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BOOK REVIEWS

Two volumes on the Himalayas and Tibet

Shackleton, R. M., Dewey, J. F. and Windley, B. F. (editors), 1988. *Tectonic Evolution of the Himalayas and Tibet.* Philosophical Transactions of the Royal Society of London, Series A. 325 pp. Price £65.

This book reviews recent work on the world's highest mountain range and highest plateau and is based on a meeting held at the Royal Society in November 1987. Not all the papers given at the meeting are included here; one appears in the separate volume on Tibet from the same source. However, the present book is reasonably comprehensive in its coverage of topics, including Tibet. Two rival models for the deep structure are given. One by A. Hirn shows a Moho beneath the Himalaya and Tibet that is not flat or horizontal and the crust is not homogeneously thickened. Instead the lithosphere is imbricated and crustal thickening takes place in steps. P. Molnar provides a valuable critique of the step model which he regards as being inadequately documented. Molnar favours a smooth, N-dipping Moho and cites focal depth, fault plane solutions and body wave propagation data in support. Molnar considers that the existence of underthrust Indian shield beneath Tibet is not proved. Likewise the conclusion that important variations in crustal thickness occur under Tibet is not well established. However lateral heterogeneity is clearly shown by body and surface waves. Low velocity regions in the upper mantle of N. Central Tibet indicate partial melting which is also shown by late Cenozoic vulcanism in that region.

Palaeomagnetism and palaeontological evidence bearing on the pre-collision history of the terranes is reviewed by J. Lin and D. R. Watts and by A. B. Smith, respectively. Lin and Watts argue that the Lhasa terrane and Kohistan were attached to India in the Carboniferous and that Cathaysia existed as a composite continent dividing the Tethys Ocean. Lin also gives a palaeomagnetic test for the huge rotations of Indo-China involved in the Tapponnier 'expulsion' model. Smith gives a valuable discussion of endemism across East Asia and reviews the significance of the various sutures recognised there. The Cimmerian Continent (most of Cathaysia) was an integral part of Gondwanaland in the early Permian until it rifted away on the Zangbo line. Thus Smith concludes that Palaeotethys must have existed north of Tibet.

Several papers deal with the structural and metamorphic evolution of different sectors of the Himalaya and Karakoram. A. J. Rex, M. P. Searle, R. Tirrul, M. B. Crawford, D. J. Prior, D. C. Rex and A. Barnicoat, and M. P. Searle, D. J. W. Cooper and A. J. Rex depict the Karakoram as an Andean arc which underwent low-pressure metamorphism in Jurassic times. The Kohistan–Ladakh island arc was accreted to the Karakoram in mid Upper Cretaceous times prior to eventual collision with the Indian continent in the Eocene. These authors invoke large-scale underthrusting of India as a cause of the uplift of the Karakoram. Both the Karakoram and the Himalaya show an important phase of post-collision metamorphism *ca* 45–35 Ma. Searle *et al.* opt for a 'folded isograd' model to explain inverted metamorphism.

M. P. Coward, R. W. H. Butler, A. F. Chambers, R. H. Graham, C. N. Izatt, M. A. Khan, R. J. Knipe, D. J. Prior, P. J. Treloar and M. P. Williams use balanced cross-sections to demonstrate nearly 500 km shortening across the N. Pakistan sector. Their study includes an interesting application of 'wedge' theory to Himalayan thrusts. Critical wedge taper is lower in N. Pakistan than elsewhere, reflecting the supposed low basal shear strength of the wedge. Taper has been maintained by 'back steepening' and back thrusting within the wedge. K. V. Hodges, M. S. Hubbard and D. S. Silverberg describe two prograde metamorphisms of Tertiary age in the Himalaya—an early high P and T event associated with collision and a later moderate P, high T event related to the emplacement of leucogranites. These authors think that the famous inverted metamorphism of the Himalaya results from different causes in different places, reflecting the differing character of the Main Central thrust. K. S. Valdiya discussing the evolution of the Kumaun Himalaya, also stresses the concept of two metamorphic events in the Higher Himalaya.

P. Le Fort reviews the granites of the Himalaya and Karakoram. Four major plutonic belts of Mesozoic–Cenozoic age are described: the earlier are Andean-type belts (Karakoram–Kohistan) related to ocean subduction while the later belts, covering a much shorter time-span, are related to intracontinental subduction on the Main Central thrust. During movement on this thrust fluid released from the footwall promoted anatexis in the hot hanging wall.

Lastly, P. C. England and G. A. Houseman discuss the application of continuum deformation of a thin viscous sheet to the Himalaya and Tibet. They focus on the problem of the recent E–W extension in Tibet. This they attribute to loss of the lower part of the continental lithosphere, that is the upper thermal boundary layer, which is replaced by hot asthenosphere. This process has caused 3–4 km uplift.

The editors and the Royal Society are to be commended for producing this excellent volume which will serve as a 'state of the art' review of what one contributor calls the "world's great laboratory". Certainly anyone interested in the operation of the earth's processes on the grand scale will find much inspiration in this book. The general reader will appreciate the introductory chapter provided by B. F. Windley. There is a selection of the discussions from the meeting, including an extended exchange on the use of balanced cross-sections in metamorphic orogens. The one serious complaint is that the price is so high.

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Chang Chengfa, R. M. Shackleton, J. F. Dewey and Yin Jixiang (editors/leaders) 1988. *The Geological Evolution of Tibet—Report of the* 1985 *Royal Society–Academia Sinica Geotraverse of the Qinghai-Xizang Plateau.* The Royal Society, London. 413 pp. Price £95.

A major consequence of the post-collision northward motion of India by over 2000 km has been the creation of the world's highest plateau. Tibet has roughly a double thickness of continental crust but its lithosphere is only three-fifths the thickness of the Indian lithosphere. There are at least three well-known hypotheses to explain the excess of continental crust beneath Tibet.

(1) The underthrusting of Indian continental crust beneath that of Asia.

(2) India, acting as a rigid indenter, penetrating Asian lithosphere which underwent lateral extrusion.

(3) A separate 'indentation' model in which Asia responds by viscous vertical plane strain: horizontal shortening and vertical stretching in advance of the 'bull-dozing' Indian continent.

Set against these inspiring hypotheses is the scanty knowledge of a long-inaccessible region. The history of geological research in Tibet is a short one—Littledale (1896) noted the young volcanics, Sven Hedin (1915) made sample collections and Norin (1946) was the first to map and to record folds and thrusts. Chinese geologists must take the credit for opening the present phase of activity—it was they who identified the ophiolites which follow the several sutures which cross Tibet. But apart from the Franco-Chinese expeditions, this book marks a landmark in the development of Earth science work in Tibet, and is anyway a notable achievement in international co-operation. The book is based on a geotraverse in 1985 organized by the Royal Society and the Academia Sinica, a multidisciplinary study around the road section between Lhasa and Golmud. Ten scientists from the U.K. and U.S.A. and 15 from China took part. The Chinese did important preparatory work. The results are presented here in 14 chapters, plus a coloured 1 : 125,000 geological map and microfiche 1 : 100,000 maps showing locations of structural data. Copies of the maps along with satellite imagery are stored in the British Museum of Natural History. Type specimens of fossils are kept in Nanjing.

The subject matter, chapter by chapter, is as follows: Stratigraphy (Yin Jixiang, Xu Juntao, Liu Chengjie and Li Huan); Palaeontology

(A. B. Smith and Xu Juntao); Sedimentology, palaeoecology and palaeoenvironments (M. R. Leeder, A. B. Smith and Yin Jixiang): Plutonic rocks (N. W. B. Harris, Xu Ronghua, C. L. Lewis and Jin Chengwei); Volcanic rocks (J. A. Pearce and Mei Houjun); Metamorphic rocks (N. W. B. Harris, T. J. B. Holland and A. G. Tindle); Ophiolites (J. A. Pearce and Deng Wanming); Palaeomagnetism (Lin Jinlu and D. R. Watts); Isotope geochemistry (N. W. B. Harris, Xu Ronghua, C. L. Lewis, C. J. Hawksworth and Zhang Yuquan); Geological mapping (W. S. F. Kidd, Pan Yusheng, Chang Chengfa, M. P. Coward, J. F. Dewey, A. Gansser, P. Molnar, R. M. Shackleton and Sun Yiyin); Structural geology (M. P. Coward, W. S. F. Kidd, Pan Yun, R. M. Shackleton and Zhang Hu); Quaternary and active faulting (W. S. F. Kidd and P. Molnar); Cenozoic uplift and deformation (R. M. Shackleton & Chang Chengfa).

The general reader will welcome the extremely valuable final chapter of synthesis of the tectonic evolution of Tibet (J. F. Dewey, R. M. Shackleton, Chang Chengfa and Sun Yiyin). The broad picture that emerges from the wealth of new information is that the Tibetan Plateau is an assemblage of terranes or microplates which were accreted to Asia before the Indian–Asian collision in the mid-Eocene. The history starts in the later Precambrian as there is no evidence of Archaean or early Proterozoic rocks and it seems that crust of 1000 Ma or older occurs beneath the Plateau. There is evidence of an end Proterozoic ('Pan African') collision.

The later Palaeozoic and Mesozoic history of terrane assembly and dis-assembly with the formation of the Kunlun–Qinling suture (late Permian), the Jinsha suture (late Triassic) and the Banggong suture (late Jurassic) involved a succession of Palaeotethyan oceans and a Neotethys which opened in the Trias between the Lhasa and Himalayan Terranes, reached a width of at least 6000 km, and then closed in mid-Eocene times. The terrane nomenclature is a little confusing but the broad picture is clear enough. Significantly at least two of the terranes (Qiangtang and Lhasa) come from Gondwanaland and split away from it as late as the Permo-Trias.

Discussing the Tertiary history, the authors of the synthesis favour the England–McKenzie–Houseman viscous continuum deformation model, rather than the earlier indentation model of Molnar and Tapponnier. Thus the thickening of the Tibetan crust to almost double the normal thickness resulted from northward-migrating N–S shortening and vertical stretching occurring between the mid-Eocene and the earliest Miocene. Uplift in Tibet therefore is held to precede that in the Himalaya, hence the formation of the famous antecedent drainage. In this period (Phase 1) India moved north relative to Asia by 1000 km. Palaeogene and older strata on the Plateau were deformed by this essentially thrust-dominated process. Pediplanation had produced an erosion surface by mid to late Miocene times (~10 Ma). In Phase 2, northward-migration thickening became 'locked', because the strong lithosphere of the Tarim Basin resisted the deformation. Instead the northward motion of India was accommodated partly by thrusting in the Himalaya. In Phase 3, from the early Pliocene to the present day, the Tibetan Plateau has risen by about 2 km and has suffered E–W extension across N–S grabens and along conjugate strike-slip faults. Rapid uplift was accompanied by volcanism. The synthesis invokes catastrophic delamination of the thickened lithospheric 'root' beneath the Plateau. The indentation model of Molnar and Tapponnier is not favoured because there is little evidence of eastward lateral extrusion. During Phases 2 and 3 some 1420 km of India–Eurasia convergence has been partitioned into about 440 km of shortening on the Himalaya and about 980 km north of Tibet. The late-stage extension seen on the Tibetan Plateau may perhaps give a key to understanding the process whereby orogenic belts return to normal crustal thickness.

The authors of the synthesis are careful not to claim that they are presenting other than their own views. But the 'general' reader would have found it helpful to have important disagreements set out in an introductory chapter. The conclusion by Coward *et al.* that thrusting is not intense enough to account for the crustal thickening is one notable example of disagreement. Again the role of lateral extrusion is still controversial. Dewey *et al.* reject lateral extrusion as a primary response to indentation, one reason being that it fails to account for the crustal thickening just ahead of the indenter.

Collision tectonics, terrane assembly, crustal thickening, mechanisms of uplift, delamination of the lithosphere, extensional tectonics, lateral extrusion—these major topics of interest to Earth Scientists are central to the understanding of the evolution of Tibet and the Himalaya. In this sense this book is a very important document. Let us hope that it does not mark the end of an era and that the many pathways for research opened-up here will be pursued in the near future.

REFERENCES

Hedin, S. 1915. In: *Zur Petrographie und Geologie von Sudwesttibet, Southern Tibet, Vol.* V. (edited by Hennig, A.). Kung. Boktryckeriet, P.A. Norstedt, Stockholm.

Littledale, St G. R. 1896. A journey across Tibet from north to south, and west to Ladak. *Geogr. Jl*, 453–483.

Norin, E. 1946. *Geological Explorations in Western Tibet.* Sino-Swedish Expedition Publication 29. Tryckeri Aktiebolaget Thule, Stockholm.

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Structures at Bedtime?

Roberts, John L. 1989. *The Macmillan Field Guide to Geological Structures.* Macmillan Press Ltd, London. 250 pp. Price £12.95.

This pocket-sized and (just) pocket-weight book is billed by Macmillan to be a valuable reference book for amateur geologists on fieldtrips. That may be so, but it will doubtless grace their coffee tables, along with those of their professional colleagues.

Almost every geological structure of sedimentary or tectonic origin, together with a good many igneous and metamorphic features, is photographically illustrated in this guide. The 254 photos which form the kernel of the book are grouped in threes on the right-hand side of each double page, with supporting text on the facing left page. Text and photographs together are organized into six parts: sedimentary rocks; igneous and metamorphic rocks; unconformities and the geological record; mountain building and the tectonic record; structural relationships in folded rocks; and basement rocks.

This book forms a spectacular collection of superb colour photographs. These have obviously been taken by John Roberts over many years of geological travels and we would guess after more than one visit to some localities. Our favourites include a French bioturbated limestone from Aveccil and cleaved graded beds from Islay in Scotland. The famous breached fold pair at Broad Haven, SW Wales, must surely have been specially floodlit and an artificial blue sky dubbed in later! The photographs are undoubtedly the high spot of this book, and paradoxically it would be a shame to ruin them by taking them into the field to be rained on. For the enthusiast, details of film and photographic technique have been included in a paragraph at the front of the book, together with a note that slides and copies of photographs are available from the author: he deserves to do a roaring trade.

In stark contrast to the photographs, the text is disorganized and must seem almost haphazard to the non-specialist. Two examples illustrate the point. "Metamorphic processes" are in section 2 together with igneous rocks, whereas "metamorphic fabrics" are in section 4 with mountain building, and "migmatites and basement gneisses" are in section 6. Section 2 is billed as igneous and metamorphic rocks, and the introductory text does describe the nature of igneous and metamorphic rocks at a fairly basic level, but the photographs in this section are almost all of igneous features, with just a few dealing with igneous contact rocks. No regional metamorphism here at all.

For the most part, though, the text is clearly written and will be readily understood by a reasonably informed and interested amateur geologist. Sadly, some parts, for example the section on crenulation cleavage, require a pretty full understanding of the concept before you can grasp the meaning of the text. Some of the definitions compound the problem; the term "lag" is incorrectly defined, and mysterious terms (to us) such as "fishtail" and "snake's head folds" appear in the text.

Not withstanding these criticisms, the book will be of considerable use for the non-specialist. If you are looking to see an excellent example of a dyke or a load-cast or a normal fault, this guide is well organized enough to let you do it. Enthusiasts who want to go and see these structures in the field could, however, be hard pushed to find them. An accurate location along the lines of "300 metres south of Wigan Pier" would have cured this. The grid reference quoted for each locality is precise enough, but field parties may well have difficulty locating the exact site of the photograph, within the 100 m^2 of the grid reference. Amateurs and aspiring professionals will, perhaps, miss some discussion about the setting of the feature within its wider stratigraphic or tectonic context. Almost all the examples come from