

L. LLIBOUBY. *Traité de glaciologie. Tom. 1. Glace—neige—hydrologie nivale.—Tom. 2. Glaciers—variations du climat—sols gelés.* Paris, Masson et Cie., 1964–65. 2 vols.: vi, 427 p.; 429–1040 p., illus., maps. Fr. 140, 190.

IN a postscript to this comprehensive work, Professor Lliboutry records how its compilation lasted five years during which the growth of glaciological literature threatened to be greater than he could assimilate or edit, and he says that he suspects he will be the last to achieve such a synthesis. The task he set himself is truly vast. He attempts to introduce the reader to all the important fields of glaciological work, whether they are physical, geological, geographical or meteorological, and to do so in considerable depth so that it is based for the most part on the original papers, and the main theories are developed in full in this work. The resulting two large volumes are necessarily somewhat daunting to contemplate, but the rewards to be gained from reading such a synthesis are considerable, provided it is genuinely authoritative and does not omit important developments. Such a work is more than a textbook, it is a valuable source-book for future workers to use to lead them into the literature of their subject, spread as it is among the learned journals of many disciplines.

Whether any one individual can do this completely satisfactorily is doubtful, and the present work, magnificent though it is, suffers from some faults that probably spring from the impossibility of one man doing all that is necessary in the time available. The coverage of the volumes is excellent, but the ability to use the vast amount of literature they condense is reduced by the unfortunate fact that the method of referring to papers cited in the text is somewhat inadequate. No clear indication is given in the text to tell the reader which of the authors mentioned are represented in the collections of references at the ends of the chapters, nor is it clear in all cases which pieces of work are to be found in which papers, and there are many surprising omissions from these lists of papers which readers might want to consult to read further about work described in the text. Thus on p. 224 Lliboutry refers to Bader, 1955, as having derived a density at which snow becomes impermeable, but 1955 is not the date of any of the three papers by Bader quoted, while on the next page radiation crust is said to be described by Kotlyakov, but in which of the three papers quoted is not stated. As examples of omitted references, it will be hard for the reader to follow up remarks such as that on p. 331 that Swinbank and also Cramer and Record have made a direct measurement of heat flux under certain circumstances—neither paper appears in the references, nor does a paper by Shelzer, referred to on p. 379. Further examples are a paper by LaChapelle quoted as the origin of a figure on p. 448 and an interesting reference to how the variation of specific budget with height varies from year to year in northern Tien Shan, referred to on p. 455 as due to Kalmynkina. These are but a few of the many examples that this reviewer happens to have noticed without a systematic search. It is possible that some of the missing references occur elsewhere in the book, but the apparently deliberate omission of an author index (in his preface the author seems to think these are only of use to administrators!) makes it virtually impossible to tell.

The work starts with an introduction on glaciology and its historical development, which is a useful brief review, and then gets down to business with a chapter on the physics of ice. This, as might be expected from an author with a physics background, is quite well presented, though the reviewer would question the ease with which the author gets over the zero-point entropy of ice by remarking “this seems contrary to the Nernst Heat Theorem but we know that hexagonal ice is not the stable form at absolute zero”—do we? If it is not, what is? All the evidence so far indicates that the cubic form of ice is not stable under any conditions, and that, even if it is, it has the same sort of entropy problem. If ice is ferroelectric according to the Kahane model favoured by Lliboutry, then it should have a much lower entropy in that state than is calculated from the Pauling model, and this should be capable of experimental verification. This chapter contains a useful summary of the formulae for the depression of the

freezing point of ice under a uniaxial stress, though again the reference problem arises since while Weertman is mentioned in the text, he does not appear in the references, while Kamb appears there but not in the text.

The next chapter deals with the mechanical properties of ice and is again overall a useful treatment, though the author is not very clear on dislocation theory. On p. 75 he seems to imply that screw dislocations cannot contribute to the plastic deformation of ice—he says “only edge dislocations, whose line lies in a slip plane . . . contribute to plastic deformation in ice”. It is probable that he meant to imply that edge dislocations on other slip planes do not so contribute, but coming shortly after the clear definitions of edge and screw dislocations, this cannot but mislead the novice, as will the statement that only dislocations that come out from the surface can produce visible deformation (p. 80). It is also untrue that work softening (the phenomenon that allows ice single crystals to creep at increasing rates as time proceeds) is peculiar to ice (p. 78). It also occurs in LiF, germanium, and many other non-metallic substances.

The third chapter deals with the petrography of ice with a general description of the crystal shapes and orientations of different forms of ice. In this the change from vertical to horizontal *c*-axes in ice formed from the liquid is not discussed, indeed in this and the next chapter on sea and fresh-water ice the impression is given that ice grown by the freezing of fresh water from the top always produces columnar crystals with their *c*-axes vertical, while sea ice always grows with its *c*-axes horizontal. Apart from this, the petrographic chapter summarizes succinctly the various forms of ice, a subject dealt with at much greater length by Shumskiy, and the chapter on sea and fresh-water ice reports briefly on lake and river ice, and in much greater length on sea ice, its forms, formation and mechanical properties. There follows a chapter on hydrometeors, in which cloud physics and the formation of solid precipitation and frost phenomena are described. This chapter also covers snow survey measurements and the isotopic constitution of snow. Having reached snow the next four chapters deal with the evolution of snow cover, the mechanical properties of snow, snow in civil engineering and the thermal balance at the surface. These four chapters constitute nearly half of the first volume. They represent a very considerable treatment of snow science, and with the wide range of coverage, will be most useful to many readers. One small criticism concerns the apparent use of grains and crystals as synonyms in the discussion of the study of snow stratigraphy on p. 228–30. The work of Schytt (1958, p. 52) in the Antarctic has shown that it is often dangerous to assume that a grain is necessarily a single crystal. The tenth chapter discusses ablation and refreezing forms on both snow and ice. Here the author discusses the penetration of radiation into ice and ablation forms produced by the resulting melt water. Among these he includes seracs, of which he says that summer rains melt the seracs and transform them into blades and needles of ice. It would be interesting to see evidence of the relative importance of rain and of radiation and sensible heat in this transformation. From here the next topic discussed is penitentes, on which Professor Lliboutry is very knowledgeable indeed, and the account is a useful short summary of our knowledge commendably not given too much emphasis. The effects produced by morainic cover and by the greenhouse effect are then discussed as well as other melting and refreezing forms. The final section of this chapter concerns ogives, a subject still somewhat controversial. In a brief account he favours Nye's theory of wave ogives and (rather less convincingly) a consequent origin for the dark stripes—his explanation does not seem to account for the presence of large boulders as opposed to small debris in the Forbes bands of many glaciers. The final chapter of the first volume concerns the temperature in snow covers and glaciers.

The second volume, which is quite markedly larger than the first, is mostly devoted to glaciers. It starts off with an introductory chapter called “Generalités sur les glaciers”, in which the definition of glaciers and the various proposed classifications are discussed, as well as matters concerned with the mass budget of glaciers, and the kinematics of flow. This is

followed by a substantial chapter on the geographical distribution of present-day glaciers, a chapter which commendably, if surprisingly, does not overemphasize the European glaciers in the Alps (1½ p.) in comparison with other areas. In this otherwise very comprehensive chapter, I felt the Barnes Ice Cap in Baffin Island might have been discussed a little more to bring out its very peculiar situation, sited as it is on bedrock not noticeably higher than in many other neighbouring places; its origin is a matter of great interest. Also no mention is made here of glaciers in the North Island of New Zealand, though the ice cover on Ruapehu is mentioned much later when discussing ice-dammed lakes. In this chapter, too, I missed a reference to the comprehensive paper of Hoel and Werenskiold (1962) when dealing with Norwegian glaciers.

The fourteenth chapter deals with geophysical and glaciological techniques, and the fifteenth with stresses, strains and crevasses in glaciers. This chapter will be somewhat too mathematical for any but the best equipped glaciologists, but for them it is a most useful summary of our knowledge derived completely from the beginning. From an historical point of view he credits Somigliana and Lagally with the explanation of marginal crevasse patterns, though Hopkins (1862) derived these over 100 yr. ago, and in discussing shear planes no mention is made of the first observation of actual shear movement on such a plane by Chamberlin (1928), but on the technical side this chapter presents a good introduction to and critique of the Nye theory of glacier flow, as of its predecessors. This is followed by a chapter on the slip of a glacier on its bed and sudden glacier advances. This is of course not only a controversial subject, but one in which Professor Lliboutry is one of the main active workers. We have here a statement of his position as at the time of writing; a point of view criticized by Professor Weertman elsewhere in this issue, and a further statement by Professor Lliboutry is promised for a coming issue, but this section is only a small part of the whole chapter, which contains a most useful review of the experimental measurements of relevance to the subject and of sudden glacier advances and kinematic waves. In this analysis Professor Lliboutry makes the useful distinction between a glacier with an equilibrium profile, defined with respect to mechanical forces, and one with a stationary profile, resulting from a balanced mass budget, a useful distinction in considering glacier stability, even though it leads to the at first sight strange statement that a glacier for which the conditions at the bed change (for example by reaching the melting point) may undergo an advance while having a stationary profile at all times. Following this, there is a chapter on glacial erosion and deposition in which the various mechanisms are discussed and an estimate of their efficacy is given. This is a subject that is fraught with difficulties at the present stage of our knowledge of glacier flow, and the great difficulty of explaining large amounts of subglacial erosion is described. While no answers can yet be given to all these problems this account will help to remove some loose thinking on the subject. Following this there is a chapter on the fluctuations of temperate glaciers, which details the historical evidence though curiously omitting the recent advances of glaciers in the Pacific Northwest of the U.S.A., and also presents the kinematic wave theory of Finsterwalder and its developments by Nye, and then there is a chapter on the flow and auto-evolution of ice sheets and post-glacial uplift. In this the possibility that the ice sheets modify their own budgets by having a profound effect on the atmospheric circulation is taken as the starting-point for a discussion of the various possible modes of evolution and disappearance of ice sheets, as well as the more usual subjects of flow of an equilibrium ice sheet, and theories of isostatic rebound.

Professor Lliboutry then turns to climatic variations in a chapter which works back from recent fluctuations to palaeoclimatology, setting the scene for a further chapter on the glacial periods and their causes, in which he favours the Ewing and Donn theory of auto-oscillations within a glacial period itself determined by the location of poles relative to land masses.

The final section of the book concerns frozen soil. There is one chapter on its formation,

mechanics and mechanical properties and another on the effect of frozen ground on the soil and its effect on engineering works.

The whole work is thus a vast coverage of glaciology, and in the postscript the author indicates how the method of its preparation allowed him to bring parts of it up to date so that it was possible to include advances made right up to the year of publication. This will certainly extend its life as an introduction to current glaciology, even though in some places ideas that will prove temporary may have been given undue prominence. The text is illustrated by 80 plates, grouped together in groups of about 4 to 16. These are of a very high quality and add considerably to the value of the work. Unusually, for a French book, it is bound and has an index, though the latter is rather minimal—it does not include “moraine”, for example. Its price is, by any standards, very high, reflecting no doubt the relatively limited circulation that can be expected, but this is a great pity as it will no doubt deter many individuals from buying it and benefiting from having all this information available to them, for I am sure it will be much used by any serious glaciologist for many years to come. To sum up, this is a very important and remarkable work, and it is a pity that it is marred by relatively minor faults which will, nevertheless, be very annoying to readers.

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