

cooling on the elastic thickness of the lithosphere, which should cause the downwarp and peripheral arches to broaden with time. Boillot also discusses the more controversial possibility that extension and thinning along continental margins can occur soon after continental rifting, by gravitational spreading of the still hot and relatively ductile continental crust towards the ocean basin. He does not, however, mention an important predictive test of this hypothesis: if it does occur, there should be a corresponding zone of compression (thrusting?) in the oceanic crust under the continental rise. Such a zone is not apparent in seismic sections across continental margins, but recent data from the NW European margin (Avedik *et al.* 1981) suggest that there are considerable difficulties in reconciling the structure of the upper crust with the amounts of extension required to thin the crustal section as a whole. A possible explanation is that the normal faults seen in seismic sections are growth faults, with considerably greater displacements at depth than near the surface. This, of course implies slow and prolonged extension: not the instantaneous stretch envisaged by McKenzie (1978). Incidentally, Boillot does not explicitly discuss growth faults in this book, although they are implicit in his figures.

In Chapter 3 Boillot elaborates on the sedimentary and structural evolution of rifted margins, including discussion of the successive stages in the evolution of a rift zone into an ocean basin. He also has an overly brief section on strike-slip margins, which he explains as oblique transforms forming along rifted margins. This seems to ignore the realities of major strike-slip margins such as those of western North America, where ridge-trench intersections and migrating triple junctions are involved.

Chapter 4 deals with the morphology and structure of active margins, and is a useful and up-to-date account. I found the section on the evolution of marginal basins a bit too brief to be clear to students. The sections on the back-arc structures in Cordilleran type margins are inevitably somewhat speculative, and there is a danger that students may take the 'models' too literally. One or two real cross-sections of Cordilleran margins would have been valuable here.

In Chapter 5, Boillot discusses the magmatic and metamorphic characteristics of active margins. He presents the essential magmatic information clearly, and wisely avoids dwelling on the increasingly inconclusive geochemical discussions of their origin. The section on metamorphism begins well, but is marred by his unwillingness to accept the real implications of blueschist facies metamorphism. He presents the data from experimental petrology, but suggests on p. 93 that blueschists can form at around 15 km depth. On p. 97 he reduces this to *less than 10 km*. This is unacceptable: not only does it make the distinction between metamorphic baric types meaningless; but if true, it would mean that most low-grade metamorphic domains and slate belts, and many of the deeper sedimentary basins, should show blueschist facies mineral assemblages.

In Chapter 6, Boillot discusses collisional orogeny. I found this chapter the least effective: the writing and organization become confused and haphazard, and a student would be unable to gain any idea of the structure of real collisional orogens. Much of the chapter concerns a comparison between Aubouin's (1965) geosynclinal theory and current ideas on the structure of continental margins. This is of considerable interest from a historical viewpoint, but is probably confusing for students being educated 15 years after the onset of plate-theory.

Some general comments. There are few documented examples, and those that are given are not always representative: the submarine canyons of the French Mediterranean margin, for example. When discussing gravity data, Boillot fails to distinguish between free-air, isostatic, and Bouguer anomalies. This confuses several discussions (pp. 9–10, 21, 65–66, and fig. 4.10). Many of the figures are reproduced with little modification from the literature and lack scales (e.g. figs. 1.5, 3.9 and 5.1), orientation (figs. 4.6, 4.7 and 4.8) or adequate explanation in the legend (figs. 4.4, 4.7, 4.8, 5.2 and 5.8). Problems with idiom and terminology are surprisingly rare, in view of the range of subjects covered, and the problems of translation. Some quibbles: 'friction (shearing)' presumably means strike-slip or transform on p. 12. On p. 16, 'more viscous' should be less viscous, or more ductile. Note 2 on p. 35 probably contains a misprint. 'Pitching' on p. 73 apparently refers to the direction of thrusting.

In summary, this is a remarkably useful text, summarizing an amazing amount of up-to-date information on continental margins at a level suitable for second-year undergraduates. At £4.95, it is priced within the reach of the most impecunious undergraduate: no small matter in these days of symposium volumes at ten times this price. Some parts are inevitably better than others: Boillot is at his best on passive margins, and where he is summarizing well established morphological and geophysical data. Scattered inadequacies in text and figures will, I hope, be eliminated in future editions.

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Thrust and Nappe Tectonics

McClay, K. R. & Price, N. J. (editors) 1981. *Thrust and Nappe Tectonics*. Special Publication No. 9, Geological Society of London. Blackwell Scientific Publications, Oxford. 539 pp. Price:

This report of a three-day conference on the subject of thrust and nappe tectonics, held at Imperial College, London, in April 1979, fixes in book form most of the papers read on that occasion. Much of the material is available, however, in a well-stocked library. Publication for those without access to such a library should be in a cheaper form than this hard-back book. It is surely true, but irrelevant I suppose, that a more comprehensive text could have been written by the same authors had the articles been designed to complement one another.

However, in spite of the unsurprising lack of coherence the collection is of considerable interest to anyone concerned with understanding thrust fault regimes. Some of the articles, notably that by Ramsay on the Helvetic Nappes as well as those by Price, Thompson, Brown & Hatcher should make useful reading for senior undergraduates in addition to more experienced geologists seeking an up-to-date review of thrust regions with which they are themselves unfamiliar. A companion review in the North American section (Brewer, Cook, Brown, Oliver, Kaufman & Albaugh) provides an introduction to continent-scale reflection profiling. In a way it is surprising that the North American regional descriptions are at the end of the book. Because modern views on foreland thrusting depend on a knowledge of Rocky Mountain and Appalachian structure, there was a good reason to put them first amongst the regional descriptions.

There are some useful points made in the four-page introduction provided by the editors as a commentary to the whole book. It is interesting, as they say, that the works of Hubbert are referred to relatively little. In fact they are listed after only four papers (there is a subject index but no author index). It is my guess that it is the theoretical works of Elliott (1976 a, b) to which most reference is made (cited 23 times in 20 articles), followed by those of Dahlstrom (1969, 1970 cited 15 times in 14 papers). It would be difficult to better a close study of these four papers together with another (Elliott & Johnson 1980), which was in press while the book was being prepared, as a basis for understanding foreland thrusting. I do not think that this book can compete successfully with them.

The two-page record of a discussion of the meaning of the word thrust and other terms, put together by one of the editors, is less satisfactory. While a thrust fault is defined as a map-scale contraction fault (dip irrelevant to definition), a contraction fault is allowed to shorten an arbitrary datum plane (again no attitude specified). Yet an Andersonian normal fault qualifies as it shortens a vertical datum plane. A 'duplex' is a thrust sheet (mass) which is bounded by a 'floor' thrust and a 'roof' thrust, seeming to imply that all thrust sheets, except those carrying the earth's surface must qualify. "Often duplex structures are imbricated" (my italics) yet imbrication seems to me to be inherent in their construction. Certainly, no imbrication exists at the start, merely a ramp (Elliott & Johnson 1980, fig. 3). But then does a duplex exist until successively new ramps develop through the carriage under the upper thrust sheet of the detached fragments or imbricates? Or do I misunderstand the terminology or the definition?

The paper by Bally, in the section on the Mechanics of Thrusting, emphasising the importance of the limited degree of subduction of continental crust that he argues has taken place, is in the welcome form of an essay. So also is that of Smith on a possible link between foreland

thrusting and the development of a magmatic/metamorphic welt. The paper by Gretener on the themes of pore pressure, isostasy and thrusting, as well as papers by Mandl and Crans on gliding in deltas, and by Mandl & Shippam on a mechanical model for the gliding and imbrication of thrust sheets, also show broader vision. One might also add Murrell's article, providing as it does a review of thrusting from the point of view of rock mechanics. Ramberg's account of the role of gravity in orogenic belts considers gneiss domes and spreading nappes with reference to the northern Appalachians, the Scandinavian Caledonides, and theory and experiment. Ramberg does not explain why he groups together as lower Proterozoic, the varied granitic rocks of the central Norwegian Caledonides into the single category of "Nordland granites", whether they be sheets in vein complexes, (undated themselves and in metasediments of unknown age), intrusions with Caledonian whole-rock isochron Rb-Sr ages, or basement gneisses (dated in the same way). The more specialized remaining papers in this section, by Wiltshko on modelling the deformation at a ramp, and Rogers & Rizer on deformation near the leading edge of a thrust fault, both contain examples of the interesting and provocative predictions that are needed to sharpen responses to the results of field survey.

Of the second group of papers, those on the Rock Products of Thrusting, I thought only Talbot's paper on a salt glacier in Iran offered a broad approach to its subject matter. Was it not odd of the editors to accept the term "regularization of a curve" (Aprahamian & Pairs)? And can I be alone in finding it difficult to understand diagrams loaded with numbers listed in a caption which may not even be on the same page? The claim (Bouiller & Quernardel, p. 193) that the orientation of the lattices of quartz crystals in nappes in a 50 km section through the north Norwegian Caledonides may show not only that the direction of flow was constant during their major tectonic evolution, but that the stress direction may also have been then constant, seems literally incredible. The proper place for such short papers as these, and the others in this second group, seems to me to be in a scientific journal. All are too brief and limited in scope to be of much use to anyone without some prior acquaintance with these subjects. It might be thought that some of them could have been seen to be more relevant if they had been arranged around the appropriate regional papers (most obviously those by Spang & Brown on the dynamic analysis of an imbricate thrust from the southern Rocky Mountains, and Schmid *et al.* on the microfabrics of calcite tectonites from the Helvetic Nappes). The paper by Behr *et al.*, although interesting, seems equally out of place but for another reason; it is concerned to deny a previous hypothesis of thrusting from the Damaran Orogen of Namibia. Finally both papers on the Alpine Fault of New Zealand (Sibson *et al.* and Adams) are research reports. While dealing with relevant material, in that a degree of up-dip-slip has occurred on this fault they are too close to the detail of their subjects to be suitable here.

Turning to the second half of the book, on the description of thrust faults and thrust fault assemblages, we discover that most papers in the first subdivision fall outside the declared category of regional descriptions of Caledonian thrusts, (e.g. Cooper: a discussion of the internal geometry of thrust nappes; Milton & Williams: a strain profile above a thrust; Hutton: a discussion of tectonic slides). The same is true in its way of the companion paper by Phillips on the rate and amount of absolute lateral shortening in the British-Scandinavian sector of the Caledonides. Incidentally, the two-plate framework ignores the probability that there was a mid-European arm of the system. There are some unacknowledged repetitions and near repetitions in illustration between the two papers that deal with the rocks and structures of the Moine Thrust Zone, as well as unexplained differences between sections through identical tracts of ground. For example, section B-B' (Fig. 3b, p. 244, McClay & Coward) is almost coincident with Section E-E' (Fig. 2, p. 277 Coward & Kim), but in the first section, Durness rocks alongside Loch Eriboll are shown in a klippe overlying imbricates, but in the second section as belonging with them. One figure in the second paper (Fig. 6, Coward & Kim, p. 279) is a repeat of the left-hand end of one in the other (Fig. 4b, McClay & Coward, p. 249). The mountain, Ben Uidhe, referred to in the latter paper (p. 254, McClay & Coward) is not named on the accompanying map but is marked on a figure in the other

account (Fig. 5 Coward & Kim p. 279) although no reference is made to it in the text. The omission by McClay & Coward of the south Assynt area from the regional description is unexplained.

Reference has already been made to Ramsay's review of the Helvetic Nappes, the more detailed paper by Pfiffner, on the Glarus nappe, can be seen as complementary to it. Laubscher's attempt to report very briefly on a complicated sequence of events of detachment in the Jura, although interesting is not a success. Here again the editors have been too tolerant. What for example is an "instabilization?" And surely the "rails" of the conclusion should read 'relays'? The other two papers, by Beach and Graham respectively, report on fault development in the French Alps. The former provides much detail on minor structure while the latter is written at the level of map-scale arrangements.

The section following that entitled Caledonides (of Europe) and Alpine (of Europe) is headed Eurasia, surely a geographic entity that includes the former? In fact all the descriptions in this section are Asian and 'Alpine', except the first, which deals with European and Variscan rocks. In this latter section, Matte & Burg outline very briefly their view of the collision and character of the Variscan arc in western Europe. The thrusts and nappes of the western Himalaya are reviewed in a paper by Thakur. A preliminary report on wrench-related thrusts from southwest Turkey by Woodcock & Robertson is followed by a set of similarly specialised papers on neotectonics. These range over thrusting and earthquakes in the Zagros Mountains (Jackson *et al.*) the Chaman transform zone of Pakistan (Lawrence *et al.*) geometric problems associated with collision between the Banda arc and the Australian Plate (Audley-Charles), and nappe emplacement from a frontal arc in New Guinea (Milsom). Finally there are some cautionary comments on the interpretation of the seismic records from modern convergent margins (von Huene and Arthur & Carson).

Of the papers not already mentioned in the concluding section on the Americas, that concerning deformation in two fault zones (Cowan & Miller) would have been better placed in the section on Rock Products as it has little or no connection with the regional descriptions. The account of the thrust nappes of the Canadian Rockies near Alberta (Charlesworth & Kilby) seems to be complementary to that by Spang & Brown. I think they would have been better placed side-by-side. The last paper in this section, on mechanisms of basement shortening in the foreland belt of the southernmost Andes (Winslow), is referred to elsewhere in the book (Jackson *et al.*) in a manner that it would have been useful for the editors to have encouraged other authors to follow.

I can only end in the somewhat grudging spirit in which I began this review. For its price this book does not seem good value. Spending a good deal less on copies of the papers listed below would surely provide better food for thought. Above all, a cheaper production would have encouraged wide-spread individual ownership, in my experience a greater stimulus to detailed study, such as that which a reviewer is enabled to undertake.

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