

are observable processes producing charge separations which may account for thunderstorms, theoretical mechanisms which can explain the observed magnitudes of these charge separations are still lacking.

The report can be recommended as a massive source of both experimental and theoretical information, but a careful examination for conflicting results is needed.

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R. F. FLINT. *Glacial and Quaternary geology*. New York, etc., John Wiley and Sons, Inc., [1971]. xiii, 892 p., illus. \$24, £10.95.

THE review of *Glacial and Pleistocene geology* ([1957]) in this journal in 1958 (Vol. 3, No. 24, p.325) included a lengthy comment on the tremendous increase in glacial and Quaternary research since publication of Professor Flint's earlier work, *Glacial geology and the Pleistocene epoch* ([1947]). Needless to say, the output of Quaternary research has continued to spiral, furthermore the glacial epoch of many areas has been pushed back well into the Tertiary. The resulting expansion of the science has in part been taken into account by enlargement (by greater than 30%) and extensive revision of the 1957 volume to this new one. It is suggested in the preface that the work contains "about 80 percent new material" and this is readily apparent as is the very noticeable increase in references and citations. Basically, however, it has a similar format to and only slightly greater scope than the previous volume, covering glacial geology as well as the stratigraphic, environmental and historical interests of the late Tertiary. It also has the same logical organization, direct analysis and well presented conclusions as the 1947 and 1957 books. The new chapter "Overall view of late-Cenozoic climate and glaciation" clearly defines the diverse problems and prepares the student for the multiple approaches considered in this volume.

The emphasis of this book, as of its predecessors, is toward the physical side but this volume is more strongly punctuated throughout by palynologic or ecologic observations and a new chapter, "North America outside the glacier-covered regions", relies almost entirely on faunal or vegetational interpretation. There are also the two very comprehensive chapters on Quaternary fossils which have been enlarged and extensively rewritten.

We cite as examples of new material on physical processes and interpretation the thorough review of snow line, the large addition of sedimentological studies in one of the two chapters on glacial drift, and the greatly expanded chapter on fluctuations of sea-level. The latter section, nearly twice its old length, has been revised completely to stress the importance of terrace sediments rather than terrace elevations in correlation and interpretation. In these and most other sections the author has been able to extract pertinent ideas from a large, and frequently complicated and controversial, literature.

"Glaciers of today" is a chapter that will be of considerable interest to the readers of this journal. It is, in general, an excellent review of existing knowledge and goes a long way toward bridging the gap between the physicist and non-specialist reader. However, it is unfortunate that the recommendations of this journal (Vol. 8, No. 52, 1969, p. 3) have not been used when dealing with such terms as "annual snowline", "net mass budget" and "regimen". The section on net mass budget would benefit from a more formal tabulation of the component parts of the mass balance equation together with their relative significance. The suggestion, at the bottom of p. 37, that latent heat can be neglected when considering ablation is decidedly misleading. The paragraphs dealing with "movement" include a very clear explanation of the way in which a glacier moves, but Flint's use of mixed units leads to some confusion. For instance, to be compatible with the units listed on p. 39, the equation for

shear stress on the same page should be $\tau = 10^{-6}\rho gh \sin \alpha$ and that for surface velocity on p. 42 should be either

$$V_1 = (\rho g \sin \alpha)^{3/4} h^2 / 2B^3$$

for a very wide glacier of uniform thickness, or

$$V_1 = (\rho g \sin \alpha)^{3/4} h^4 / 16B^3$$

for a glacier with a semicircular cross-section. With $B \approx 2$ in these equations, V_1 becomes the surface velocity in cm a^{-1} . We feel that SI-units should have been adopted throughout the book, particularly in view of the recommendations in the *Journal of Glaciology* (Vol. 7, No. 50, 1968, p. 151).

Despite these criticisms, the introduction to the dynamic background and simplified mathematical generalization is most useful. Many readers may be disappointed that a similar treatment was not also applied to such topics as glacial erosion, drainage, aeolian features, or stream regimens where there is a relatively large and recent quantitative literature. However, the discussions of these topics do give a good account of the problems and their applications to glacial geology and the detailed aspects may usually be found in the extra references conveniently cited by the author within individual chapters.

Some indication of the trend and progress of "Quaternary" science can be drawn from the great quantity of detailed palaeoclimatic information found in the literature to-day. No longer is it sufficient to describe the physical results of glaciation, the sediments, or associated drift sheets. With the diverse field and laboratory techniques now available, we are more than ever attempting to make detailed climatic or geographic inferences from our field data. The results of a good cross-section of climatic analyses are included in the new chapter "Late-Cenozoic climates". No less than 11 figures are given with climatic curves, including some of the more interesting work from "Camp Century", Greenland. The attempt (stated in the preface) to integrate new fields of study such as pollen stratigraphy, sea-floor stratigraphy and isotopic geochemistry into the classic work shows up in this systematic chapter and even more clearly in the regional stratigraphic histories of the following chapters. Here, many detailed correlation charts such as those for Wisconsin stratigraphy in North America or Weichsel sequences of Europe are presented for the first time in this series of texts.

Whether the general treatment of European late Tertiary stratigraphy or for that matter the discussions covering other areas of the world, will satisfy all local specialists is doubtful (and probably a good omen for future research); the literature is vast in most cases and stratigraphic compilations or interpretations by individual authors are relied upon here more frequently than in the chapters on North America. Most readers will welcome the realistic displacement of the classic Alpine stratigraphy to a less commanding position in the European review but as implied by Flint, the terms presented and the discussion may appear controversial to those familiar with the details. Likewise, the great increase in knowledge and dating of ice-marginal fluctuations in Antarctica is clearly presented although individual specialists will disagree with the timing or sequence of particular fluctuations presented by the author.

Two of the most useful features of this text (and of the previous volumes which enjoyed wide circulation) are the clear definitions and comments thereon. Most of the less familiar terms such as "diamicton" or "geopolarity units" are introduced with accompanying figures or tables. Recommendations are made to drop some of the older usages, e.g. "Quaternary and Tertiary systems", or "classic Wisconsin" while at a few points modification of commonly accepted definitions is recommended. Glacial geologists should note for example that the terms "glaciation" and "interglaciation", or "stade" and "interstade", are classified as glacial-stratigraphic units by Flint without the strict and unrealistic climatic implications imposed by the American Code of Stratigraphic Nomenclature.

Many will find faults with *Glacial and Quaternary geology* to add to the very few we have thought worth while to cite. Some may wish more detail, a more or less quantitative treatment, while others will find they are not satisfied with the historical treatments given for various regions. Most of us will complain strongly about the high purchase price. However, by any reasonable measure, it is an important contribution to glacial geology and understanding of the late Tertiary, and certainly the most up-to-date one-volume introduction to the subject written for English-speaking readers. Quite fittingly, the work is dedicated to the "Friends of the Pleistocene", the very successful "nonorganization" Richard Foster Flint helped to found many years ago.

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