the archaeological record. Twenty to thirty thousand years ago the oldest known, definitive instances of such art pop up in archaeological sequences in several far-flung parts of the world, for instance South Africa, Australia and Europe.

John Pfeiffer's book deals with two questions. Why art? And why at this point in the development of the human condition? He tackles them by considering one class of art in particular, namely the representations which were painted, engraved and sculptured deep in the caves of France and Spain. He considers that the appearance of the art can best be understood in relation to new and crucial social needs. More specifically, he argues that by 30,000 years ago the volume of information to be transmitted from generation to generation in some societies had risen to levels such that indoctrination involving the dramatic presentation of materials was essential to ensure accurate uptake and further propagation. He argues that the representations in caves are surviving evidence of rituals which not only helped to establish the authority of those who controlled the elaborate rules but also encoded parts of the programmes in unforgettable ways.

The view that the deep-cave art of Europe was surrounded by magico-religious ceremonies is not at all new. What is new is the explicit argument that during the Upper Pleistocene the information load to be transmitted had become so complex that special encoding and dramatic mnemomic systems become adaptive for the first time. John Pfeiffer is not alone in starting to think about such questions, his work joining the small but significant corpus of such scholars as Meg Conkey, Les Freeman, Clive Gamble, Michel Lorblanchet, Peter Ucko and Martin Wobst, among others. All of these have begun to be concerned with the problems of information flow in band societies, and with how archaeologists might monitor changing patterns in the Pleistocene. Pfeiffer's focus on the deep-cave art, however, and his argument for drama and situation as memory-imparting devices are, as far as I am aware, quite distinctive.

The book has several aspects: first it provides a brief synopsis of prehistory in general; second it presents vivid accounts of the author's own impressions and experiences in visiting the sites of deep-cave art; third it describes in qualitative terms features of the art, its context and other, associated traces; and fourth it advances the arguments already alluded to regarding the novel social needs of Upper Palaeolithic societies. The book is clearly intended to be read by a general as well as a scholarly audience, and the first three features have evidently been included to make the book accessible to non-archaeologists. Expositions of the drama of the setting of the art are repeated in several parts of the book. I found this material convincing the first time but thereafter it may be that some readers, like me, will find it overdone and repetitious.

The book includes a chapter on myth, ritual and art in Australia, considered as an effective way of imprinting complex topographic, economic and social information. Pfeiffer coins the apt phrase "tribal encyclopedia" for the sum of shared information learned and transmitted in non-literate societies.

Femme à la Corne, a rock carving ascribed to the Upper Perigordian *c.* 23,000 years BP. The figure is 44 cm high and found in Laussel, a rock-shelter in the Dordogne. Photograph: B. Biraben.

As a non-specialist in cave art I found that the book included a variety of information that was new to me, for instance the fact that footprints of adolescents are commonly found in various deep caves where tracks are preserved. Such evidence adds plausibility to Pfeiffer's argument that initiation and indoctrination were important social functions of the art. Initiation is in fact a possible usage that had earlier been suggested by Breuil, though without explicit consideration of the overall function of the transmission of information. Clearly key points of evidence such as the proportion of juvenile prints and other quantitative data will need to be more systematically presented by Pfeiffer, or some one else, before their implications can be fully assessed.

As indicated at the outset, the transformation of cultural systems during the upper Pleistocene seems to have been the launching pad for technological, economic, demographic and social changes that began to accelerate then, and which are still gathering speed. Pfeiffer is very probably correct in suggesting that new mechanisms for channelling the flow of complex information played a crucial part in this take-off, and he has produced a well-illustrated and provocative book about it.

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Reversals of fortune

F.J. Vine

The Road to Jaramillo: Critical Years of the Revolution in Earth Science.
By William Glen.
Stanford University Press: 1982. Pp.459. $37.50.

THE MAIN title of William Glen's book is rather esoteric and perhaps a little deceptive in that it suggests a racy novel; the subtitle, on the other hand, is considerably more informative. Readers of fiction will not be entirely disappointed however for the story Glen has to tell, while firmly based in fact and soberly recounted, is a gripping one.

In essence the book covers events in three sub-disciplines of the earth sciences — geochronology, palaeomagnetism and marine geophysics — during the years 1954 to 1966; events which resulted in the definition of a geomagnetic reversal time-scale and the confirmation of the hypothesis of sea-floor spreading. Glen considers that these were the crucial developments which led rapidly to the general acceptance of the theory of continental drift and to the formulation of the modern paradigm of plate tectonics.

The Road to Jaramillo is therefore in the realm of the history and philosophy of science. It is, however, rather more than a straightforward history, based on months of work in the library, in that it draws heavily on the personal recollections, correspondence and records of the participating scientists. Thus the book provides a detailed and fascinating account not only of the way in which science proceeds but also of the way in which scientists behave while doing science.

In the 1970s several books were written on the Kuhnian type of "revolution" which took place in the earth sciences in the preceding decade. They included a book by Glen himself and were, in their different ways, faithful accounts. All of them, however, were broad-brush treatments, either designed to be of general interest or specifically aimed at undergraduates. Although the treatment in the latter part of *The Road to Jaramillo* is similar to that of such earlier works, the first two parts, which constitute more than three-quarters of the main text, are very different. They cover the refinement of the potassium 40–argon 40 dating technique between 1954 and 1960, which facilitated the dating of much younger rocks than had been possible previously, and the subsequent application of this technique, together with palaeomagnetic measurements, to geologically young lava flows in order to determine their age and the direction of their "fossil" or permanent magnetization, i.e. whether it was essentially parallel (normal) or antiparallel (reverse) to the present direction of the Earth's magnetic field. In

this way a time table of reversals of the field during the past four million years was painstakingly built up, the last important detail — the resolution of the Jaramillo event, a short period of normal polarity rather less than one million years ago — being added in 1966.

It is made clear in the author's preface that the book is an outgrowth of a doctoral dissertation, on the history of the elucidation of the reversal time-scale, which was then expanded to include details of the all-important precursor to that work. As a geologist turned historian, Glen is well-qualified to relate this story and he is also well-placed in that these developments largely took place at institutions in the Bay area of California where he and most of the participants still live. Thus the author

IMAGE UNAVAILABLE FOR COPYRIGHT REASONS

Photograph J.R. Cann.

F.J. Vine and Drummond Matthews at UEA in 1970. Their explanation, using the reversal time scale, of how the sea-floor developed a striped magnetic pattern (a theory developed independently by Lawrence Morley in Canada) eventually triggered the modern revolution in earth science.

was able to draw in particular on the recollections of Jack Evernden and Garniss Curtis — who refined the potassium–argon dating technique at Berkeley in the 1950s — Allan Cox, Richard Doell and Brent Dalrymple — all former Berkeley students, who worked on the definition of the geomagnetic reversal time-scale at the US Geological Survey in Menlo Park, California, in the early 1960s — and their more senior mentors at Berkeley, John Verhoogen and Francis Turner. Many others however were involved not only from the United States but also, notably, from Canada, Australia and Britain. Glen claims to have interviewed over 80 scientists for a total of more than 300 hours, 130 of these being preserved for posterity on tape. In doing this he has performed a valuable service to both scientists and historians; the book captures something of the sociology as well as the history of events before the record has been tidied-up, abbreviated and over-simplified by the passage of time.

Inevitably perhaps, because the book goes into a few topics in great detail, the general reader may find some of Glen's scientific and historical points somewhat esoteric. One might also quibble with the odd minor detail or ambiguity, but in general the treatment is objective and factually correct, the whole constituting a scholarly and authoritative work. As one who was privileged to be involved with the latter part of the work described, I was fascinated by some of the details given earlier in the book which previously I knew only in outline. This is particularly true of the developments in the potassium–argon dating technique in the mid to late 1950s and may, I suspect, be a more general reaction in that the history and significance of these developments has been poorly documented, indeed largely overlooked, in the past. Similarly the sudden growth in palaeomagnetic research, and the eventual divergence in the approach of the English as opposed to the American/Australian schools in the 1950s makes interesting reading. Work in England under the leadership of Keith Runcorn concentrated on the definition of polar wander curves in the past for different continents; by contrast research in the States under Cox and Doell, and in Australia under the direction of Ian McDougall, was largely concerned with the elucidation of the reversal time-scale which was eventually to have such a dramatic impact on the resolution of the continental drift debate.

One is tempted to make comparisons with James Watson's *The Double Helix*, in some respects an analogous book. I suspect, however, that the success of the latter in capturing the popular imagination resides in its autobiographical approach and in its concentration on feuds and personalities. Here one can read about the rivalries, disagreements and personality clashes but they are more deeply buried in objectivity and detail. Indeed this is altogether a more weighty tome, painstakingly annotated, referenced and indexed; at the same time it should be said that the main text is attractively written and is leavened — and enlivened — by numerous photographs, typically of the leading characters in the story.

The road to Jaramillo was far from straight and well signposted and many travellers clearly missed crucial turnings on the way. But they all shared an enthusiasm for the unfettered pursuit of pure science, and had an instinctive faith in the ultimate, if unforeseen, fruits of their work. In this regard a salutary and poignant note is struck in an appendix in which Brent Dalrymple, in a letter to the author, questions whether such triumphs of pure science are as likely or even possible today in an atmosphere of financial stringency and in which the emphasis is on mission-orientated and applied research. □

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Wrendered complete

Carole Stott

The Mathematical Science of Christopher Wren.
By J.A. Bennett.
Cambridge University Press: 1983. Pp.150. £15, $29.95.

ASK THE man in the street to name an English architect and the chances are he'll say Christopher Wren. Follow this by asking for an English astronomer and your money is safe that he'll "pass" rather than answer Wren.

It is understandable why Wren is popularly acclaimed for his architecture. His most obvious legacy, his buildings — St Paul's, numerous churches, the Sheldonian Theatre, Oxford, the chapel at Pembroke College, Cambridge — are there for all to see. Yet before becoming a professional architect Wren had a highly successful career as an astronomer, firstly as Gresham Professor of Astronomy (1657-1661) in London and then as Savilian Professor of Astronomy at Oxford (1661–1673). These two seemingly distinct careers, architect and astronomer, have always been treated separately by historians. *The Mathematical Science of Christopher Wren* by contrast covers Wren's professional life as a whole, explaining what today would be a most unusual transition rather than, in those days, one of job rather than of career.

Whilst at Gresham College, Wren was at the historic centre of mathematical science in England, steeped in tradition concerned with the exploitation of mathematics to practical ends. The philosophy of the mathematical practitioners of the time and Wren's involvement are treated first by Bennett, before covering in successive chapters the mathematical sciences tackled by Wren — astronomy, longitude, cosmology, mechanics, microscopy, surveying, medicine, meteorology and architecture.

An early problem that concerned Wren was that of explaining the different appearances of the planet Saturn. Since Galileo had turned his telescope to the heavens and viewed what he thought was a central globe flanked by two smaller ones, astronomers had put forward various explanations for their observations. Wren observed the planet too and hypothesized that Saturn was circled by an elliptical ring the width of which varies from a maximum at the two points where it is furthest from the body to zero at two points where it touches the planet. Although this was a considerable advance on any previous explanatory attempt, Wren soon abandoned his theory in favour of Christian Huygens' model.

Self-devised improvements in the telescope helped Wren in his astronomical