gists than geology. The author seems to have known all the leading participants in the development of American geology during the twentieth century. The old departmental battles are fought over again and we are impressed or bullied by the Great Men; I was particularly taken by the portraits of A.C. Lawson, the "King" at Berkeley (who fathered a son at 88) and of Harlen Bretz (one of my own heroes) who was belatedly awarded the Penrose Medal at the age of 97. Yet there is also a great deal about a vast variety of geological topics, from teaching methods to the effects of current history on the geological world (though to a European the great depression and prohibition seem to figure larger than the two World Wars).

Included, too, are day-by-day accounts of Pettijohn's long early canoe journeys to the north, with painful portages and campsites on Indian graveyards, plus the ever present mosquitoes and blackflies. We experience with him the excitement of going and seeing geology, for instance the discovery of a Precambrian tillite and the three-billion-year-old conglomerate that was the subject of his PhD thesis (on a lake island in northern Ontario). And we are reminded of a world in the early 1930s when $200 was enough for the expenses of a three-month field season on the Canadian Shield together with those of a graduate field assistant. Pettijohn was always mapping and studying sections, but he was at the same time asking fundamental questions such as how one produces pure quartz sands before the development of land vegetation.

Though the author's main interest is in the sedimentary rocks, he does not say much about fossils. One wonders if this is the result of an early education, in which the literal truth of the Bible was taken for granted, and a first teaching job in a small college where geology had started out as a "Department of Harmony of Science and Revelation". But among his many distinguished later students it is interesting to note John Scopes, the Tennessee school teacher who was to be tried in 1925 for teaching the theory of evolution.

It was observed of Winston Churchill that he both made history and wrote it. Much the same might be said of Francis Pettijohn. This is a splendid, readable history of American geology in the twentieth century, by one who played a great part in its making. □

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The Pleistocene ways of death

Leonard Krishtalka

Quaternary Extinctions: A Prehistoric Revolution.
Edited by Paul S. Martin and Richard G. Klein.
University of Arizona Press: 1984. Pp.892. $65.

THE plot seems simple enough. At the end of the Pleistocene, between 12,000 and 10,000 years ago (yr BP), the mammalian faunas of two continents were decimated. North America lost 33 genera (or 75%) of its megafauna (body size of 44 kg or greater) and four genera of small mammals. The extinctions and extirpations struck two entire orders, the Proboscidea (mammoths, mastodonts, gomphotheres) and Perissodactyla (horses, tapirs), the families of camels, ground sloths, glyptodonts and peccaries, and genera of cheetah, sabertooth cat, bears, giant rodents, deer, musk oxen and moose. In South America, the 46 genera that became extinct were all large mammals: edentates, rodents, carnivores, endemic ungulates (litopterns, notoungulates), horses, mastodonts, peccaries, camels and deer.

Australia's fauna fared no better. During the late Pleistocene, between approximately 40,000 and 15,000 yr BP, some 55 species vanished. The megafaunal tombstone reads two echidnas, two marsupial carnivores, three wombats, seven diprotodonts (large marsupial herbivores), 33 macropodids (kangaroos, wallabies and their relatives), a varanid lizard, a horned tortoise, three birds and a giant snake.

In contrast, the faunas of Europe and Africa emerged from the Pleistocene comparatively unscathed. Of the 13 genera that disappeared from Europe, three (woolly rhinoceros, woolly mammoth, giant deer) were true extinctions, whereas the remainder (rhinoceros, horse, dhole, hippopotamus, musk ox, hyaena, antelope, elephant) survived elsewhere. In Africa too there were numerous local extirpations, but only a handful of species (long-horned buffalo, giant hartebeest, giant Cape horse, two springbok and a warthog-like pig) vanished from the continent at the Pleistocene–Holocene boundary. Africa had already suffered the extinction of 21 genera (one primate, one carnivore, 19 artiodactyls) during the early Pleistocene (1.8–0.7 Myr BP), and nine genera (one elephant, one horse, seven artiodactyls) during the middle Pleistocene (0.7–0.13 Myr BP).

Asia, like Europe and Africa, appears to have suffered only modest losses at the end of the Pleistocene, but an accurate checklist of the genera and species involved has yet to be compiled.

Now the plot thickens: is it a "whatdunit" or a "whodunit"? One school of palaeobiologists blames rapid climatic and environmental change, namely, the final glacial retreat at the end of the Pleistocene and its consequences: a decrease in equability and in the diversity, quality and quantity of plant resources; a concomitant increase in "continentality" of climate, in seasonal extremes, and in the homogeneity and zonation of plant communities. These biotic changes played havoc with late Pleistocene, co-evolved ecosystems, such as grazing and browsing associations and gestation and growth periods among mammalian herbivores, quickly leading to the extinction of the megafauna, as well as dwarfing among the extinct and surviving lineages. This "glacial retreat" model is specific to the Americas, Europe and Asia,

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Extinct — *Elasmotherium*, from the steppes of Eurasia.

but climatic–environmental change is also invoked to explain the earlier extinctions in Africa and Australia.

A second school implicates a different but familiar culprit, *Homo sapiens*. It claims that a rapidly spreading "front" of palaeolithic hunters decimated the now extinct megafauna of the Americas, beginning in Canada about 12,000 yr BP and ending in Patagonia some 2,000 years later. The same "overkill" occurred in Australia following man's first invasion about 40,000 yr BP; in Africa, the shadow of Acheulean culture hangs over the early Pleistocene extinctions.

For more than 100 years natural historians have camped on either side of this Pleistocene battlefield: climatic–environmental change versus human overkill. Into the fray now marches *Quaternary Extinctions: A Prehistoric Revolution*, a volume armed with 38 chapters and 47 contributors. Extinction is no laughing matter, but, after reading this work, I'm reminded of the quip of the American humorist, Robert Benchley: "The world is divided into two kinds of people — those who divide the world into two kinds of people and those who don't". The two camps, still divided, are almost as entrenched as ever. Nevertheless, the editors, Paul S. Martin and Richard G. Klein, have produced a superb single-volume treatment of Pleistocene–Holocene extinctions and of the debate which surrounds them.

The 38 chapters are organized into seven

sections. The first sets the stage with papers on nineteenth-century explanations of Pleistocene extinctions, a bestiary of Pleistocene mammals and an account of New World mammoth distribution. Section 2 examines five significant late-Pleistocene sites, four in North America and one in Venezuela. Sections 3 and 4 present "the theoretical marketplace" through seven papers on the climatic-environmental version of extinction and six on the overkill model. These contributions deal mostly with the North American record, but Paul Martin's chapter, the longest and perhaps most eloquent in the book, presents the case for overkill on a global scale. Also, he alone deals in detail with the extinct Pleistocene faunas of South America and Europe. Section 5 examines the record of extinctions in northern Eurasia, China (mammoths only), the Levant, Africa and Madagascar, while the sixth covers environmental change, the archaeological record and the severe extinctions in Australia, New Zealand and the Hawaiian Islands.

Taken together, these first 35 chapters comprise an indispensable and almost encyclopaedic reference text on Pleistocene and Holocene faunas, chronologies, environments and extinctions. The data, analyses and bibliographies are massive in amount, virtually worldwide in scope and up to date. But the volume doesn't end there.

In the seventh and final section, an excellent and incisive three-part overview, L.G. Marshall, D.K. Grayson and J.L. Diamond step back from the myriad facts, figures and interpretations to view matters in a broader, more comprehensive light. The particular illumination provided by Marshall is that of conceptual clarity. Ten issues — terminology, scientific method, chronology/correlation/causation, historical perspective, extinction, turnover, megafauna, dwarfing, overkill and climate — and their treatment by the various authors are dissected, compared and evaluated. For Grayson, the history and structure of the debate on Pleistocene extinctions is the barometer by which to judge the competing environmental and overkill schools. Diamond plumbs historic extinctions for the ecological and biogeographical principles and patterns that could make sense of Pleistocene–Holocene events.

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Extinct — *Macrauchenia*, a litoptern from South America.

All three authors would postpone making the final verdict on the climate–overkill debate. I agree. Its resolution, despite the mass of data collected together in *Quaternary Extinctions*, awaits a more precise and dense palaeontological and archaeological record. Both models are rooted in exact chronological correlations. Crucial to the overkill model is whether the late Pleistocene extinctions indeed followed the first appearance and spread of a new predator, *H. sapiens*, in the Americas and Australia. As Grayson points out, this correlation is virtually the only evidence the overkill camp can marshall. Their selective acceptance of only the "good" dates — those that fit the model (for example dates for human beings in North America no older than 12,000 yr BP, and those for mammoths no younger than 10,000 yr BP) — may play fast and loose with the evidence that doesn't fit.

Other problems with the overkill theory are the *ad hoc* escapes from attempts to falsify the hypothesis. If overkill occurred in the Americas and Australia, why is there a dearth of kill sites in the archaeological record? Overkill partisans answer with the "blitzkrieg" addendum: overkill was so swift and devastating, that few kill sites are to be expected. Not only is this untestable, but contrary reasoning is applied to New Zealand, where abundant associations of prehistoric man and 22 extinct species of moas are cited as evidence *for* overkill. Moreover, one simulation of the blitzkrieg model for North America (Whittington and Dyke, Chapter 20) allows for overkill to have occurred in as few as 250 or as many as 22,000 years. This, as Grayson notes, "removes the critical chronological test for the general overkill hypothesis" (p. 812). No one doubts the hand of man in the extinction of faunas of New Zealand, Madagascar, Hawaii and other islands within the past 1,000 years, but, as Diamond and others show, overkill was merely one of a litany of lethal weapons, including habitat destruction and introduction of herbivores, predators, competitors and disease. In many instances, the effects of climatic change and man added up to a one–two punch.

Does the climatic model fare better? Somewhat. It too owes its first allegiance to chronological correlation, namely, the synchroneity of megafaunal disappearances and terminal Pleistocene post-glacial climatic change. But, as with the overkill model, a correlation is not a cause; it is merely a good reason to look deeper for the knots that tie climate to extinction, specifically, cause–effect processes and evidence that link the degree and kind of climatic, environmental and ecological change to observed extirpations and extinctions. Here, preliminary research has been encouraging. According to palaeobotanical evidence cited by a few of the authors, the breakdown of climatic equability at the onset of the last interglacial may have been much more severe than in previous interglacials. If so, this explains why the megafauna would be extinguished during the last glacial retreat after having survived at least three previous ones. Five of the chapters begin to implicate post-glacial vegetational zonation and simplification in the North American extinctions, and one paper indicts late Pleistocene aridity cycles for the Australian disappearances. Unlike the overkill model, much of the climatic–environmental case is testable in the fossil record.

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Extinct — *Nothrotheriops*, the Shasta ground sloth from North America.

But the climatic model too has problems. Diamond wonders why the megafaunal extinctions were not accompanied by equivalent plant extinctions, how poikilotherms (reptiles, amphibians, fish and beetles, for example) escaped devastation when homoeotherms (mammals) did not, and why the final glacial retreat ravaged the North American megafauna but barely scarred the Eurasian one. Beyond the need for more data, the answers to these questions and, ultimately, to the overkill–climate debate, await a less polarized approach to the problem. Different causes of extinction may apply to particular faunas, landmasses and their subsets. Similarly, a one–two effect of climatic–environmental change and cultural decimation — acting in different proportions — may account for the selective and differential extinctions between landmasses and faunas. Most of the workers in the climatic camp have begun to think along these lines.

Two flaws in *Quaternary Extinctions* deserve mention. Except for Martin's chapter, South America and Europe receive little treatment and Asia virtually none. This may be more a comment on the state of the science than an act of omission. More minor a failing, but irritating nonetheless, is the absence of a list of institutional affiliations of the authors.

This work is a welcome sequel to Martin and Wright's *Pleistocene Extinctions: The Search for a Cause* (Yale University Press, 1967), which is out of print and out of date. As such, *Quaternary Extinctions* represents a leap in our knowledge of Pleistocene and Holocene palaeobiology. Many volumes on our bookshelves are destined to gather dust rather than attention. But not this one. □

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