the elegance with which the experimental biologist demonstrates the subtlety of the relationship between changing environment and plant or animal response, even under the necessarily simplified conditions of his laboratory, most of us are still all too ready both to propose simple climatic explanations for observed biological variations and to rely heavily on evidence from fossil plant and animal remains for quantitative indications of past climatic change. Other lines of evidence, especially for pre-instrumental variations and for very long-term changes, are unfortunately still scarce. However, if it is accepted that we need to know more about long-term climatic variation, and that biological evidence will inevitably contribute to the analysis, then a more critical use of the results in the light of recent work in physiology, experimental taxonomy and genetics is required. In this way, we should perhaps move further away from the dangers of circular argument inherent in so much palaeoclimatology and nearer to providing a factual framework within which the genuinely accurate begins to replace the spuriously precise. Meanwhile, we should take note of the following comment in the paper by Beverton and Lee: "It is deceptively easy to deduce causal connections between two sets of fluctuating data, especially when their reliability and true relationship, if any, are unknown". FRANK OLDFIELD

GEOCHRONOLOGY

Applied Geochronology

By E. I. Hamilton. With a chapter on Comparative Geochemistry by L. H. Ahrens. Pp. xiv + 267. (London: Academic Press, Inc. (London), Ltd.; New York: Academic Press, Inc., 1965.) 59*s*.

THE observation of radiogenic argon-40 in potassium-bearing minerals by Aldrich and Nier in 1948 heralded a new era in geochronology. The seventeen brief years which have elapsed since then have seen the establishment of routine analytical techniques for the dating of rocks and their minerals by the potassium–argon, rubidium–strontium and uranium–thorium–lead methods. Progress has been so rapid, in fact, that a considerable gap has appeared between practising geochronologists and the main body of geologists. It was Hamilton's purpose to help bridge this gap with *Applied Geochronology*.

Each major method has a chapter to itself, with the rubidium–strontium and common-lead techniques receiving the most detailed attention. The book opens with a useful, brief chapter on comparative geochemistry by L. H. Ahrens, followed by a historical sketch of the development of geochronology up to 1945.

Chapter 2 is a review of general methods. The techniques of stable isotope dilution and mass spectrometry form the backbone of geochronology and receive detailed description. However, it should be noticed that the two principal equations of isotope dilution are stated incorrectly and there are several minor errors in the account of vacuum technology.

An extensive summary of the various methods of potassium and argon analysis is given. The section on potassium will be found particularly useful. Since the original measurements of Aldrich and Nier, tremendous strides have been taken, and this method is now being used to date rocks in the age range 30 thousand years to 4·5 billion years. Hamilton rightly emphasizes the contribution of Reynolds with his pioneering applications of the ultra-high-vacuum method. This chapter ends with a short discussion of the problems of interpretation of potassium–argon ages obtained on minerals from igneous, metamorphic and sedimentary rocks.

The principles of the potassium–argon method are immediately apparent to the geologist. The rubidium-strontium, uranium–thorium–lead and common-lead approaches, however, are in general not so readily digested, and each one makes a strong appeal to graphical representation. These three topics are dealt with in Chapters 5, 7 and 9 and occupy almost half the book. Until 1958, it had been usual to examine separated minerals with the rubidium–strontium method. Then, in rapid succession, Schreiner in South Africa and Compston and Jeffery in Australia extended their efforts to include samples of whole rocks. It was clearly demonstrated that it is often a risky business to date a rock solely by examination of its separated constituent minerals. Mild tectonic disturbances readily cause the migration of isotopes in and out of minerals to yield anomalous mineral 'ages'. However, in a very large number of cases the average diffusion length is sufficiently small to allow volumes of the whole rock to remain effectively closed systems. Compston and Jeffery emphasized that not only the age of emplacement, but also the initial strontium-87/strontium-86 isotope ratio may be experimentally determined by whole rock analysis. Hamilton devotes much space to a consideration of their graphical representation of whole rock and mineral data. His treatment of this presentation is, however, not so clear as his account of the graphical plot developed by Nicolaysen. The application of the whole rock method to the dating of sediments is discussed and is illustrated by reference to the work on the Hamilton Shales by Whitney and Hurley. Finally, the petrogenetic significance of strontium isotope ratios is illustrated.

The interpretation of uranium–thorium–lead ages is based on the work of Ahrens, Wetherill and Tilton. Ahrens observed that suites of minerals yielding discordant lead ages produced a straight line when their lead-206/uranium-238 ratios were plotted against the corresponding lead-207/uranium-235 values. It was then shown by Wetherill that such a pattern would result if the minerals were all formed simultaneously and remained completely closed systems apart from undergoing a single period of lead loss during their history. He further showed that the two points of intersection of the straight line with the 'concordia' curve gave the times of mineral formation and metamorphism. Tilton then proved that a similar pattern (over a wide range) ensues if, in fact, lead has been continuously diffusing from the crystals throughout their existence. These various arguments are discussed and illustrated with examples from the literature.

Forty pages are devoted to the intricacies of interpretation of common lead isotope abundances. This is a fascinating topic, intimately bound up with the questions of the age of the Earth, the modes of formation of ore bodies, the growth of continents and the uniformity of the mantle. Hamilton reviews the somewhat contrasting theories of Gerling, Holmes and Houtermans, on the one hand, and Alpher and Herman, and Cumming, Russell and Farquhar on the other. One wonders how many geologists will have the persistence to absorb the whole of this chapter. Their way will be somewhat straitened by the errors in some of the equations, but those who make the effort will be amply rewarded by the challenge to sit back and produce their own interpretations.

Applied Geochronology will certainly acquaint the geologist with the tremendous variety of methods available for determining geological ages. Apart from those mentioned in some detail in the foregoing, Hamilton discusses techniques involving carbon-14, rhenium and osmium, ionium and thorium and radiation damage.

The book also contains a wealth of useful references and deals in a pleasing way with work done in the U.S.S.R.

The geological reader, however, will be disconcerted by the imprecise style and the unusually large number of errors. Equations, numerical values of quantities and details of mass spectrometric technique are particularly ill-treated. The book is well produced and bound and the price is reasonable. DEREK YORK