Quaternary Geology Reviewed

Quaternary geology in the United States and in northern Europe is summarized in two recently published books, and in a third that has been announced. One, **The Quaternary of the United States** (Princeton University Press, Princeton, N.J., 1965. 922 pp., $25), edited by H. E. Wright, Jr., and D. G. Frey, is a review volume for the VII Congress of the International Association for Quaternary Research. The second book, volume 1 of **The Quaternary** [Interscience (Wiley), New York, 1965. 322 pp. $15], edited by Kalervo Rankama, summarizes Quaternary geology in Denmark, Norway, Sweden, and Finland. The third book, announced as volume 2 of *The Quaternary* and also edited by Rankama, will summarize Quaternary geology in the British Isles, France, the Netherlands, and Germany.

The two published books are highly satisfactory reviews of present information and fashions in Quaternary geology, a chapter of geology that is becoming of increased interest because of growing awareness that the Quaternary offers more practical day-to-day challenges than the rest of the geologic column combined. This is the land and these are the surface deposits on which we live. Their economic aspects include water supply, mineral resources, vegetation, soils, and problems in erosion and sedimentation, engineering, and land use. Moreover, if the doctrine of uniformitarianism is true, and the present is the key to the past as geologists proclaim, the Quaternary needs intensive study for better understanding of processes that shaped the more ancient rocks and geologic past. Devastation by earthquakes and tsunamis remind us that we still have much to learn about present-day structural geology. Such practical aspects of Quaternary geology are not covered in these books, but the authors, editors, and publishers are to be congratulated for providing so broad a basis for reviewing the status of Quaternary geology.

The Quaternary of the United States is divided into four main parts. Part 1 treats the areal geology, with emphasis quite properly on the stratigraphy. The glaciated areas east of the Rocky Mountains are described in seven papers (128 pp.) covering Quaternary deposits in the northern Great Plains, Minnesota and Iowa, Indiana and Michigan, the Erie Lobe, New York, and New England. The unglaciated eastern and central United States are described in four papers (87 pp.) covering the Quaternary of the Atlantic Coastal Plain and Appalachian Highlands, the western Gulf Coastal Plain and shelf, Nebraska and northern Kansas, and the southern Great Plains.

Quaternary deposits and related features in the western United States, including Alaska, are described in nine papers (157 pp.) covering the glacial geology of the Rocky Mountains, the history of the Columbia Plateau and the northern Rocky Mountains, the nonglacial Quaternary geology of the southern and middle Rocky Mountains, the Snake River Plain, the Great Basin, the southwestern states, the Pacific Mountains in California, western Washington and Oregon, and Alaska. Hawaii and Puerto Rico are not covered.

Part 2 deals with biogeography. A first section, of eight papers (131 pp.), discusses phytogeography (academicia for plant geography) and palynology in northeastern United States, unglaciated eastern North America, the Great Lakes region, the Southwest, southern Rocky Mountains, the Pacific Northwest, and Alaska; two rather specialized (for this volume) papers deal with bryophytes and polyploidy. A second section, of nine papers (133 pp.), deals with animal geography and evolution. Its first paper treats the Quaternary mammals. Others discuss avian speciation during the Quaternary, amphibian speciation, reptiles, freshwater fishes, insects, nonmarine mollusks, other invertebrates, and Recent adjustments in animal ranges.

A third section (one paper, 9 pp.) discusses Pleistocene nonmarine environments. This discussion, by E. S. Deevey, Jr., offers the provocative thought that our basic stratigraphy, the division of the Pleistocene into four glaciations and three interglaciations, may be incorrect. This thought points again to an old ailment in Quaternary stratigraphy, the numbers game. Given one glaciation, it must be Wisconsin; given two, they must be Wisconsin and Illinoian; given three they must be Wisconsin, Illinoian, and Kansan, and so on. To use a phrase borrowed from the *New Yorker*, this is reducing the infinite variety of glacial history to a classic norm. A little paleontology, as noted below, would help.

Part 3, which deals with archeology, consists of five papers (65 pp.) describing prehistory in the northeastern states, southeastern states, plains, desert west, and Pacific Coast. The archeology of Alaska is presented with the paper describing the areal geology.

Part 4, which is too varied to be summarized under a single topical heading, consists of 11 papers (170 pp.) categorized by the editors as "Miscellaneous studies." These papers cover such diverse Quaternary subjects as the continental shelves, isotope geochemistry, paleopedology, the geochemistry of some lake sediments, paleohydrology, glaciers and climate, volcanic-ash chronology, paleomagnetism, tectonics, dendrochronology, and theoretical paleoclimatology.

The book is well illustrated and includes an index of authors cited and a subject index. Each paper is accompanied by an abstract, but several of these could have been improved had the authors and editors paid heed to Ken Landes's famous satire on the qualities of abstracts [*Bull. Assoc. Petroleum Geol.* **35**, 1660 (1951)]. To paraphrase, the bad examples tell us "Quaternary geology is described. Correlations are discussed. Conclusions are reached."

One might quarrel here and there with overenthusiastic assertions; there is room for disagreement about the suitability of the emphasis in some papers, and even about the suitability of including some of the more narrowly specialized ones in so general a book. But these would be minor criticisms of

a major work. The book provides an excellent basis for reviewing the status of this corner of geology, and I use it as basis for comment on a few problems of the science.

Current Problems: Stratigraphic Nomenclature

A first problem of Quaternary geology that struck me while reading the book concerns stratigraphic nomenclature. This has several facets.

One is the proliferation of *formal* (contrasted with *informal*) stratigraphic names. Cumbersome nomenclature hampers rather than aids communication, and Quaternary geologists need be wary of the bottomless pit of verbiage from which petrologists are extricating themselves and in which soil scientists still lie buried (and continue to burrow in the wrong direction!). Minor and isolated deposits that offer little promise of regional importance can be referred to informally without cluttering the nomenclature; simple descriptive English can assist communication where formal terms defeat it. As Arthur Holmes wrote: "There is undoubtedly an attraction in the creation of new names . . . [but, in many cases] three words are better than one. Brevity of expression is by no means an unmixed blessing and the one word may require a whole paragraph of explanation" [*The Nomenclature of Petrology* (Murby, London, 1920), p. 5].

In the glaciated Middle West, type section for our glacial chronology, a plethora of local subdivisions with new formal names has resulted in changes of names at state lines and confused correlations across them. The confusion simply illustrates that detailed and modern geologic reporting can successfully conceal mountains behind molehills.

The problem reappears in the glaciated West. There has been disagreement about correlations with specific Pre-Wisconsin or with specific Early or Late Wisconsin glaciations or interglaciations, but for more than half a century there has been general agreement about the separation and identification of deposits correlated as Pre-Wisconsin, Early Wisconsin, and Late Wisconsin. Why then not use those terms, which are widely known and meaningful, and end the nonsense of introducing new, formal stratigraphic names in every Rocky Mountain valley? It seems time to suggest that a committee of individuals, familiar with Rocky Mountain and Pacific Coast Quaternary, select for abandonment and burial as many as possible of the several dozen local names that have been applied there, and to substitute for them Late (Upper) Wisconsin [Etymological logic is all on the side of those urging that this term should be Wisconsinan; euphony and long usage are on the side of those favoring retention of the state name. How pure must we be?], Early (Lower) Wisconsin, and Pre-Wisconsin. Minor subdivisions that can be recognized locally can be accommodated by this nomenclature, and the use of a query can indicate correlations that are doubtful. This change would reduce printing costs. It would no longer be necessary to print tables with every paper showing the correlations that explain what the author means; in this book alone at least a half dozen pages of tables, all showing about the same general correlations, could have been thus eliminated.

Still another facet of the nomenclature problem concerns the definition of "Recent." About a third of the 900 pages of this book deal with the Recent, yet hardly any two authors use the term in the same sense. The escapists' terms "Holocene," "post-glacial," and "post-Wisconsin" are no better. With so much emphasis on this youngest part of the geologic column, it would seem desirable to find a definition so we may all use the term in the same sense.

One difficulty seems to be a misconception that the Recent must begin simultaneously all over the world, although no other geological period did. This has led to the suggestion that a particular year or a change in sea level be designated as marking the end of the Pleistocene and the beginning of the Recent. But shoreline displacements are the net effect of eustatic change of sea level, isostatic change of the land, and tectonic displacement. I submit that the Pleistocene-Recent boundary should be defined on the same basis as the others in the geologic column, namely on the basis of paleontology, and that changes of sea level and absolute dates should be used to determine the direction and to measure the degree to which the boundary cuts across time lines. Charles Lyell, a hundred years ago, gave us such a definition when he wrote, "In the Recent we may comprehend those deposits in which not only all the shells but all the fossil mammals are of living species. . ." [*The Geological Evidence of the Antiquity of Man* (Childs, Philadelphia, 1863), p. 5]. This definition is perfectly usable, whether the geology is being done indoors or outdoors. Where formations are nonfossiliferous, other criteria must be used for making correlations, but this difficulty is not at all peculiar to Quaternary geology. If Lyell's definition is finally accepted, after a hundred years have been devoted to futile efforts to arrive at a better one, there still would be need to agree about whether the boundary should be taken at the last appearance of some species considered typically Pleistocene or at the maximum change in fauna.

Regardless of definitions, the problems of correlation would continue to be with us, but difficulties become compounded if our stratigraphic nomenclature is cumbersome or inconsistent.

Biogeography and Quaternary Geology

Refreshing recognition of the mutual interests of Quaternary geology and of biogeography, past and present, is provided by the fact that more than a quarter of the book is given to papers on this subject. Without saying so, the papers illustrate that, in order to study relationships and mutual dependencies between geology and, say, plant geography, maps are needed, at all scales, showing existing vegetation, not in terms of alleged climaxes or other genetic bases, but in the real terms of what is growing in particular areas.

Plant formations could be mapped and categorized with general names in the same way that geological formations are treated. It is true that no two plant stands have exactly the same composition, but neither do any two geological formations. Different names are not needed for every plant stand. Geologists may hide their mountains behind molehills, but botanists are equally successful in hiding their forests behind trees. Of course details are needed, but so are generalities. Satisfactory classification and nomenclature can bring out homogeneities and differences at all scales. C. H. Merriam generalized field distributions in what he termed life zones [*U.S. Dept. Agr. Biol. Survey* **10**, 79 pp. (1898)], but the tendency of modern botany is to discard this old and useful concept without substituting a usable alternative—another example of overly sophisticated education concealing the obvious.

Some of the problems of disjunct populations and of the extent of displacement of biotas during the glaciations, discussed in several of the papers, would be clarified if there were maps showing present plant geography. Such maps would have great scientific interest and would more than pay their costs in practical uses pertaining to problems like deterioration or destruction of stream and field habitats and, with growing population, increased problems of land use, development, and management. But there is no organization, no "U.S.B.S.," to provide such mapping.

Palynology

That pollen studies, chiefly of late Pleistocene and Recent deposits, are very much in vogue is illustrated by the numerous papers on this subject. The laboratory methods for preparing and studying samples obviously are highly refined, but the stratigraphic usefulness of pollen profiles is severely limited because the techniques are poorly suited for facies studies. Little is known, for example, about irregularities or orderly changes in the distribution of even modern pollen. Profiles of older deposits are like other stratigraphic sections in which correlations must be based on similarity of fossil sequences. But we know well enough that such similarities can be introduced by lateral changes in facies as well as by changes with time. Willis T. Lee, 50 years ago, referred to them as "homogenetic equivalents" and recognized them as traps for the unwary stratigrapher. Any paleontological study must take account of the lateral as well as the vertical changes; pollen studies are no exception.

It would help if techniques were developed to enable the scanning of pollen samples *in the field*, sufficiently at least to identify and locate major lateral changes in pollen content, which then could be sampled and given proper laboratory analysis. The problem is like some in geochemistry where rocks selected in the field for analysis in a laboratory may first involve field microscopy. When pollen studies give adequate attention to facies changes in the older deposits and to the nature and kinds of irregularities in the distribution of modern pollen, a lot of stratigraphic surprises can be expected.

One of the papers in the miscellaneous section discusses the Quaternary history of the continental shelves and sea level changes, but marine biogeography and paleontology are given little other attention. This lack perhaps reflects the traditional bias towards, and emphasis on, continental Quaternary deposits and history. Yet the marine deposits offer greater promise for a complete Quaternary stratigraphic section and for correlations between the northern and southern hemispheres. In addition, those deposits possess very great resource potentials.

Archeology and Prehistory

The archeological papers summarize what is known about our prehistory but give little hint of the usefulness of archeology for subdividing the Recent or for developing information about changes in environments—such as changes in water tables which lead to flooding or to drying up of springs, lakes, and streams; changes in position of some woodlands or of some meadows in mountain forests; deterioration of plant stands; rates of weathering; and changes of sea level. In regions that are tectonically active, archeology can be, and has been, used to develop information about late Pleistocene and Recent earth movements.

A satisfactory subdivision of United States prehistory, brought out in this book as well as elsewhere, begins with a Paleo-Indian period, which is late Pleistocene and ends with the extermination of the Pleistocene game animals (Lyell's definition). This is followed by an Archaic period, which is pre-pottery and pre-bow and arrow and ends roughly A.D. 1. In the western United States at least, this period probably can be divided into early and late Archaic, corresponding to the dry, early Recent (altithermal or hypsithermal) and the comparatively moist middle Recent millennia just prior to A.D. 1. The Archaic is followed by the pottery and bow-and-arrow period, but this change, like other paleontological changes, was not simultaneous everywhere; it occurred about 1000 B.C., or earlier, in the southeastern United States and about A.D. 500 on the Pacific Coast.

Several papers fashionably charge man with exterminating the Pleistocene animals in North America, although this ignores the fact of parallel exterminations in Eurasia where man lived during much or all the Pleistocene. Man no doubt contributed to the extermination, but, in my view, natural causes must have been paramount, for the change seems to have been worldwide.

Archeologists now accept man in North America at the time of the last glacial maximum. Thirty-five years ago such a view was heresy; now, whoever does not have a Paleo-Indian site just isn't in. Yet this volume again includes criticism of George Carter for his unorthodox views about the early arrival of man in this hemisphere.

It is doctrine in archeology that man came to North America by way of the Bering Land Bridge, although neither this book nor the rest of the archeological literature records any supporting evidence. The problem has overtones suggestive of those of the still undiscovered Tertiary land bridges that enabled North American vertebrate faunas to mix intermittently with European ones.

Constant reiteration does not make man's use of the land bridge a fact, and what little evidence there is suggests that he may have used some other route. In the first place, Pleistocene mollusks along the arctic coast of Alaska have Atlantic rather than Pacific Ocean affinities, suggesting that the bridge existed during much or all of Pleistocene time and cut off contact between the Arctic and Pacific Oceans. There is no need then to labor the point about a bridge developing because of lowered sea level; the bridge was there, but it just was not used (according to doctrine) until the last glacial maximum. At that time, that area must have been bleak, permanently frozen ground and immigration across it would have been the original ice folly. To this observer it would seem that one of two archeological doctrines will have to go—either man reached North America by a route other than the Bering Land Bridge, or George Carter has been right in saying that man arrived on this continent before the last glacial maximum.

Soil Science and Geology

Soils of Pleistocene age, paleosols, are widely used for separating Pleistocene deposits of different ages, and are the subject of one of the miscellaneous papers. Recent soils, including the modern ones, are not considered in this book, which once again points up the unfortunate disciplinary split between Quaternary geology and soil science. Whether in universities or in government, soils are in one department, geol-

ogy is in another. Yet the two subjects are obviously of great mutual interest. Quaternary geology, for example, might offer a solution to the classification and nomenclature dilemma that confronts soil science. The dilemma arises because no two spadefuls of soils are quite alike and there has been, and continues to be, a tendency to create a new name for every spadeful. Quaternary geology might offer a solution by providing a stratigraphic basis for Recent as well as older soil features. But to develop a workable and mutually useful classification will require the joint efforts of the specialized departments now isolated from each other.

Dating Methods

Varves, despite their importance to the development of thought about the Quaternary, here and abroad, do not receive enough mention in this book to be listed in the subject index. Dendrochronology and isotope dating receive up-to-date treatment. The discussion of dating by isotopes is encouraging. As some skeptics predicted, conflicting dates were to be expected when isotopic methods could be developed for checking one another (ten methods are described). This conflict has led to conservative interpretation of dates and less of a tendency to rewrite geologic history because of some new surprising laboratory tests. Some extravagant statements of the past might be reconsidered in the light of the cautious statement that " . . . much of what is said here will more than likely be out of date within a few years" (p. 737). Although many consumers continue to misuse the product, isotope dating of Quaternary events is achieving a disciplined basis.

Not discussed in the book, but still not to be overlooked, are such methods as fluorine, thermoluminescence, hydration of obsidian, development of iron and manganese stain (desert varnish), patination, depth or degree of leaching under various environments, and rates of speciation. All these methods, like rates of erosion and sedimentation, have major shortcomings, but they have their uses too. For example, the fluorine method, which has proved useful for determining the contemporaneity of associated bone, contributed greatly to settling the controversy about the Piltdown skull [W. L. Straus, Jr., *Science* **119**, 265 (1954)].

Finally, mention should be made of the usefulness of volcanic ash beds, which are discussed in one of the miscellaneous papers, not only for correlation but also for dating.

Quaternary in Europe

Most of the foregoing observations about the Quaternary geology of the United States apply also to the Quaternary of Europe. My comments on volume 1 of Rankama's *The Quaternary*, therefore, will be restricted to a summary of the contents.

This book describes the Quaternary geology in the Baltic countries in four papers dealing with Denmark (90 pp.), Norway (48 pp.), Sweden (59 pp.), and Finland (73 pp.). In an introduction, R. F. Flint discusses some principles and problems relating to Quaternary stratigraphy. An author and subject index is included. Although the book is illustrated, maps showing locations of places referred to in the texts are inadequate. To make full use of this book, the non-Scandinavian reader will need an atlas.

The paper on Denmark, by Sigurd Hansen, describes the pre-Quaternary substratum and the extent of the Quaternary deposits, their lithology, weathering (including periglacial effects), structural changes, stratigraphy and chronology, geomorphology, sea level changes, earthquakes, economic geology, and archeology.

In discussing Norway, Björn Andersen describes the distribution of Quaternary deposits, the glacial history and stratigraphy, shore lines and their displacement, the different kinds of sediments, geomorphology, earthquakes, and archeology.

In Jan Lundqvist's paper, a summary of the Quaternary evolution of Sweden precedes discussion of the dating methods (pollen and varve), ice movements, deglaciation, changes in sea level, earthquakes, development of the climate, and biological development.

J. J. Donner, in the paper on Finland, outlines the pre-Quaternary setting, including the pre-glacial (or interglacial) weathering of the bedrock recorded by locally preserved patches of paleosols; this precedes discussion of glacial erosion and ice movements, the glacial deposits, eolian deposits, periglacial phenomena, post-glacial weathering, varve chronology, shoreline displacements, shell beds, late glacial and post-glacial stratigraphy, fossil mammals, certain animals surviving from the glacial age, and archeology.

Assuming that volume 2 of *The Quaternary* is as satisfactory as volume 1, both of these books and *The Quaternary of the United States* will be wanted by everyone interested in Quaternary geology, and they can be recommended for reading by those who are interested in the other geological systems; what is happening today happened during the Quaternary, and what happened then happened before.

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Applied Meteorology

Radiative Heat Exchange in the Atmosphere. K. Ya. Kondrat'yev. Translated from the second Russian edition by O. Tedder. C. D. Walshaw, Translation Ed. Pergamon, New York, 1965. x + 411 pp. Illus. $15.

In the U.S.S.R. the major preoccupation in the field of applied meteorology is with the marginal thermal conditions in the vast Siberian territories.

The radiative balance of the earth's surface is susceptible to measurement and to theoretical analysis, and there are simple measures (exploitation of slopes, greenhouses, and smudge pots, for example) that can be of real economic value. These considerations are recognized in the U.S.S.R. by an unusual concentration of research talent in the field of atmospheric radiation, and particularly in those aspects connected with surface climatology.

One of the best known research groups is that of the physics department of Leningrad University under the direction of Professor (now Rector) K. Ya. Kondrat'yev. During the past 18 years this extraordinarily prolific worker has not only produced many original contributions, but has written a series of valuable books (I know of six, but am not sure of the exact total) on all aspects of the subject. Now, at last, one of these books is available to Western scientists who, until recently, have had to be content with reviews of special topics.

The book deals with the transfer of long-wave, thermal radiation in all its