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of North America must be largely reconstructed from the observations of travelers and studies made from other viewpoints ; hence it will, of necessity, be incomplete. »

Nevertheless a scanning of the hundreds of references cited throughout the text convinces the reviewer that Shelford failed to use the rich, available geographical and historical literature for relevant and supporting environmental-cultural evidence about the sixteenth century. The book tends to over-stress certain known facts of historical biology without actually reconstructing sixteenth century environment. This oversight leads the text away from the ecological past to emphasize the ecological present. After reading a few chapters it becomes obvious that the author could have presented a sounder, more thorough ecological interpretation of the pre-European settlement period by using standard, well-known geographical references like Brown, Sauer, Thomas, and many others. These omissions lead to unfortunate statements in the text. One obvious example can be cited in Chapter 2, The Temperate Deciduous Forest Biome, when Shelford states : « Fire was sometimes used (by the Indians) to remove trees, and fires also resulted from lightning. However, fires were generally unimportant, since the shady forest held considerable moisture and the many streams prevented their spread. » The latter statement is completely false as illustrated by many examples in the Appalachians. Numerous glades and meadows were formed there by repeated Indian burning. Perhaps even the origin of « balds » in the Southern Highlands stem from a similar human cause. Likewise « Indian Old Fields » existed in various parts of the Piedmont Plateau and in the Ridge and Valley province before the period of European exploration and discovery in the sixteenth and seventeenth centuries.

Another major criticism of the reconstruction of the sixteenth century is the volume's imbalance of environmental characteristics. Edaphic conditions are almost totally neglected for this period, while topographic features fare only slightly better. Little if anything is mentioned about past climatic events, such as pluvial versus dry cycles in the southwest, the natural agency of lightning strikes in the Sierra Nevadas, the effects of salt spray and wind shear on Pacific Coast communities, and so on. All of these conditions, plus many more, were apparently just as prevalent in the sixteenth century as they are today.

In summary, this book approaches the claim of enabling ecologists to better interpret present-day conditions by giving them useful background information on the ecology of North America. However, it falls short of its goal of being an ecological reconstruction of sixteenth-century North American environments. Further, the volume hits and misses at establishing a means of evaluating the changes in North American animal and plant resources wrought by civilization over the past four hundred years. The book will not appeal to the average farmer, sportsman, or general readers (as claimed on the front jacket) due to its scientific style. For the serious student of ecology, however, the work will aid and indeed stimulate further efforts « to learn the structure, composition, and dynamics of the original communities of North America before they finally succumb to the advance of civilization. » Perhaps for modern ecologists and biogeographers this quote by Shelford is no longer feasible.

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## GÉOMORPHOLOGIE

LLIBOUTRY, Louis. **Traité de glaciologie.** Tomes I et II. Paris, Masson & Cie, 1965.

Glaciology, as Professor Lliboutry points out, is « l'étude de toutes les formes que prend la glace dans la nature, de leurs circonstances d'apparition et de l'action de la glace sur les sols ou sur le relief ». Its techniques thus are as diverse as its subject matter is wide ranging. In recent years, particularly since the International Geophysical Year, the output of glaciological publications has been enormous, and the subject continues to advance at a rate which makes difficult any attempt to keep abreast of advances. The absence of a good general treatise dealing with the entire range of glaciological topics has been very apparent, and it is fortunate that this gap has now been filled by the publication of Professor Lliboutry's two volume work.

The more obviously practical sides of glaciology, such as the forecasting and control of avalanches, the study of the mass balance of glaciers which are used as a source of water for hydroelectricity schemes, and the investigations of those characteristics of the snow cover which are of importance in constructional and engineering projects in the Arctic and Antarctic, could not develop without advances made in our general knowledge of ice and snow, and in theoretical considerations of their behaviour. It is satisfying, therefore, to see much of the *Traité de glaciologie* devoted to the physics, mechanics and petrographical characteristics of ice.

Volume One deals with the physical and mechanical properties of ice and snow. The dynamics of avalanches and methods of avalanche control are discussed at some length, and there is an interesting section dealing with temperatures in snow and glaciers. A discussion of the temperature conditions at the base of the inlandsis is included. Surface features of glaciers and snowfields are described, and there are some particularly striking and beautiful illustrations of *pénitents* resulting from solar radiation and evaporation.

Geographers will find much of interest in Volume Two of the work. Investigations during the International Geophysical Year greatly increased our knowledge of the world distribution of ice and permanent snow. Professor Lliboutry, for instance, mentions the 955 glaciers discovered in Nan-Chan, in the Chinese People's Republic, where they cover 1,280 km<sup>2</sup> between Tibet and the Gobi Desert. In a lengthy section dealing with the world's major ice-covered areas, he indicates the location of most known glaciers. Several maps are included, but the small scale somewhat reduces their value, and the absence of a key is a drawback to some, particularly to the map of the Alps (fig. 13.1). European glaciologists will find particular interest in the accounts of the glaciers of Asia and South America, and all will welcome the summary of recent advances in Antarctic glaciology.

The chapter on *Les grandes glaciations et leur origine* will be read with interest. Lliboutry emphasises that it is unwise to assume that all glaciations depend directly upon a single external cause. Palaeoclimatic studies must be undertaken in the southern hemisphere, since almost all theories of ice ages depend upon assumptions concerning the simultaneous occurrence of glaciations in the two hemispheres.

Lliboutry, who supports a theory along the lines of that proposed by Ewing and Donn, draws attention to the possibility of spontaneous *auto-oscillations* of temperature and glaciations arising from variations within the system constituted by the atmosphere, the oceans and the ice sheets. A periodic impulse from outside the system could control the period of oscillation, and Lliboutry suggests that variations of the plane of the ecliptic, with a period of about 41,000 years, dominate the occurrence of successive glaciations. When the continents are conveniently situated in relation to each other, whilst mountains exist at latitudes high enough to serve as centres of glaciation, and the atmospheric content of carbon dioxide is low, then ice sheets appear in one hemisphere. Their development leads to freezing of the ocean and to the formation of stable anticyclones. During each glaciation in the hemisphere of onset, the ice sheet in the other hemisphere increases because of the glacio-eustatic marine regression. This increase is only partially offset during the subsequent interglacial, so that the ice sheet increases more and more. Cessation of the conditions favourable to glacial auto-oscillation is caused, above all, by the modifications of relief which result from erosion and orogenesis. Lliboutry concludes that we are probably now at the beginning of an interglacial period, and that numerous glaciations must succeed each other in the future. However, their appearance and disappearance always will be sufficiently slow for man to have time to adapt himself to the changes.

Much of the *Traité de glaciologie* is given to an analysis of problems associated with the flow of glaciers. For several years Professor Lliboutry has devoted attention to the nature of basal sliding, which remains one of the major unresolved aspects of glacier behaviour. He has gradually refined his contribution to the theory, and his principal achievement has been to draw attention to the possibility that the detachment of glaciers from parts of their beds may lead to an increase of the rate of sliding. Field observations of a « stick-slip » motion of ice against bedrock lend support to his idea that alternating quasi-static and dynamic friction occur there under certain conditions. Lliboutry believes that subglacial cavitation may be more important in controlling the sliding velocity of a glacier than are the alternative processes of regelation, slip and

plastic flow. However, seasonal variations of flow at the upper surface of glaciers are now known to be fairly common, and it seems clear that the availability of water at the bed is important, especially where basal sliding is responsible for a large part of the movement measured at the upper surface. It is unfortunate that numerical values assigned to certain factors which influence the working out of the theories cannot adequately be checked in the field. Observations made beneath glaciers in Norway and in the United States of America, however, suggest that predictions of plastic deformation against obstacles less than about one metre in size are in error.

Weertman has proposed that certain catastrophic advances of glaciers may be due to a sudden increase of the amount of water at their beds. Lliboutry, however, believes that the most likely cause is a change of temperature conditions resulting from a change of the mass balance of a cold glacier. If ice formerly buried by snow and firn becomes exposed at the surface, a considerable increase of the temperature gradient in the glacier may result, so that the bottom, which previously was frozen to the bed, attains the pressure melting point. The ice then becomes detached from the underlying rock. It is possible that, when sliding starts, the glacier is in unstable equilibrium, since with subglacial cavitation the friction decreases with increasing speed. A catastrophic advance may then occur.

The *Traité de glaciologie* deals with many types of ice other than that of glaciers — ice on rivers, on lakes, on the sea and in the ground. Frost action in the ground produces a variety of features, several of them still not fully understood. Lliboutry's approach to these is by way of the mechanics of active processes, and he suggests that current, purely morphological classifications of patterned ground should be replaced by a genetic classification, the basis moving from geomorphology to geodynamics. As the forms evolve principally during short periods of activity of the soils, measurements of soil temperature and humidity should be made during these periods. Professor Lliboutry believes that seven elementary processes are important, and he examines each of these in detail. He excludes wind action, which he considers to have been exaggerated by other writers. An extensive review of investigations which have been carried out by workers in the laboratory as well as in the field is accompanied by an analysis of some of the many theories proposed to explain forms developed by frost action in the surface mantle. The importance of careful studies of the effects of ice in the ground is indicated by an account of the problems associated with construction of foundations, buildings and routeways in areas of frozen ground.

In discussing glacial erosion, Lliboutry points to the general lack of basal moraine at temperate glaciers which are stationary or receding, and suggests that proglacial erosion is much more effective than is subglacial erosion. Although advancing glaciers do not erode much more *in situ* bedrock than do receding ones, they may remove considerable masses from the terrain previously weathered by frost action; a layer of debris may be incorporated into the base of the glacier as a result of refreezing of meltwater at the downstream side of obstacles. Whilst one agrees wholeheartedly with this view, some doubt must be thrown on the suggestion that seasonal oscillations of the glacier front may be important, since many glaciers undergoing general retreat today do not display minor readvances during the winter. One must support Professor Lliboutry's statement that much more study of actively forming moraines is essential.

The *Traité de glaciologie* is extremely well produced, and the quality of the illustrations is superb. The index, though brief, is helpful, and the extended summary of the contents aids the reader to find the whereabouts of particular matters in which he is interested. The general presentation and lay-out of the two volumes is clear, and useful lists of references, including many of recent publication, are included at the end of each chapter. Readers who are not mathematically minded should not be deterred from taking up these volumes by the extensive use of equations and formulae, for there is much of interest in this fine work not only for the specialist but also for the mountaineer and the skier.

Professor Lliboutry and his publishers are to be congratulated upon their achievement.

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