BOOK REVIEW

The Climatic Record in Polar Ice Sheets. Ed. G. de Q. Robin. Cambridge University Press, Cambridge, 1983. 212 pp. £32.50.

Impurities trapped within the polar ice sheets have preserved a frozen record of climate extending at least into the last ice age. Most progress in the last 15 years has been made in the study of stable isotope variations in ice cores which have given exciting new evidence for temperature changes both during and since the last ice age. However, a variety of complicating factors have made it difficult to interpret quantitatively past temperatures, particularly at great depth in an ice core. This has generally slowed the acceptance, by other disciplines, of isotopic evidence for past temperature changes.

Against this background, in 1973 Gordon Robin convened an international workshop at the Scott Polar Research Institute which brought together specialists from the field of stable isotope glaciology and those concerned with modelling present and past ice sheet dynamics. Their specific purpose was to examine the connection between stable isotopes and temperature and to test its validity in times past by combining surface temperature changes deduced from isotope studies with flow models of the ice sheet. In this way they were able to calculate temperature profiles with depth through the ice sheet and compare them with directly measured profiles.

Ideas for this monograph were drawn up at this meeting. Although the theoretical development and results of the modelling studies have remained central to the whole work, a major part of the book gives a broader perspective to the problem. It examines in detail related data and techniques which must be considered in order to achieve an insight into the past behaviour of polar ice sheets. The first part of the book examines the evidence for past variations in the dimensions and flow patterns of the Antarctic and Greenland ice sheets. It draws on observations by glacial geologists and deductions from theoretical models. Necessarily brief, these sections will be of particular value to non-specialists in glaciology who need to understand the physical basis on which ice core data are interpreted. These interpretations are dependent on a knowledge of many parameters which influence the behaviour of an ice sheet.

A substantial chapter, which brings together papers by authorities in each field, provides a valuable and up-to-date review of the most widely used techniques for measuring parameters such as ice flow, thickness, accumulation rate and temperature. In each case, due importance is given to the accuracy of measurement and the confidence in its interpretation. This section also surveys the factors that control the present-day distribution of stable isotopes over the ice sheets and examines the influence of diffusion processes which tend to smooth the isotope record in a deep core.

The scene having been set in the first half of the book, Chapter 4 lays down the data base available for modelling. With the exception of data from the recent Dye 3 borehole in Greenland, temperature and isotope profiles for all the major boreholes on both the Greenland and Antarctic ice sheets are presented. Although not comprehensive, in view of the enormous potential volume of data, each profile is given in sufficient detail for climatic variation studies. The profiles are primarily plotted as a function of depth to emphasize the fact that age scales, a more usual form

of presentation, are dependent on the assumptions built into a particular model of ice flow, and it is often difficult to assess fully their reliability. Confidence limit bars have been introduced at intervals along each profile to indicate whether the deviation of a particular isotope value from the mean trend line truly indicates a temperature fluctuation. For each drilling site there is a useful summary of topographic and glaciological characteristics of the site together with a brief discussion of the more important features of the isotope profiles.

By this stage of the book the reader has been well prepared to move into the 'core' of the monograph that develops in detail the models which are then used to calculate the present-day temperature profile through an ice sheet given a knowledge of the ice sheet dynamics regime and the time-series of isotope-derived temperatures from an ice core (based on the present-day conversion factor). This section requires a working knowledge of physical glaciology in order to appreciate detailed features of the models, and their limitations. However, it has been written as a self-contained section so that the reader may move on to the conclusions and tests of the models against authentic data, at the climax of the monograph, without losing the general argument.

Two complementary approaches to modelling are described. The first considers heat flow down a vertical column fixed in space through which ice is moving, whilst the second, the flowline model, follows a parcel of ice along a flowline to trace the horizontal temperature gradient. Both models were applied to the Camp Century data, and both supported the main conclusions that the present-day temperature distribution through the ice sheet can be matched very closely by models in which the ice sheet is allowed to build up over the last 15 000 years under a temperature regime calculated from the time series of isotope values. Close matches were also obtained for the Byrd and Vostok cores in Antarctica, using the flowline model.

The total change in temperature deduced from isotope values includes the effects of changes in both climate and elevation. In general elevation change itself is a combination of downslope movement of the ice and changes in ice thickness. These problems are considered in one section covering measurements of the total gas content of the ice. From these measurements it is possible to estimate the atmospheric pressure, and hence surface elevation of the ice sheet in the past. The correction can be a large one. For example in the case of the Camp Century core it is estimated that of a total inferred temperature change of 18 degrees between the coldest part of the last glaciation and the post-glacial period, around 10 deg. resulted from an elevation change and only 8 deg. was due to net climatic change in the region. Whilst the modelling studies have clearly verified the connection between isotopes and temperature over time scales of thousands of years and shown that long-term climatic changes may have been similar over large areas of Antarctica, they could not achieve a good match in the uppermost part of the ice sheet (covering approximately the last 400 years).

In the final chapter Gordon Robin looks more closely at the connection between isotopes and temperature on shorter time scales (15–100 years). By introducing the concept of 'isotopic-temperature noise' (short-period isotope variations unrelated to temperature) he has been able to evaluate the effective error in mean temperatures derived from averaging isotope values over varying periods. Areal irregularities in snow deposition, melt-water percolation and the sampling pattern of an ice core all contribute to variance in the isotope value which would not be duplicated in an adjacent core and hence would not reflect a real temperature shift. Such considerations are essential in order to make a proper comparison of data from different ice cores and to relate climatic records from ice cores to those from other

sources. In a brief conclusion the deep ice core records from both Greenland and Antarctica are brought together and compared with worldwide climatic trends over the last 130 000 years.

This monograph makes a very important contribution to the rapidly expanding literature in the field. It should be essential reading to scientists from many disciplines who need to understand the physical basis and limitations of isotope-derived temperatures from ice sheets. Broad in scope, the work has been very carefully compiled, clearly illustrated and shows a high level of coherence often assisted by well-placed and substantial contributions from the editor. Although much progress has been made in the field since the monograph was initiated most of the individual papers reflect work and ideas that have been published up to 1982. The main exceptions are in some of the short background papers in the earlier part of the work but these omissions are not serious and in no way detract from the value of the whole.

We should now have much more confidence in the exciting prospect that future deep cores from the polar ice sheets will help us to unravel the history of world climate and improve our understanding of the causes of ice ages.

D. A. Peel