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Book Reviews

Text-book of structural geology

Hatcher, R. D. 1989. *Structural Geology, Principles, Concepts, and Problems.* Merrill Publishing Co., Columbus, Ohio, U.S.A. 531 pp. Price $49.95 (hardback).

Despite declining numbers of students entering geology programs worldwide, new structural geology text-books continue to appear with increasing frequency. The latest addition is Professor Hatcher's large volume *Structural Geology, Principles, Concepts, and Problems*. This book was designed for the single-semester undergraduate courses offered in most North-American universities. Its stated purpose is "to bridge the gap between older, less quantitative, texts and newer, but more advanced, mathematical structural geology books". The contents are divided into five parts: *Introduction*; *Rock mechanics*; *Fractures and faults*; *Folds and folding*; and *Fabrics, structural analysis, and geophysics*. Many seismic sections, geophysical maps and tables of field data are included. The 28 × 21 cm page format accommodates lots of large, legible line-drawings; however, some of the photographs lack crispness.

The two chapters of Part 1 (*Introduction*) deal with a wide range of topics—geologic principles, tectonics, plate tectonics, geochronology, isostacy, primary sedimentary structures, salt structures, and impact structures. The treatment is generally low-level; for example, students having difficulty with three-dimensional geometry are advised to "begin by attempting to think about familiar objects in three dimensions, such as your car, house or room, then move on to work with less familiar tectonic structures". Flat vision is certainly a problem for some students but one wonders if this advice will help.

Part 2 (*Rock mechanics*) is divided into five chapters: *Stress*; *Strain*; *Measurement of strain in rocks*; *Mechanical behavior of rock materials*; and *Microstructures and deformation mechanisms*. Here becomes evident the book's principal weakness, namely the frequent occurrence of mistakes ranging from typos, such as the interchange of $(\sigma_1 - \sigma_3)/2$ and $(\sigma_1 + \sigma_3)/2$ in the derivation of stress (Fig. 3-9a), to misunderstandings of concepts, as on p. 51: "a *second-rank tensor* consists of vectors and nine components; an example is the northeastward motion of the Gulf Stream at a surface water velocity of 150 cm/s". Space does not permit a full listing of errors, but the most important should be mentioned.

The concept of stress at a point is treated as follows (p. 55ff.): three principal stresses σ_1, σ_2 and σ_3, are considered to act on the faces of a cube; the cube is shrunk to a point and the principal stresses replaced by a single stress σ_0. This stress σ_0 is then resolved into normal and shear stress components on each face of the cube! This treatment guarantees that most students will misunderstand stress for the rest of their careers. Page 61 states that circular sections of the stress ellipsoid define planes of maximum shear stress (this error is repeated for shear strain, p. 72) and in Fig. 4-13 it is suggested that a Mohr envelope be constructed in strain ($\lambda'\gamma'$) space! The errors extend into the special topic boxes (simple shear and pure shear are confused in Fig. 4E-1, for example), the problem sets (e.g. p. 78, "elongation strains $e_1 = 0.6$ and $e_2 = 1.2$"), and the glossary (p. 496, "**LS-tectonite:** Deformed rock wherein linear structures dominate over foliation or cleavage").

Chapter 6 deals with mechanical behavior of rock materials, and again there are confusing errors. A number of graphs are incorrect (e.g. Fig. 6-1d) or mislabelled (stress–strain instead of strain–time in Fig. 6-13b). Page 112 states "From equations (6-1) and (6-6), $\dot{\gamma} = (\tau/G) + (\tau t/\eta)$" but the cited equations are $\sigma \propto \varepsilon$ and $\sigma \propto d\gamma/dt = \dot{\gamma}$. Students will have a hard time deriving the former from the latter. Chapter 7 on *Microstructures and deformation mechanisms* is a considerable improvement with some clear explanations. However the sinistral *S–C* mylonite fabric supposedly illustrated in Fig. 7E-2 is neither sinistral nor an *S–C* mylonite.

Part 3 comprises six chapters: *Joints and shear fractures*; *Fault classification and terminology*; *Fault mechanics*; *Thrust faults*; *Strike-slip faults*; and *Normal faults*. There are many useful diagrams here. However, I found the argument on p. 155 obscure, particularly for students, and the illustration of effective normal stress ($\sigma - P$) in Fig. 8-13 is incorrect. The reader is referred to Fig. 9-2b for an example of a strike-slip fault, but the figure shows oblique-slip with incorrectly arrowed strike- and dip-slip components and the components of slip and separation in Fig. 9-4 do not seem right. The hanging wall and footwall of the thrust in Fig. 9-11 are incompatible, and the offsets and omission of stratigraphic markers in the block diagrams of Fig. 9-12 are incomprehensible to me. However, I thought most of the fault mechanics material was treated well. Chapter 11 on thrust faults begins with the history of the thick vs thin-skinned thrust controversy. Here, the author is on his own ground and the discussion of Appalachian tectonics is quite high level. There follows an introduction to thrust terminology and mechanics. The real maps and cross-sections are informative, but five of the author's simplified sections are impossible to restore or balance. The following two chapters on strike and normal faulting, respectively, are a little short, in view of the amount of recent interest in these areas.

Part 4 deals with *Fold geometry and classifications*, *Mechanics of folding* and *Complex folds*. I found some confusion over the definitions of hinge vs crest lines on p. 279, and supratenuous folds in Fig. 14-14 (d). Definitions that ought to be clear and concise are not; "The direction of leaning (the opposite of dip direction) of the axial surface, sense of shear, or the direction of overturning (producing an inverted limb) is called the *vergence* of a fold" (p. 281).

The final part covers *Cleavage and foliations*, *Linear structures*, *Structural analysis* and *Geophysical techniques*. Most of the text and illustrations in this section are good. The structural data from Woodall shoals and the geophysical maps and data make particularly good laboratory exercises. Unfortunately, the discussion of balanced cross-sections refers back to Fig. 11-37 where the perplexed student will find, not the promised deformed and restored sections, but rather, the photoelastic effect around a crack tip in Plexiglass! I felt unsure about calling stretched pebbles "natural strain ellipsoids lineation", calling mineral lineations and boudinage sense-of-shear indicators, or calling porphyroblast rotation axes a lineation (pp. 404–405), and I remained unconvinced that the garnet in Fig. 18-7 displays "δ-porphyroblast form". Question 6 (p. 433), "Why is identification of kinematic axes in most areas considered useless or even impossible?" may cause some confused students to reject the important field of kinematic analysis. I couldn't do the last part of question 4.

There are three appendices which deal with *Fabric diagrams*, *Structural measurements and observations* and *Woodall shoals fabric data*. The procedure for plotting a line (Fig. A1-6) is confusing since its trend is repeatedly referred to as its "strike", and in Fig. A2-2b, the "plunge" of a fold axis appears to be a pitch. In general, descriptions of plotting procedures are insufficient for the uninitiated and superfluous for the experienced student. Lower-hemisphere projection is assumed but not explained.

My general conclusion is one of concern for those students who do not have a diligent advisor to guide them through this text-book's innumerable errors and misunderstandings, a small sampling of which are cited above. Even if they were corrected in a revised printing, a general lack of clarity is pervasive and the emphasis on descriptive classification rather than process is reminiscent of Hills (1963) or Billings (1973). In view of the strong competition from other texts, teachers may find the inclusion of a good geophysics section and good field data insufficient compensation for other shortcomings.

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Rocky Mountains meet the Cordillera

Schmidt, C. J. and Perry, W. J. (editors) 1989. *Interaction of the Rocky Mountain Foreland and the Cordilleran Thrust Belt.* Geological Society of America Memoir 171. Geological Society of America, Boulder, CO, U.S.A. 597 pp with three pocket-plates and one microfiche card. Price $78.

The Rocky Mountain foreland of the central United States deserves its status as a classic orogenic belt, combining very good exposures with excellent subsurface information from the oil and gas industry. G.S.A. Memoir 171, *Interaction of the Rocky Mountain Foreland and the Cordilleran Thrust Belt*, has taken a different approach relative to previous memoirs on the Rocky Mountains by attempting to be as inclusive as possible, frequently at the expense of being contradictory. Its predecessor, GSA Memoir 151, *Laramide Folding Associated with Basement Block Faulting in the Western United States* edited by Matthews, presented a series of tight, focused arguments for the vertical uplift model of foreland uplifts based on field and theoretical research from the academic realm. This memoir provoked a strong backlash from the Rocky Mountain oil and gas industry, whose seismic and well evidence provided a resounding rejection of the vertical tectonic hypothesis in the 1983 Rocky Mountain Association of Geologists (RMAG) Memoir entitled *Rocky Mountain Foreland Basins and Uplifts* edited by Lowell, and the 1985 RMAG Folio *Seismic Exploration of the Rocky Mountain Region* edited by Gries & Dyer. One unfortunate consequence of this debate has been an unfortunate, yet partially deserved distrust of academic research by industry geoscientists.

GSA Memoir 171 addresses three major areas in its 32 chapters by different authors:

(1) reviews of Rocky Mountain basement-involved structures, showing the consistency between industry data and balancing criteria;

(2) description of the overlap region between thin-skinned and basement-involved thrusting; and

(3) sedimentologic and stratigraphic studies in the overlap province.

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I will concentrate on articles from the first two areas since the sedimentologic studies are mostly regional in implication and scope. However, the potential for testing complex structural chronologies with quantitative flexural subsidence analysis was clearly shown by Shuster and Steidtmann for the northern Green River basin which was loaded by both thin-skinned and basement thrusts.

Brown's largely descriptive summary of his extensive industry and academic experience in Rocky Mountain basement-involved uplifts provides a good illustration of the gaps in our understanding of these basement-cored structures. Reviews of Rocky Mountain tectonics by Hamilton and balancing constraints by Spane, Evans & Cook show the necessity for horizontal shortening on reverse and thrust faults underlying the folded cover strata while demonstrating the lack of consensus (and data) on the structural style at deeper structural levels. An intriguing paper by Chester, Spang & Logan compares analog experiments using cm-scale, layered rock models underlain by pre-cut faults with Laramide structures.

The bulk of the memoir (22 out of 32 papers) describes the geological constraints on the interaction of the basement-cored foreland uplifts with the Cordilleran thrust sheets. The differences in structural fabrics between the two provinces are well defined by Mitra *et al.* in their comparison of minimally deformed fabrics from the northern Wind River Mountains with thrust sheet fabrics immediately to the west. The complexity of the overlap province is immediately apparent from the geometric modelling of Kulik & Schmidt, Schmidt *et al.*, Kraig *et al.* and Skipp as well as the opposite interpretations presented in several pairs of papers. These papers show that geometric modelling based on field observations alone does not usually provide unique interpretations of structural sequence. Articles integrating additional evidence from fabric analysis (Craddock *et al.*, Bradley & Bruhn), industry subsurface and palynological data (Hunter), gravity modelling (Kulik & Perry) and paleomagnetic rotations (Eldredge & Van der Voo) provide the best constraints on the timing of foreland and thrust belt structures. These analyses show that the Cordilleran thrust belt and the basement-involved foreland uplifts were coincident in time, with the basement-cored foreland uplifts both buttressing advancing thrust sheets and deforming previously emplaced thrust sheets. Kulik & Schmidt convincingly argue that this coincidence in time and space indicates that both provinces share an underlying mechanism of horizontal compression, with variations in crustal decoupling causing the differences in structural style.

Schmidt & Perry are to be commended for the inclusive nature of this volume. They have attempted to air all points of view, allowing the readers to make their own conclusions. However, the inclusiveness of this volume results in a very large book (582 pages) with highly variable manuscript quality, some of which would not have been published in major geological journals. GSA Memoir 171 is a valuable addition to the libraries of institutions and individuals puzzling the complexities of thrust interactions. The memoir, like previous memoirs on the Rocky Mountains, will serve to focus international attention on the structural geology of the region. The sparse industry representation and data (only one small seismic line) is largely the result of the industry downturn which focused attention away from the Rocky Mountains. Those interested in the area are urged to complement Memoir 171 with the industry-based Rocky Mountain Association of Geologists volumes on the Cordilleran thrust belt and Rocky Mountain foreland provinces. Memoir 171, *Interaction of the Rocky Mountain Foreland and the Cordilleran Thrust Belt*, breaks no new theoretical ground, but does a good job describing the complex geometries resulting from the overlap of thin-skinned and thick-skinned thrust faulting in the Rocky Mountains.

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Celebrating the Scandinavian Caledonides

Gayer, R. A. (editor) 1989. *The Caledonide Geology of Scandinavia*. Graham & Trotman, London, U.K. 312 pp. Price £95, $159.

This volume contains an edited selection of some 25 papers presented during a conference at University College, Cardiff, U.K., in September 1987.

From the title, readers might reasonably expect a book to complement the 1978–1979 review volume on the British sector of the Caledonide Orogen—*The Caledonides of the British Isles Reviewed* edited by A. L. Harris, C. H. Holland & B. E. Leake (*Spec. Publs geol. Soc. Lond.* **8**). Instead the scope and coverage are much more limited, with some 14 out of the 20 papers on the Scandinavian Caledonides being concerned with various aspects of the understanding of the Caledonian evolution of Finnmark and adjacent areas of northern Norway and Sweden. Indeed, a specific section is devoted to papers concerned with controversies surrounding the timing, status and characterization of the Finnmarkian "Orogeny"—the early tectonometamorphic phase (or phases) which affected the leading edge of the Baltic plate in northern Norway prior to the eventual closure of Iapetus Ocean and its collision with the Laurentian continental plate during the climactic stage of the Caledonian orogeny.

This special emphasis stems from the fact that the Cardiff conference was held to celebrate the 25th anniversary of the Norwegian Caledonides research group at University College, Cardiff. Hence the coverage in this volume strongly refects the direct interests and important contributions made to the understanding of the Caledonides in northern Scandinavia, by the Cardiff research group, led in recent years by Rodney Gayer—the editor of this volume.

In terms of both size and coverage, this latest volume certainly pales alongside the 1266 page two-part tome *The Caledonide Orogen—Scandinavia and Related Areas* edited by D. G. Gee & B. A. Sturt (John Wiley, Chichester, U.K. 1985), based on papers read at the major symposium held in Uppsala, Sweden, in 1981. However, a largely different authorship has ensured that there is in fact little overlap in content with this earlier, more comprehensive, review text.

In view of the title, it does, however, come as a surprise to find included a section containing five papers on the East Greenland Caledonides.

Within this volume, papers are grouped into seven parts. The opening and most specific and unique part is entitled *Finnmarkian geology*, and comprises five papers. The first by R. B. Pederson, G. R. Dunning & B. Robins provides new zircon ages from nepheline syenite pegmatites in the synorogenic Seiland igneous province which suggests that deformation in this region had ceased by mid to late Cambrian times. R. D. Dallmayer, A. Reuter, N. Clauer & N. Liewig provide K–Ar and ^{40}Ar–^{39}Ar ages for illites formed during low-grade metamorphism of the Lower Allochton and Autochthon in Finnmark which refute previous suggestions of a Finnmarkian history. From nappe correlation in NE Troms and W. Finnmark, R. E. Binns questions previous age data and the existence of the Finnmarkian orogeny. However, in the following paper, D. Tietzsch-Tyler presents evidence for an early Caledonian deformation in central Norway suggested to correlate with the Finnmarkian orogeny. In the final paper of this section, C. Townsend & R. A. Gayer present a summary of data, ideas and problems concerning the timing of orogenesis in Finnmark. The consensus view presented is that a Finnmarkian "orogeny" at 540–490 Ma, as previously defined, did not occur as such. Rather, evidence indicates two or possibly three distinct pre-Silurian phases of orogenesis in this region.