of the century, the world's rocks and their arrangement were virtually unknown, even in the most civilized lands; at its end, the areas still unexplored by geologists had become few and remote.

Raphael Pumpelly's life and attainments come close to epitomizing these changes. He was born in 1837 to a prominent New England family and, while in his teens, taken for scientific training to Europe. There he learned the German language in Hannover, studied geology in Paris under Charles d'Orbigny (brother of the more celebrated Alcide), and undertook a solitary and perilous journey in Corsica. During this, Pumpelly learned to endure rough conditions and gained a taste for adventure in wild places that was never to leave him. After that he was persuaded to go to Freiberg, where a number of other Americans were already ensconced. As happens so readily among students, so rarely in later life, they established enduring friendships, as well as receiving a training as mining geologists and engineers that could not be matched elsewhere. When they returned to the United States, Pumpelly went to work for the Santa Rita Mining Company in its Arizona silver mines, learning much practical metallurgy under the perilous conditions of the raw frontier. Then off he went to Japan as a mining consultant and, after that, to China.

Pumpelly's accounts of his adventures and observations gained him eminence and an invitation to work with the Michigan Geological Survey, plus lecturing opportunities at the Harvard and Columbia schools of mines when winters made field work in that state impossible. Next, he was appointed Director of the Missouri Bureau of Geology and Mines and, after that, served as special agent for the Tenth Census, charged with investigating economic resources in states east of the Rockies.

By then, Pumpelly was becoming affluent as well as eminent. He had bought a mansion in Newport, Rhode Island, for his wife and growing family. When engaged by Henry Villard, the notorious entrepreneur who had founded the Northern Pacific Railroad, to undertake what was to be styled the "Northern Transcontinental Survey," Pumpelly's horizons seemed again to be enlarging. The Survey made a brave beginning, during which Pumpelly travelled widely in the mountains of the northwest, and was the first geologist to see the glaciers (one of them bears his name) of what is now Glacier National Park. Unhappily, Villard's financial empire collapsed and the Survey came to an abrupt, sadly premature, end.

Fortunately, Pumpelly had by then made investments in mines and land that enabled him to enjoy the ensuing few years of leisure, using them to undertake such researches as he fancied and to develop Ferdinand von Richthofen's ideas concerning the formation of the loess of northern China. This spell as "gentleman geologist" was productive in new hypotheses, yet it did not fulfil Pumpelly's urge to explore new terrains in unfamiliar country.

No doubt it was with a sense of relief, therefore, that he accepted a position with the United States Geological Survey in 1884, under John Wesley Powell's benign directorship. He was appointed head of the Archaean Division and assigned the task of mapping the Green Mountains of Massachusetts, an area of contorted metamorphic rocks that presented particular problems of interpretation. All went well and his report was considered masterly. Unfortunately, budget cuts in 1892 ended this congenial employment; perforce, Pumpelly became again the "gentleman geologist."

Pumpelly had already been interested in the question of the Aryan (*i.e.*, Indo-European) origins of civilization, as a consequence of his Asiatic travels. Although approaching 65, his exploratory urges were not yet exhausted. Consequently, in 1903 and with backing from the Carnegie Institution, he set off to what was then Russian Turkestan, to put his theories to the test. Along with him went his son Raphael, the geomorphologist William Morris Davis, the archeologist Richard Norton, and a young man named Ellsworth Huntington who had worked in Turkey and knew both the Turkish and the Armenian languages. (Huntington was destined later to become, like Davis, a leading US geographer). They explored especially the Trans-caspian Basin, discovering ancient Caspian shorelines, finding ruined towns located on delta oases, and viewing the evidences of postglacial erosion, the loess deposits in particular. There was a second expedition in 1905, but this time with a specifically archaeological aim: the excavation of the abandoned city of Anau, at the foot of the Kopet Dagh in Turkmenistan. This was successful, four cultural levels being recognized, but po-

litical problems prevented a planned third expedition in 1906 and essentially wrote *finis* to Pumpelly's explorations.

Pumpelly's last years were spent in writing up his discoveries and in penning his *Reminiscences* (1918). He died in 1923, in his eighty-sixth year.

This, then, was a life of exploration, adventure and scientific attainment, meticulously documented by the author. There are a few unfortunate errors. Georges Cuvier and Alexandre Brongniart certainly did *not* use "fossils from the chalk to identify individual strata within the Tertiary formation" (p. 12), since the Chalk is of Late Cretaceous date. With less confidence, I suggest that "Johann Schiel" (p. 36) was in fact Jacob Heinrich Schiel: and "amygdaloids" (p. 87) are *certainly* not synonymous with "trap." However, such slips are few and perhaps forgivable in a non-geologist like the author.

A greater problem, though, is that this reader feels he knows all about what Pumpelly did, but almost nothing about him as a person. This is in part because so little of his correspondence is quoted — quite probably, little survives — and in part because there are too few quotations from his own writings on his life and travels. In consequence, this is a book from which one learns much, but whose principal protagonist never comes alive.

That is a pity, because Pumpelly is a fascinating figure. Perhaps it will require a fictionalized biography, rather than so severely factual a study as this, to enable us to come closer to understanding him.

REFERENCE

Pumpelly, R., 1918, My reminiscences. New York: Holt, 2 vols., xiii + 438 p.; xi + 439-844 p.

Geoindicators – Assessing Rapid Environmental Changes in Earth Systems

Edited by A.R. Berger and W.J. Iams
A.A. Balkema, Rotterdam
1996, 466p., US$99.18

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If the symptoms can be recognized early it may be possible to mitigate, or to avoid, impending illnesses. Happily, this approach often works with individual people, plants and animals, but when the patient is the Earth and the sicknesses appear to be a cascading series of runaway and contagious maladies, there is less reason for optimism. The Earth appears to be becoming more inhospitable to the human race at a time when the latter is increasing rapidly in numbers. W.S. Fyfe emphasizes in the Introduction to this volume that the short-term well being of Homo sapiens and many other life forms is being threatened increasingly by the consequences of excessive greenhouse gas generation, ozone depletion, soil deterioration, and lack of clean fresh water. In part these threats have grown from human activities, in part, they involve naturally occurring processes. In combination, however, the symptoms look ominous, so it is imperative that we seek remedies where feasible.

First, however, we have to devise techniques for monitoring the relevant global changes, before we can hope to understand their dynamics well enough to attempt to modify or reverse some of them. This was the mandate given in 1992 to the Geoindicator Working Group of the International Union of Geological Sciences, by the latter's Commission on Geological Sciences for Environmental Planning. This volume is the product of an International Workshop on Geological Indicators of Rapid Environmental Change held in Newfoundland in July 1994, which brought together some 40 earth scientists. The Geoindicator Project represents a direct attempt by the international earth science community to define sound environmental indicators of the kind that government regulatory agencies are seeking. Thus, although the papers in this volume sidestep modelling and predicting Global Change, they address the practical aspects of measuring the effects. Many can be sensed by "geoindicators," which are defined by the working group as: "measures of surface or near-surface geological phenomena that vary significantly over periods of less than 100 years and that provide information that is meaningful for environmental assessment."

Most of the geoindicators described herein are well-known phenomena such as coral growth patterns, glacier fluctuations, changes in groundwater levels and recurrent seismicity, as well as temporal variations in shoreline position, soil quality, subsurface temperatures, and volcanic activity. Others, such as desert crusts that diagnose aridity, have received less attention. All are summarized in point form in the final chapter. This invaluable checklist is worth reading, first, because it is an ideal introduction to the specific review papers. These cover measurable changes involving: the cryosphere and periglacial environment, fluvial systems, groundwater, the marine environment, the coastal environment, peatlands, arid and semi-arid environments. In addition, human factors, theoretical considerations, and policy considerations are discussed.

Rather than mention every paper, some representative contributions are summarized here and the authors' names given in brackets. Ice cores record climatic variations in polar and alpine regions, which are complemented by the discontinuous records of glacial deposits (A. Nesje). International monitoring of glacier advances and retreats began more than 100 years ago, with the longest records coming from the Alps and Scandinavia. The growth of corals provides logs of oceanic environmental data in the tropics that can later be recovered and dated, albeit *via* expensive chemical analyses (G.T. Shen). The potential products include temporal records of mean temperatures, salinity, fertility, sea level, and general stress events that cause growth disruptions. Pollutants such as organic pesticides have been detected in corals, as has wind-born dust and other climatic indicators. On land, fresh water abundance in semi-arid regions can be calibrated to the areal extent of lakes and to sand dune activity

(R.E. Vance and S.A. Wolfe). Both can be monitored by aerial photography and satellite imagery at modest cost, once the local situation and responses have been documented. For geological indicators to provide the desired information, we need to define what will constitute minimum data sets for specific investigations (F.J. Pierce and W.E. Larsen) before making measurements, and we need to take account of the potential interactions between changes that occur naturally and those that are human-induced. In all natural systems, there is potential for much confusion in the interpretation of significant thresholds. Effective geoindicators must satisfy basic tests of relevance, measurability, repeatability and comparability and they must possess a range of variability in time and space that permits meaningful extrapolation (D.C. Elliott).

This carefully edited volume throws down a huge challenge to responsible citizens of the planet. Here is a tool box, certainly not full yet, but one that contains cheap and simple techniques for assessing global changes, diagnosing their causes, and identifying tactics for reversal. In many countries, some of these geoindicators are being used responsibly to monitor environmental health, and to limit the harm induced by human activities, but international and local efforts need to be increased by an order of magnitude. This will involve commitments far greater than those required to implement treaties to limit nuclear arsenals. Do we have the means? Scientifically speaking, yes, as this book makes clear, and we can expect such capabilities to grow. Is there the will? Maybe there is, amongst a small percentage of the middle classes. Tragically, in the writer's opinion, for most politicians, lawyers, economists and business people, the necessary will is lacking. Today's capitalist economies have little incentive to preserve the fundamental sources of their wealth. The ongoing trend towards "multi-national corporations operating in a global village" means that many real environmental concerns in countries large and small are overwhelmed by what are perceived to be "national objectives." All too often, the latter factorize into programs that benefit only the greed of those who are already monetarily rich. We are casting aside the stewardship of landholders and replacing it with exploitation by urban profiteers. Until nurturing the Earth's environment becomes part of the equations of trade, it does not seem probable that the messages of the geoindicators will be heeded by those who now hijack the Earth's biota with their currency speculations and short-term commercial practices.

If *Geoindicators* can help curb these propensities, it will have more than served its purpose. It is a book that should be examined by all earth scientists and one which deserves to be discussed widely in graduate courses.

Burgess Shale Guide A Geoscience Guide to the Burgess Shale

By Wayne Powell
Yoho-Burgess Shale Foundation
1996, $7.00

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This economically produced ringback-bound book with black and white figures runs to 37 pages and contains excellent geological information about the area around Field, British Columbia. It is written at a first year undergraduate level and serves as a guide/souvenir booklet for the Yoho–Burgess Shale Foundation's guided hikes to the Burgess Shale quarries. Some knowledge of earth science, its terminology and jargon, is required to comprehend everything, but broadly educated tourists should be able to understand most of the material. View photographs are printed in grey half tones with map information (faults, formations, contacts) overlaid in solid black lines to explain the geology. Middle Cambrian fossils from the main collecting localities are described and illustrated with good black and white reproductions of photographs. Text and figures, however, are not completely harmonized. For example, "Opabinia" is described and discussed enough to make one want to see what the animal looked like, but it is not illustrated. The maps show quarry locations, and the text emphasizes that unsupervised visits are unlawful and collecting is forbidden. Besides the main text, which focusses on the geology of Yoho National Park and the Burgess Shale fossils, there are margin discussions of topics such as plate tectonics, the Cambrian world, glacial hazards, the Little Ice Age, climate change at Lake O'Hara, fossilization and Charles Walcott, which add to the interest of the book. Clearly it is a timely publication, since the first edition has already sold out! It merits a more opulent second printing.

The Sternberg Family of Fossil-Hunters

By Martin O. Riser
Lewiston, NY, Queenston, ON and Lampeter, Wales
Edwin Mellen Press
1995, xi + 495 p., US$119.95

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Charles Hazelius Sternberg and his three sons formed a fossil-hunting team, unique in the history of paleontology and likely to remain so, since the days of wealthy collectors who supported their activities are long gone. After years of neglect by scientific historians, the Sternbergs are today gaining the attention they merit. Charles H. Sternberg's two autobiographical works, *The Life of a Fossil Hunter* (1909) and *Hunting Dinosaurs in the Bad Lands of the Red Deer River, Alberta* (1917) have both been republished (by Indiana University Press (1991) and NeWest Press, Edmonton (1985), respectively), the latter with an excellent introduction by David Spalding. Katherine Rogers (1991) has written *The Sternberg Fossil Hunters. A Dinosaur Dynasty* (1991), which concentrates especially on the life and work of George Fryer Sternberg, and there have been at least a half-dozen shorter articles on the Sternbergs.

The work here reviewed is a manifestation of the increasing interest in this

remarkable family. It focusses, in particular, upon the elder Charles, but deals also with his sons and with collateral branches of the family, of varying degrees of eminence. Potentially, at least, it should have been a most valuable document, and, indeed, it contains much fresh information. Sadly, however, it falls far short of attaining its potential.

When I received my review copy, I was quite taken aback by its physical condition: a dark green cloth binding from which the spine and front-cover titles had already faded to virtual illegibility. It looked, indeed, like a book that had been exposed on a shelf in strong sunlight for many years, scarcely the appearance that one expects in a fresh copy, and reflecting great discredit on the publishers, especially in view of the extraordinarily high price.

In consequence, I opened the book with grave misgivings. These were fully realized as I read it. If ever a text needed editing, this was the one, yet it is all too clear that the manuscript received no editing whatsoever, and very little revision, either.

First, there are numerous inaccuracies. These begin in the "Author's Note," when he expressed gratitude to "A.E. David Spaulding" (properly, David A.E. Spalding). The Permian reptile *Edaphosaurus* is incorrectly stated to have been carnivorous (p. 141); but then, as Riser notes (p. 152) "Permian fossils were so illusory." Moreover, Canada has never had a "Central Pacific Railway" (p. 223) and no British peer has ever had so large an estate as "Admiral Lord Beresford of Britain" (p. 224).

There are invented words: "Bequeathment" (p. 9) for bequest; "unsatiable" (p. 184); "functionality" (p. 108). Many other words are simply misused: Sternberg's "tenure as a bone-hunter" (p. 25); "such grizzly evidence" (p. 43-44); "his errored conclusions" (p. 86); "minute traces of a particular strata" (p. 166). There are recurrent punctuation errors, in particular misplaced apostrophes (*e.g.*, p. 179, 181, 191), and a misuse of capitalization and italicization in popular and scientific names, with such words as "Oreadont" (p. 97) unnecessarily capitalized but family names without capitals (*e.g.*, "ceratopsidae" etc., p. 222). There is even the double error of both capitalizing and italicizing *Pterodactyl* (p. 79).

Other problems, alas, abound. Tautologies are numerous: "the debauchery and untamed atmosphere... is a matter of historical record that cannot be denied" (p. 15); "[Sternberg] had one bad ear in which he was totally deaf" (p. 21); "Cope himself was personally impressed enough..." (p. 87); "the colour of their hue" (p. 91). There are platitudes and absurdities: "The hills... were all to evident to Sternberg" (p. 92); "Once Cope and Marsh were dead and buried, their rivalry was no longer fed" (p. 112); "Troops from Fort Harker... were literally the life blood of the railway workers" (p. 117); "This again provided impetus to Charles, since he was in the spare Permian" (p. 153).

There are contradictions, as when Quantrill is called "a vile and dangerous man" on page 124 yet has his vilification regretted on the next page, or when an area of Texas in which fossils were stated to be hard to come by (p. 143) is characterized on the next page as giving up fossils with great alacrity. There are obscurities also; why, for example, was Charles Reynolds' appointment as chaplain to the Territorial Legislature considered "an indication of his political leanings" (p. 292)?

All these minor problems are distracting enough to the reader, but there are major problems as well. The organization of the text is, at times, baffling: chapters 16 and 17, for example, are vastly out of order, and duplication of information abounds. Had the duplication been eliminated, this long book would have been very much shorter and very much less wearisome to read.

That is the trouble; because of bad writing and an utter lack of editing, my reading of this book was indeed a wearisome task. That is sad, for it represents eight years' work by the author and does bring together a great deal of very useful information about the Sternberg family. Moreover, the plates are excellent, being as well reproduced as the less-than-ideal paper allows. Since I share Mr. Riser's enthusiasm for the Sternbergs, and in particular for old Charles himself — even though I don't share Mr. Riser's philosophies, and there is much philosophizing — I can only regret that such energetic researches were squandered in such a poor product. If Mr. Riser had only found himself a good and critical co-author, or if his publishers had properly shouldered what was certainly a massive editorial task, this could have been a classic study. Instead, the definitive work on the Sternbergs remains to be written.