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BOOK REVIEWS

A big look at the small-scale

Passchier, C.W. and Trouw, R.A.J. 1996. *Microtectonics*. Springer-Verlag, Heidelberg. ISBN 3-540-58713-6. Price: DM 64, ca £25.00, S.Fr. 61.5

What is "Microtectonics"? This was my first question on hearing of this book. It is, the jacket claims, "the interpretation of small-scale deformation structures in rocks". One might react by thinking that this subject is well covered in existing texts—but in fact this contribution is a different and individual approach to these studies, and is very up to date on many issues which are still the subject of ongoing research and debate. It covers both the theory and practice of microstructural interpretation and, not surprisingly (in order to provide a coherent picture), brings in many metamorphic concepts along the way as well. The intended audience includes advanced undergraduates and graduates. I think any researcher would find it useful, though in some places issues are glossed over which could have been explored in more detail: a function, doubtless, of the level of the target audience as well as space constraints.

The book begins with the theoretical framework for understanding how microstructures evolve, addressed in the first chapter in terms of a general scheme, highlighting what microstructures can and cannot tell us, then in terms of basic strain and kinematic concepts (Chapter 2), and then deformation mechanisms (Chapter 3). We then move on to observables: foliations and lineations, and how they develop. Following a chapter on shear zones, specific sets of microstructures are discussed: dilatation sites in Chapter 6, porphyroblasts and their textural relationships in Chapter 7. Natural "microgauges"—the authors' general term for microstructural/chemical features which can be used to infer stress, temperature, or any other aspect of a rock's history—are described next. A chapter on special techniques of observation is followed by one on sampling and thin section preparation. Finally, in Chapter 11, we are presented with a set of exercises which, basically, consist of photographs of thin sections, which the reader is invited to interpret.

From this list, it is clear how wide ranging this book is—including the theory of microstructural development, the practice of observing the results, framework for sample preparation, exercises, and (at the end of the porphyroblast chapter), how it all links to larger scale processes. In 289 pages, packed with illustrations, there is a limit to the depth in which these diverse topics can be addressed. In some parts, then, the discussion serves as an extended introduction to the topic, rather than a comprehensive analysis. But offset against this are the number and quality of illustrations: photomicrographs of natural textures—largely selected from the extensive collection now housed at Utrecht—and generally excellent line drawings covering many concepts and techniques. These authors think in pictures and the extra effort required to produce so many of them is commendable. They state clearly at the outset that "we commonly think that we 'see' dynamic recrystallisation, refolding and grain growth, while all we actually see are geometric patterns that may have formed in a number of different ways". This is a key theme in microstructural analysis, and it is the researcher's task to make the transition from description to interpretation as logical as possible.

Chapter 1 indicates fundamentals which few would dispute, such as: small-scale observations can indicate large-scale processes; they can indicate relative but not absolute timing of events; deformation "phases" may be diachronous. Chapter 2 addresses finite and progressive strain concepts, distinguishing coaxial and non-coaxial flow and defining vorticity. A few words on stress and rheology lead us into the next chapter where deformation mechanisms in rocks are summarised: 32 pages cover cataclastic flow, pressure solution, dislocation creep and twinning, followed by recovery and recrystallisation (static and dynamic). The rheologies of common minerals are summarised, and we finish with a section on deformation mechanism maps. Some of the most interesting (and contentious) parts concern not the theory of dynamic recrystallisation, but the lines of *evidence* that can be followed to distinguish different processes: for instance, how do we distinguish grain boundary migration recrystallisation from subgrain rotation recrystallisation? These points are made in "boxes" included in, but distinct from, the main text, a format which works rather well. Chapter 4 introduces fabric concepts—what they are and how they may be produced. We find fairly standard models for solution transfer and dynamic recrystallisation together with a cautionary section on mimetic growth. Subsequently, how foliations relate to outcrop and larger scale structures is indicated, and then lattice preferred orientations are introduced. This last topic has been developed a great deal in the last twenty years and therefore this material is not so easily found in other texts. Quartz is the main mineral under discussion, but brief summaries for other minerals form useful pointers to recent literature.

The title of Chapter 5, "Shear Zones", reflects both the authors' interests and those of perhaps the majority of structural geologists today. It is at this point that the book becomes somewhat polarised: there is no chapter on "Folds" to act as a counterbalance! It is interesting (and to some, I know, alarming), how our conceptual models of large-scale deformation have moved away in recent years from those of pure shear, or of overprinting folding events, towards models of crustal-scale shear zones, perhaps linked, partitioning strain. Whilst no geologist would deny that both folds and shear zones are important, and whilst maybe this represents my own biassed view of what has happened, it nevertheless seems that the elegance and relative simplicity of shear zones, and how their kinematics may be determined and linked to larger-scale phenomena, has influenced these authors. They do discuss folds, but these formed within shear zones. The first section is built round a Sibson-style crustal-scale fault model, with different types of fault rock formed at different depths. We then move towards the Holy Grail of shear zone study: what was the sense of shear? There are 20 pages on this. We find all the diverse shear sense indicators that the first author (in particular) has publicised effectively in recent times: a section both interesting and partial. The best indicator of partiality is on p. 124 (15 pages into the discussion). "Vergence of Asymmetric Fold Sections" is dismissed in a paragraph. Yes, I know they are far from reliable, but surely those poor neglected shapes deserve better than this? All sorts of issues could have been aired here, for instance Casey's work on vergence reversal during shear, and more generally how to decide on the three-dimensional geometry of what one is examining, which would help to clarify the relationship between folding and shear.

The next two chapters are on dilatation sites and porphyroblasts. These titles may appear a bit specialised but in fact the amount of material presented is a fair reflection of the huge amount of work done on these microstructures and of their usefulness. Cartoons of the development of fibrous veins and strain shadows, together with super photomicrographs of actual examples, are prominent. The porphyroblast chapter covers the classic ideas of pre-, syn-, and post-tectonic together with more contentious material on porphyroblast rotation. An interesting section on different types of reaction rim, and how to interpret them, comes next. We jump, rather suddenly, and for a brief discussion, to how porphyroblast–matrix relationships may be used to shed light on larger-scale processes. This is, of course, a huge task and outside the scope of the book, so the discussion is really no more than a sketch.

I like the next chapter, on "Natural Microgauges". Basically, this covers all microstructures which can be used to recover quantitative information on parameters of a rock's history. Strain markers become "strain gauges", lattice preferred orientations can be used as "vorticity gauges" and recrystallised grain sizes can be used as "stress gauges". While these ideas are established, to consider them in this unified way is rather neat. It also makes clear what enormous assumptions are made in going from microstructural measurements to deductions about history. This is the last chapter which concerns the general way in which microstructures may be interpreted. The next two concern different

observation and modelling techniques—they do not follow on smoothly from the previous chapters, but their relevance is obvious. In Chapter 9 we read of cathodoluminescence, scanning electron microscopy, transmission electron microscopy, channelling, and universal stage measurements. The latter two sections are concerned with measuring lattice preferred orientations: it would be useful also to have a section on geological use of forescatter and EBSP—applications which are too new to have been included in this 1996 book, but might find a place in subsequent revisions. The only part I am uncomfortable with is the detailed discussion of how to use a universal stage. Though it could be argued that this is useful, it could equally be argued that instructions on how to use a transmission electron microscope would be useful, and so on. Chapter 10, a short discussion of sampling and section preparation, makes pertinent points about reconstructing 3D geometries from 2D thin sections. Finally, we have a problem section (photomicrographs for the reader to interpret), an extensive glossary, references (I estimate between 800 and 900) and an index.

This book, then, is a wide ranging and up to date introduction to microstructure development, covering the theoretical framework, how to interpret textures in that framework, and different methods of observation. As a result of the breadth of the topic, not all aspects are addressed in the detail that a research-level reader may need (though this is true of any book). Sometimes the depth of treatment is a clear reflection of the authors' own interests: particularly the emphasis on shear zones and how to deduce shear sense. The strengths of the book include the range of issues addressed, the quality and abundance of illustrations, and the number of recent cited papers showing how up to date the discussion is. It would be rather advanced for undergraduates as a standard text, but selected sections could be used in teaching. For postgraduate and further research level work, it provides a good introduction and enough references to allow individual issues to be pursued. In summary, a book well worth having.

John Wheeler

Liverpool, U.K.

Europe before the Permian

Dallmeyer, R.D., Franke, W. and Weber, K. (editors) 1995. *Pre-Permian Geology of Central and Eastern Europe*. Springer: Berlin, Heidelberg, New York. 604 pp., 233 fig., 30 tables. Price: DM498. ISBN 3-540-55472-6.

The volume is a report of the IGCP Project 233 "Terranes in the Circum-Atlantic Paleozoic Orogens". Eighty-six authors from eight countries have contributed to this overview on topics of the pre-Permian geology of parts of Central and Eastern Europe. Some selection criteria of the chapters are worth mentioning. There are only marginal notes on the left-Rhenish Slate mountains, Brabant massif, Hunsrück, Vosges, Black Forest, Pre-Permian of the South German block, and therefore the title and frontpiece are a little misleading. However, the older pre-Permian rocks are exposed in greater variety in the eastern half of Central Europe, so most of the contributions deal mainly with this part of Europe.

The 11 chapters are subdivided into stratigraphy, structure, igneous activity, metamorphic evolution and metallogenesis. The discussed units are Rhenohercynian foldbelt, Northern Phyllite Zone, Mid-German Crystalline High (with Spessart, Odenwald and Saar-Nahe Basin), Saxothuringian Basin, Western Sudetes, Moldanubian Region, Moravo-Silesian Zone and the North Variscan Foreland. Numerous references and a subject index assist the reader.

In some regards the book deals mostly with the Hercynian processes in Central Europe because their importance in relation to the pre-Hercynian units was underestimated. It has been known for a long time that the eastern half of central Europe is dominated by Cadomian series, processes, granites etc. with differing intensity, masked by Hercynian effects. But it would be an oversimplification to classify more than 2 000 Ma history of the "United Plates of Europe", at least in Central Europe, only as a forerunner of a Devonian development. Nearly all treated structures developed in Cadomian time, such as Avalonia or Armorica. But the accretion of the middle Palaeozoic series with other Proterozoic plates or terranes happened mostly in Palaeozoic time, like that of Avalonia with Baltica in the Ordovician. The authors demonstrate the strong Hercynian overprinting on pre-Hercynian protoliths in many parts of the Bohemian massif. The inner part of the whole Europe is built up from different units which came together in the Palaeozoic.

The parts dealing with the metallogenesis are welcomed, despite the fact that only a few ore mines have survived in Central Europe. Results for different kinds of mineralization are indicative of fluid processes, composition of deeper levels of the crust and of tectonic events and improve the knowledge of the areas. Also, these chapters balance the deficiency in the treatment of the geochemistry of sediments. The relevance of volcanic series for primary mineralization and sources for later hydrothermal leaching are shown. In general the geochemistry is discussed much more in detail for magmatic rocks than for sediments.

The uniform crustal thickness is mentioned and its Upper Palaeozoic to Cenozoic age, caused by extension and magmatism. Therefore, the map of crustal thickness is not a mirror of Hercynian structures.

It is neither difficult nor fair to find "gaps" in books of this type. Here, among other structures, the Cambrian–Lower Carboniferous zone of Doberlug–Delitzsch is not discussed. This is easy to detect because the editors mention a 50 km offset along the Elbe zone, but on p. 161, fig. 5 no offset is to be seen. The final evidence of this problem is the configuration of the synclinal zone of Doberlug–Delitzsch which crosses the Elbe zone. A further minor disadvantage is that there is no treatment of the granite bodies in the eastern Rhenohercynian zone.

Some relations are not clearly proven in the text: it may be that both parts of the "Rheno-" and "Hercynian" differ not only (as the authors believe) by their clastic (Rheno) and pelagic (Hercynian) facies. Furthermore, there is affinity in Silurian and early Devonian sediments in the Rhenohercynian areas with Thuringia and Bohemia, but the Ordovician series in both areas are different.

The basement of the North Variscan Foreland (Chapter IX) is composed of either Gondwana-related Cadomian–Caledonian terranes or of rocks from a Caledonian mountain chain. The platform stage started in Lower Devonian with Old Red formations. The Upper Devonian and Lower Carboniferous series are shelf deposits. During the Upper Carboniferous the area became the marginal basin in front of the Variscides. The external Variscides are thrust upon the Variscan foreland.

The pre-Devonian Rhenohercynian ocean (Chapter III) closed before the onset of the Rhenohercynian rifting which led to the Devonian basin. Pre-Devonian series of the Northern Phyllite Zone hint at a Cadomian basement of this area which later became a part of the southern rim of the Rhenish massif.

The Mid German Crystalline High is an Armorica-derived structure, composed of pre-Devonian and post-Devonian magmatic and metamorphic complexes. According to several seismic profiles and geological data, it is a first order boundary (e.g. north of its eastern part, the characteristic Vendian graywacke (flysch) series are missing). It was a zone of convergence between late Devonian and lower Carboniferous. Up to now, its role in the development in pre-Hercynian time is not completely understood.

The Saxothuringian basin (STB, Chapter V) belongs to Armorica. Its earlier development is Gondwana-related. The Palaeozoic development started with a Cambro–Ordovician rift basin on Cadomian crust. After controversial discussion on large-scale allochthony in the 1920s, the most prominent contribution in the last 10 years has been the assertion of the allochthonous position of large parts, as demonstrated particularily by petrological, seismic and structural data. High-pressure rocks indicate deep subduction conditions during the Hercynian collision. Later thrust tectonics and metamorphism have shaped the crust. The east Saxothuringian zone (Erzgebirge) with rocks of different P,T-conditions at the same level reveals a tectonic stratification. The Hercynian exhumation has caused the development of flat shear zones. Primary Proterozoic sedimentary features are preserved, however. South of the STB the Bohemian is discussed as either a separate basin or as a marginal part of neighbouring units.

The West Sudetes (Chapter VI) have similarities to the Saxothuringian and are characterized as a Hercynian tectonic stack of Cadomian through Hercynian components. Some of the units are described in a comprehensive way, as the Moravo–Silesian Zone, where a discussion of the palaeogeography and sedimentary processes in addition to the Hercynian nappe tectonics is included. This chapter seems to be one of the most informative ones in terms of factual completeness. In other chapters the importance of the Cadomian history seems to be underrated, as in western Bohemia, where the previous geological knowledge regarding age relationship was confirmed by age determinations. This unit is of Cadomian age and it was overprinted in Hercynian times. Most structures in the Moldanubian Zone (Chapter VII) are