Archaeological dating (Critique du livre de S. Fleming "Thermoluminescence techniques in archaeology")

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Earth science

Don L. Anderson

The Earth: Its Origin, Structure and Evolution. Edited by M.W. McElhinny. Pp.597. (Academic: London and New York, 1979.) £36, \$83.

THIS volume is a collection of 17 review papers written to honour the two outstanding geophysicists who were responsible for the development of earth sciences at the Australian National University in Canberra. Under the direction of John C. Jaeger and Anton Hales, the ANU has become a world centre of earth-science research. This book, written exclusively by present and past members of the Research School of Earth Sciences, is one of the most significant collections of papers on this vast subject to appear in some years. The 'subject' is the Earth, and the material is about equally divided between chemistry and physics. There are sections on the crust, the mantle and the dynamics of the core.

The crustal chapters include petrogenesis of oceanic crust, evolution of granitoids, and the relation of porphyry copper deposits to calc-alkaline volcanism. The power of isotopes and incompatible trace elements is fully exploited in chapters by Taylor, Compston and Chappell. The chapter by Green, Hibberson and Jaques withdraws the previous Canberra model for the origin of mid-ocean ridge basalts, the basis of the pyrolite model, in favour of the O'Hara model which had formerly been bitterly contested. Green *et al.* now prefer a picritic parent magma and conclude that there cannot be a simple direct genetic relationship between the mafic and ultramafic rocks of ophiolite complexes. This important conclusion, if verified, will make it necessary to reconsider the composition of the upper mantle.

There are four chapters covering the areas of geomagnetism, palaeogeomagnetism, polarity time-scales and apparent polar wandering, and one on the history of the Earth's rotation. Altogether there are 11 chapters with primary emphasis on geophysics.

The mantle receives a great deal of attention, but much of the discussion of composition and evolution is based on concepts developed before the constraints provided by isotopes, the incompatible trace elements and anelasticity were fully appreciated. Subjects covered include composition, structure, phase changes and elasticity. The chapter on mantle convection by Stevenson and Turner is one of the best of several recent reviews of the subject.

The chapter by Liu summarizes the large amount of information he has obtained in

diamond anvils on phase changes in mantle silicates. This productive, but exploratory, field of research has verified many of Ringwood's predictions about the crystal structure of various regions of the mantle. It is still uncertain at what depth these phase changes occur and what the physical properties, other than density, will be. For this, a large amount of *in situ* data and better controlled temperatures will be required. Liu has made a preliminary attempt to estimate density as a function of depth in various mantle mineral assemblages. One interesting point is that eclogite is denser than garnet-peridotite to a depth of about 500 km but is less dense between 500 km and 800 km. This seems to preclude subduction of oceanic lithosphere into the lower mantle. If verified, this will have enormous implications for the composition and evolution of the mantle and convection therein. Ringwood's chapter on the composition and evolution of the Earth develops the viewpoint that

the mantle is basically chondritic and homogeneous.

The book is rounded out with chapters on rock mechanics, earthquakes and plate tectonics.

The breadth of coverage from the faculty and alumni of a single institution is tribute to the wisdom and foresight of Jaeger and Hales who always managed to keep ANU at the forefront of earth science by picking the areas and people that would contribute most to the understanding of our planet. This volume is an important contribution to that end. It is probably the most comprehensive single volume on the subject of the origin, evolution and dynamics of the Earth presently available. It is unfortunate that its price will make it unavailable to students and many libraries.

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Archaeological dating

Georges Valladas

Thermoluminescence Techniques in Archaeology. By Stuart Fleming. Pp.233. (Clarendon/Oxford University Press: Oxford, 1980.) £15.50.

THE technique of dating by thermoluminescence (TL), a method which has been well established now for some dozen years, is discussed in articles scattered among many specialized journals. This book will therefore be welcome to physicists in that it gathers together the principles of the subject in one place.

The fundamentals of TL were developed in the Research Laboratory for Archaeology and History of Art at Oxford under the leadership of Martin Aitken. The author of this volume, Stuart Fleming, is one of the team of physicists trained in the laboratory at Oxford, and is thus well placed to have written this work, the fruit of experience acquired in the course of the investigations which were to provide the first absolute ages of ancient pottery.

Certain minerals making up a piece of pottery emit light when they are heated, and the older the pottery the more intense the light. The phenomenon is essentially due to the action of the radioactivity contained in the minerals. This action can be represented as the dose of radiation received by the minerals in question over the time elapsed since the original baking of the pottery, an act which destroys its initial (potential) TL. Thus the age of a piece of pottery can be deduced if the dose received in a single year is known. The book treats the following three, more or less

interdependent, subjects: (1) the preparation of the mineral after its extraction from the pottery; (2) the use of thermoluminescence to define the radiation dose received by the mineral — the archaeological dose; (3) the analysis of the radioactivity of the pottery and of the surrounding earth in order to deduce the annual radiation dose to which the mineral has been subject.

The preliminary pages are dedicated to crystalline TL and its measurement, and the properties of natural radioelements (uranium, thorium, potassium-40) and the dosimetry of α -, β - and γ -rays are the objects of a detailed analysis. The author examines the consequences of the structure of ceramics on the distribution of the radiation dose among its constituents. The radioelements are concentrated in the clay phase of the pottery and are practically absent from the crystalline inclusions. Among the latter, those which are of a certain size and occur frequently in ancient pottery, such as quartz grains, therefore receive a weaker dose than the clay fraction. Hence, α -rays penetrate to few of these grains which thus receive doses of nothing but β - and γ -radiation. This is not the case for micro-inclusions, for which the α -dose is important. Now, the TL induced in each circumstance has distinct properties. These facts lie at the root of the two principal methods of dating: the 'quartz-inclusion technique' (S. Fleming) and the 'fine-grain technique' (D.W. Zimmerman).

In Chapter 3, the quartz inclusion technique is discussed. Fleming analyses the properties of the TL of quartz and defines that interval of temperature best adapted to the determination of the archaeological dose. This is a method of great importance due to the reliability of

quartz as a dosimeter and the relative simplicity of the calculation of the annual dose. Fleming is primarily interested in pottery and does not consider the natural extension of this technique to the heated stones of prehistoric hearths (flint, quartzites, sandstone etc.), a method still in its infancy when the book was written.

Also in Chapter 3 there is a résumé of the elegant method which uses a very sensitive thermoluminescence dosimeter (fluorine) to measure directly the annual dose deposited by β -radiation in pottery. This method is also applicable to the measurement of the γ -dose coming from the soil. Here the problem of radon (radium emanation) must be considered, the active deposit of which is responsible for about 50% of the γ -dose, which therefore depends on the movement of radon in the soil. Chapters 2 and 6 give a very complete analysis of this problem.

The pre-dose technique (Chapter 5), which also involves quartz inclusions, has a use limited to those ceramics which have received a relatively low archaeological dose and are thus relatively young (< 1000 years old). On the other hand this permits it to be used instead of carbon-14 techniques which are practically useless for any period more recent than the fourteenth century.

Despite the difficulties which are inherent in it and which concern in particular the contribution of α -radiation

to the annual dose, the fine-grain technique has been brought up to the level of a routine measurement at Oxford. It is the subject of a detailed exposition in Chapter 4 which begins with the art of making the deposits of fine grains on aluminium discs which forms the basis of the whole method.

The last third of the book and Appendix E constitute an anthology of dates and of applications of TL to the authentication of ceramic artworks and of those bronzes which contain kernels of baked clay. Results bearing on the neolithic ceramics of Central Europe and Africa, relative to the Nok culture among others, are examples showing the great importance of TL for the dating of sites which in the absence of organic remains are not datable by the carbon-14 method. When the two methods have been applied simultaneously, the ages they have yielded are in agreement.

In conclusion, the methodological exposition is as complete as can reasonably be wished, given the present state of TL dating. Moreover, the book is rich in examples. Novices will find encouragement here to face up to problems which are still insufficiently resolved and archaeologists (particularly those strong in maths!) will discover the lucid explanations of the technique they have lacked until now. □

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A range of lattice path problems

Michael Berry

Lattice Path Counting and Applications. By Sri Gopal Mohanty. Pp.185.(Academic: New York and London, 1980.) \$24, £13.60.

CONSIDER the unit square lattice whose points have integer coordinates x, y , and let a 'path' be a sequence of steps between neighbouring points. How many paths run from the origin to the point with coordinates mn , ($m \neq n$) without touching the line $x=y$? It is with such problems, and their applications, that this book is concerned.

In the general case, where the lattice has more than two dimensions, where the paths are subject to more complicated restrictions (such as not touching boundaries of general form), and where diagonal steps are permitted, the enumeration of paths is very difficult. In many cases, however, recently developed combinatorial techniques make it possible to obtain solutions in closed form.

It is remarkable what a wide range of problems can be put into correspondence with the enumeration of lattice paths. The classical example, due to Bertrand, is to calculate the probability that the victor in

an election had more votes than the loser at every stage of counting. Another case is random walks on a line, for example the probability distribution of times when the walk (starting from the origin) first passes a given point. Other problems considered in the book are the lengths of queues, the enumeration of Cayley trees and the convolution identities (of binomial type) that can be proved by considering combinations of lattice paths.

For all problems treated, the exact solutions are given, involving for the most part binomial coefficients. In many cases, however, what are required are asymptotic approximations (for example as the number of steps tends to infinity), which are simpler and might be derived directly; but no such results are given here.

This is not an easy book to read. The author's style is terse, and the non-experts for whom the book is presumably intended will have to work hard to follow the argument. Such phrases as "one can easily show that" or "a little reflection will show" are unhelpful, and an argument alleged to provide "pictorial insight" would have been clearer if accompanied by an illustration. However, the book is greatly improved by the provision of extensive lists of references and challenging problems at the end of each chapter. □

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Large African wildlife

Brian Bertram

The Ecology and Conservation of Large African Mammals. By S.K. Eltringham. Pp.268. (Macmillan: London, 1980.) £15.

WE have waited a long time for this book — not only because Dr Eltringham has taken a long time writing it but also because there has been a conspicuous and lamentable absence of a book which spanned the wide and fascinating area of field studies of large African mammals. The author is thoroughly well qualified to fill the void. He was Director of the Nuffield Unit of Tropical Animal Ecology in Uganda, and has for years been Associate Editor of the *East African Wildlife Journal* (now the *African Journal of Ecology*). It is this journal which has published many of the results of the large mammal field studies conducted at the Nuffield Unit, the Serengeti Research Institute, the Tsavo Research Project and East African universities.

So Keith Eltringham knows his facts. What has he done with them that is new? Essentially he brings them together in one place, and he discusses in general terms not the various mammal species themselves but the differences between those species, the interactions among them, and human interaction with and influence upon them. The book thus complements the many excellent and detailed accounts, at both popular and scientific levels, of field studies of single species or groups. It is not a review of those accounts — rather it provides the background to them, plus a much needed dose of general knowledge, experience and common sense, which may be widely shared but is too rarely written down.

The book starts with a brief summary of the African regions, and a description of some of the techniques used in wildlife research, principally counting, marking and immobilizing methods. Each of the following six chapters takes a particular theme and considers the range of ways in which large African mammals behave in that respect. These themes are social structure and social behaviour, followed by territorial behaviour, then population ecology, reproduction, herbivore feeding and carnivore feeding. Three chapters on conservation, wildlife management, and Man and national parks complete the text. To my mind the last six chapters are much better than the four preceding ones. There is a valuable bibliography of over 400 references, maps of African national parks and reserves, and a useful list of scientific names of mammals each with its authority and date. There are 27 informative black and white photographs, about 20 tables and as many diagrams.