prepared to consider the statistics even though they have yet to be introduced formally or mathematically to their meaning.

Finally, I must emphasise that I do not wish to be critical of this book. It is certainly very good value for money at £16.95 for the paperback edition. Personally, I did not find the approach taken off-putting and I will certainly make use of it in my attempts to teach (circular) statistics to my students. For this I am indebted to the author. However, my bitter experience warns me that I should not expect many of my students to use this book when I recommend it to them. Hopefully, if they go on to serious data collection and appraisal, they will remember this book and give it the attention both it and their data deserve and demand. In the meantime, let me repeat my plea for a more intuitive approach to teaching all branches of statistical data analysis in the Earth Sciences, one which excites and therefore instructs.

References

Fisher, N .I., Lewis, T. and Embleton, B. J. J. (1987) *Statistical Analysis of Spherical Data.* Cambridge University Press.

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Skating on ice

Bennett, M. R. and Glasser, N. S. 1996. *Glacial Geology: Ice Sheets and Landforms.* Wiley. Price £19.99 softback; £45 hardback.

Research on glaciers and their geomorphic effects is conducted by scientists with widely divergent backgrounds and approaches. Scientists who have never trudged up a moraine, but with enviable facility in continuum mechanics, share journal space with those who meticulously describe and interpret glacial sediments but feel faint when confronted with differential equations. I am sympathetic toward attempts to synthesize and condense work from such different perspectives into a glacial geology text.

There is strong need for such a text. The widely used *Glaciers and Landscape* by Sugden and John is 20 years old. Drewry's *Glacial Geologic Processes* provides a good synthesis of concepts from glaciology and glacial geology but includes little on landform evolution and glacial history. Paterson's classic, *The Physics of Glaciers*, does not discuss glacial geomorphology.

The goal of this text is "to provide an account of glacial geology which is accessible to the undergraduate and uncluttered from unnecessary detail". The text, indeed, is not cluttered with details and is refreshingly thin. Its traditional but logical organization works well. After introducing the subject, the authors begin with a discussion of glacial history and the causes of ice ages. This is followed by two chapters aimed at introducing some of the fundamentals of glaciology: glacier mass balance and flow and the movement of water in glaciers. The following seven chapters focus on the processes and landforms of glacial erosion and deposition, including a discussion of lacustrine and marine sedimentation. The final chapter examines large-scale patterns of glacial sediments and landforms.

In evaluating an introductory text, such as this, a critical question is whether the authors succeed in reaching meaningful and accurate conclusions, despite the need to minimize detail. In the case of a glacial geology text, this requires a thorough knowledge of both the charactistics of glacial landforms and the mechanics of glacial processes. The authors consistently demonstrate that they are familiar with the former but not the latter. Their frequently misleading discussions of the mechanics of glacier flow, erosion, sediment transport, and deposition are the weakest parts of this book. For example, beginning students of glacial geology will learn from this book that the idealized temperature profile through a polar glacier is linear (it isn't), that the contact force between abrading clasts in glaciers and a rock bed depends primarily on the difference between the ice overburden pressure and the basal water pressure (it doesn't), and that deformation of sediment beneath the Antarctic ice streams has been observed directly (it hasn't). These and other misconceptions in this book are, in part, a result of an unfortunate reliance on interpretations, sometimes decades old, that are grounded more on intuition than on reliable measurements and sound physical reasoning. It is disturbing to see old myths perpetuated and modern studies neglected.

For this reason I suspect that structural geologists will find the descriptive aspects of the book interesting but many of the mechanical interpretations naive. Many glacial processes are highly relevant to structural geology: nonlinear viscous creep of ice, shearing, faulting, and comminution of granular materials beneath glaciers, the role of low effective stresses in sustaining fast glacier sliding, and the slow growth of cracks in bedrock loaded by glacier ice are examples of problems with obvious analogues in structural geology. Unfortunately, it is precisely these kinds of subjects that are not treated authoritatively in this text. For example, structural geologists will be surprised to learn on page 38 that creep and large-scale folding are two distinct ways in which a crystalline solid (ice) can deform.

Another shortcoming of the book is that by adopting the scope of earlier texts it does not address some to the most exciting and topical developments in glacial geology this decade. For example, the authors do not mention the discovery of quasi-periodic layers of ice-rafted debris (Heinrich layers) in sediment cores from the North Atlantic and the consequent flurry of hypotheses regarding past interactions between ice sheets, oceans, and climate. Nor do they discuss the complementary and unprecedented insights gained from recent Greenland ice cores. Structural geologists interested in the coupling between glacial erosion and tectonic uplift, an issue of widespread current interest, will find no discussion of the subject. I am tempted to attribute these omissions to the long duration of the publishing process, but citations that post-date these studies are included in the text.

It is perhaps, too easy to dwell on flaws and omissions; I would recommend this book for those interested in a concise description of glacial landforms and sediments. Geologists, however, interested in an accurate, contemporary synthesis of what is known about glacial geologic processes and history should look elsewhere.

References

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Controversies in Central America

Mann, P. 1995. *Geologic and Tectonic Development of the Caribbean Plate Boundary in Southern Central America.* Geological Society of America, Special Paper 295; 349 pp, 8 plates in pocket. Paper, $100.

This weighty volume contains 17 articles on the geology and tectonics of Panama and Costa Rica, organized by Paul Mann of the University of Texas and dedicated to Richard Weyl (1912–1988), a leader in geologic studies of Central America and the Caribbean. Though the majority of authors are American, some researchers are from Costa Rica, Mexico, Europe and Japan. There is a short biography of Weyl and a list of 33 of his most pertinent publications. Mann has written an excellent 22-page preface/introduction. The book is well-illustrated with line drawings, maps, and a few black-and-white halftones. The folded plates, split into two pockets fore and aft, are useful and amplify the texts, especially the last two which show bathymetry and a perspective diagram of offshore Pacific Costa Rica.

Paul Mann prepared a preface for the book, which contains several valuable sections. There is a history of geological work in the region, and several lists and maps of published and unpublished works. The organization and purposes of the volume are described. Mann's plan is

to produce a series of publications on circum-Caribbean geology; this is the second, following a 1991 volume (G. S. A. Special Paper 262) on Hispaniola by Mann, Granville Draper, and John Lewis. Finally, Mann lists and briefly discusses four "unresolved geologic controversies in Central America". These are: (1) Did the Caribbean form in its present position or did it move in from the Pacific as an island-arc system or systems? (2) Is the basement of Costa Rica and Panama formed from accreted fragments of partially subducted Pacific crust, from subduction zones forming in place, or from uplifted pieces of Caribbean oceanic plateau? (3) Is the Caribbean a single plate or is it a set of microplates shifting as they move between the larger North and South American plates? (4) What forms the features near the end of the Central American arc in Panama and Costa Rica: the pattern of volcanism and seismicity, and the changes in topography and bathymetry? This volume presents arguments for different views of several of these problems, generally favoring the more dynamic alternatives but in several cases accepting two views as partially correct, both contributing to a general solution. I might add a fifth problem, slightly less general: Is the border between the Caribbean and Nazca plate a transform or a subduction margin? Evidence on both sides is presented, but I would favor a transform motion.

The book is divided into three parts of 4, 8 and 5 papers each. The first four papers describe and discuss geochemical and paleomagnetic findings in Costa Rica and Panama, describing tectonic blocks, terranes, and the subduction zone angle. Plate history of the region is described, as are the problems of the southern end of the Middle America subduction zone, possible transform movement along southern Panama (J. de Boer finds no paleomagnetic evidence for transform motion), and the northern end of the Nazca subduction zone along northern South America.

The remaining two sections emphasize modern tectonics, bathymetry, and seismicity. James Kellogg and others present GPS data showing transform motion along southern Panama, and suggests that the isthmus connection between the oceans closed 6 to 12 my ago. They present a gravity map of southern Central America. S-shaped bending of the isthmus is not supported by GPS data. Graham Westbrook and his group give multichannel seismic reflection profiles with considerable evidence of left-lateral movement along the plate boundary. Mann's group present detailed structural data from the deformed belts of southwestern Panama, describing oblique subduction, collision, and oroclinal bending of the isthmus. They seem to favor subduction over transform motion for southwest Panama plate margin, but leave open the possibility of both processes ocurring. They attempt, fairly successfully, to correlate stratigraphy between the onshore and offshore rock sequences. Finally, two papers by the Eli Silver group describe the North Panama Deformed Belt, both off- and onshore, with seismic and structural profiles, showing nice details of thrusting. They quote Keller (1989) for the closing of the Panama–Caribbean seaway at 1.8 m.y., rather than the earlier 6–12 m.y. date that Kellogg uses.

The final part of the book, 5 papers, is mostly on the effects of subduction of the Cocos Ridge beneath Costa Rica. Radim Kolarsky and the Paul Mann group interpret seismic profiles, onshore data, and detailed structures to give a picture of volcanism, uplift, subsidence, and deformation related to subduction of the Cocos Ridge bulge on the descending lithosphere. Collins and others give paleontological backing for the emergence timetable, and R. Von Huene and others describe slumping, submarine faulting, and other bathymetric features near the Costa Rican Pacific coast, related to the same subduction of the Cocos Ridge and adjacent seafloor. M. Protti and others describe seismicity, the configuration of the subducting plate, and the distribution of volcanism, and F. Tajima and others describe two large earthquakes, one on the subduction zone and the other on the Caribbean coast in a "back-thrusting" zone above the subduction zone. They briefly discuss recurrence times for the two regions: 40 years for the subduction zone earthquake and 5–28 times longer for the intraplate event.

I found the volume useful for Caribbean studies, especially emphasizing tectonic and plate history aspects. It is well illustrated, clearly written, and well-organized. It is, however, expensive at $100, as most special papers and memoirs are. I hope that research centers and specialists in western Caribbean geology would get this volume. It could serve as a text for a seminar on Central American plate tectonics or geology, but probably not for any more general course. Basic data from paleomagnetism, geochemistry, structural analysis, paleontology, and seismicity can be found in several papers, and there are abundant seismic reflection profiles and bathymetric interpretations. All these different specialities are integrated into a well-composed and readable volume.

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Structures are still fun

Davis, G. H. and Reynolds, S. J. 1996. *Structural Geology of Rocks and Regions*. John Wiley and Sons, New York 2nd Edition. Price £21.95 (hardback)

This textbook, first published in 1984, has been substantially expanded and restructured to yield a richly illustrated text of some 776 pages. In the 12 year interval since the first edition several excellent books of similar scope have appeared including Suppe (1985), Twiss and Moores (1992) and Hatcher (1995) and these, taken together with the authoritative volumes by Ramsay and Huber (1983; 1987), provide the current generation of geology students with an impressive choice of undergraduate textbooks. In spite of this stiff opposition the second edition of *Rocks and Regions* will, I predict, become adopted as a course text at a large number institutions around the world.

Part 1 of the book provides the essential theoretical background necessary for the effective discussion of geological structures which takes place in Part 2. Practical issues such as fieldwork procedures are bundled together to form Part 3.

Part 1 consists of four chapters. The first of these, *The Nature of Structural Geology*, defines the scope of the subject and successfully whets the appetite for what is to come. The reader is here introduced to the idea of structural analysis; the initial data collection/mapping phase followed by the building and testing of hypotheses. Here and throughout the book the reader is eased into unfamiliar territory by the use of analogies with the tectonics of pizzas, the shear deformation of garden gates and the preferred orientation of birds. A strong sense of fun pervades the book. The next chapter *Kinematic Analysis* explains and illustrates different aspects of deformation, translation, rotation and strain. The strain ellipse concept is explained well, as is the Mohr circle for strain, though the latter would have been made easier by employing the notion of the pole. Only minor criticisms can be made, e.g. the example of constant area deformation given on page 61 is not ideal since it implies incorrectly that the percentage shortening in the S_3 direction is equal to the percentage extension along S_1.

The fundamentals of stress and rock physics are the subject of the chapter *Dynamic Analysis*. The student lacking a maths/physics background will find the material here accessible and worthwhile. The choice of illustrative material is excellent. Incidentally, the authors clearly attach great significance to Fig 3.47, which appears twice more in later chapters. In the simple calculations of stress it may have been wise to spare the student such a variety of units. A potentially fatal error is made in the calculation of the stress exerted by an ice-skater on page 106. Chapter 4, *Deformation Mechanisms and Microstructures*, has been introduced since the first edition. Clear explanations, superb photographs and professional artwork make this a useful addition to the book.

Part 2 deals systematically with the major classes of structures and opens with a chapter on *Joints and Shear Fractures*. This detailed 70-page review reflects the current emphasis on this topic and provide a up-to-the-minute summary of ideas on geological fractures and fracturing. The appearance of these structures in the field is reconciled with theoretical failure criteria and the results of laboratory testing. The importance of these structures to economic and applied geology is emphasised. *Faults* are dealt with comprehensively in the succeeding section. These are discussed from the perspective of stress (Anderson's theory) and strain (balanced cross-sections). As elsewhere throughout the book, examples are chosen from around the world, but with a natural preference shown for the authors' geological back yard, the western USA. The statement on page 229 that "slickenlines and drag folds should be mutually perpendicular", suggests incorrectly that the hinges of drag folds can be used as indicators of the slip direction. However, I have few other quibbles.

It is remarkable that the chapter entitled *Folds* is one of the shortest in the book. Is this in keeping with lower importance presently attached to these structures relative to faults? This suspicion of mine is supported by the emphasis placed on those folds that form as a consequence of faulting, fault-bend folds and fault propagation folds.