

strain theory in texts on structural geology and rock deformation. In this book the theory of strain in particular is not given in a form which is very useful to geologists.

The second section deals with a number of very specific points, to each of which a chapter is devoted. The general point is made that fracturing is characteristic of upper crustal deformation, and for the purpose of subsequent description, "geological fractures" are categorized according to whether they are joints, tension gashes, stylolites (!) or faults. A description of the geometric characteristics of each and its mode of origin are then given. The reactivation of arrays of variously oriented fractures and the use of their orientations and the orientations of slickenlines upon them to infer the principal directions of the bulk displacement field are described (probably for the first time in a textbook). Geometric characteristics of small fractures commonly associated with large faults are then discussed, and the book is concluded with a description of the commonly observed relationships between fold geometry and fault and joint arrays.

A more balanced treatment of brittle failure of rocks might include an outline of the theories of stress and strain, a description of experimental techniques used in the study of rock fracture, an outline of the principles of fracture mechanics, and the phenomenology of rock failure in compression, including the effects of dilatancy and the evolution of microstructure. A considerable amount of space should be devoted to rock friction, the localization of faults and their structural and microstructural characteristics, especially in view of the attention that subject has received in recent years in connection with earthquake hazard reduction. The failure of rocks in effective tension and the phenomenon of hydraulic fracture should receive special attention.

Various other texts also give emphasis to particular topics from this list. For example, Paterson (1978) gives a comprehensive review of experimental studies of brittle fracture, whilst the recent compilation of papers edited by Atkinson (1987) gives an overview of the application of fracture mechanics in geology and geophysics. Blès and Feuga make no mention of the concepts of fracture mechanics.

There is also a 'traditional' kind of approach to the treatment of rock fracture exemplified by Jaeger and Cook's *Fundamentals of Rock Mechanics*, in which rock failure is described entirely in terms of the applied state of stress, without reference to the microstructural changes which characteristically accompany progressive failure. In the latter text and others like it, an idealized 'Griffith fracture' approach is developed (although there is in fact little microstructural basis for doing so), but Blès and Feuga do not explore this avenue at all. The application of the Griffith energy balance concept via the Irwin fracture mechanics approach represents the only sound basis for a theoretical description of rock failure, but this is typically lacking in presentations of rock mechanics for consumption by structural geologists at this time, including the present volume.

In many of the above respects, therefore, I find the book of Blès and Feuga to be deficient. On the other hand, it would be unreasonable to expect a comprehensive coverage in such a small volume. Provided the reader is aware of its limitations, it provides a useful overview of a number of topics in rock fracture. One very positive aspect is that the translation into English is excellent and thoroughly readable.

It is not made specifically clear to what audience the book is directed. Most structural geologists will be familiar with the majority of the material, and will find several of the sections elementary. For example, the whole chapter which is devoted to relationships between fractures and folds, and the description of characteristic structures which develop at different depths within the crust, would be appropriate to first or second year undergraduate courses in geology. As a course book, I would think the text is most suited to undergraduate students of civil or mining engineering taking a course in geology.

REFERENCES

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 Jaeger, J. C. & Cook, N. G. W. 1976. *Fundamentals of Rock Mechanics*. Chapman and Hall, London.
 Paterson, M. S. 1978. *Experimental Rock Deformation; The Brittle Field*. Springer, Berlin.

London, U.K.

E. H. Rutter.

Structures in granites

Marre, J. 1986. *The Structural Analysis of Granitic Rocks*. North Oxford Academic, Kogan Page, London. 124 pp. Price £18.50.

(Translated, revised and updated from the original French language edition first published in 1982.)

This slim, hardbacked volume is one of a series of BRGM publications which have been republished in English by North Oxford Academic. Although presenting itself as a type of handbook on the description and interpretation of deformational features of granitic rocks and the relationship to emplacement mechanism, the breadth of investigation implied by the title of the volume is not found in the contents. The text is principally concerned with structural features formed in granitoids prior to their full crystallization and much of this is interpreted, following the earlier work of Cloos and Balk to be the result of flow of magma into emplacement spaces. Crystal plastic strain fabrics and brittle deformation are only dealt with where these are considered to be continuations of the "magmatic flow processes". The book is therefore quite narrow in both its scope and its interpretations.

The text is presented in three basic sections whose organization follows closely that of the classic Balk memoir and commentary on Cloos's work *The Structural Behaviour of Igneous Rocks* (1937). Part 1 deals with the microscopic description and interpretation of textures and fabrics: the recognition of magmatic textures and their modifications by crystal plastic strain and deuteric activity; the recognition and recording of fabrics and sub-fabrics and their relationship to different types of strain ellipsoids and to progressive deformation; the interpretation of the fabrics as phenocryst/crystal laden suspensions deforming in magmatic flow (the latter regarded by Marre as a purely simple shear process).

Part 2, which deals with macroscopic structures, forms the bulk of the book and is divided into flow structures, joints, contacts and enclaves. "Flow Structures" treats the description and interpretation of "platy" fabrics (including schlieren), "combined linear and platy" fabrics and "purely linear" fabrics (what other modern texts would probably refer to as S, LS and L fabrics), together with more complex situations. In the section on joints, Marre again follows Cloos in asserting that where aplite and pegmatite filled joints form in orthogonal and parallel relationship to LS flow fabrics, the joints are a "continuation" of the flow deformation: although as with this earlier work the mechanical basis for this relationship is not well understood. Igneous enclaves are divided into "elongate" and "angular". Elongate enclaves are shown to have low viscosity contrasts with the host granite and are considered to have been "liquid" at the time of deformation with the host enclave system representing evidence for a partially mixed magma. The invariably good parallelism of these enclaves is interpreted to be the result of "a shear strain of considerable intensity" (p. 67). Angular enclaves have high viscosities relative to the host, were crystalline at the time of incorporation and were, according to Marre, produced by the explosive fragmentation of the parent rock.

Part 3 on megascopic analysis (essentially plutons as a whole) begins by comparing model studies of magma emplacement with "flow patterns" in plutons themselves. This emphasizes that the orientation and strength of flow structures reflects the shape of the pluton contacts ("the nearest friction-exerting surface" of Cloos) and these in general should be dome-like. Variations on this pattern can be attributed to coeval magmas of differing viscosity creating perturbations in the flow lines. The final section analyses, using the methodology described, examples of different plutonic complexes: the inflation by successive magma injection of the Ardara granite of Donegal; the vertical ascent and lateral spreading of the much quoted Querigut complex in the Pyrenees; the roof collapse/cauldron subsidence and injection of low viscosity melts associated with the Rosses and Barnesmore granites of Donegal; the ballooning emplacement of the Spanish Sierra Morena plutons into synchronous regional shear zones and finally the varying emplacement mechanisms of a Variscan batholith in Corsica.

On the positive side, this book is short, well laid out and well illustrated (although there are no photographs). Of all the sections in the book I found that on microscopic structures the most useful in that it emphasizes the possibility of determining the progressive-deformation history and rheological changes through the orientation distributions of sub-fabrics in any given granite. The author's continual exhortations to examine and describe rocks carefully before interpreting them is to be applauded.

On the negative side I found many of the sentences badly constructed and difficult to understand (although this may partly reflect

translation difficulties). The text also tends to be longwinded and repetitive. On a more serious note the book appears to be largely a reiteration of Balk's 1937 memoir (which I find much easier to understand) and the text pays scant attention to developments in this area of study and in related fields that have been published in the last 15 years. For example, Holder and Ramsay's quantitative ballooning model is not mentioned, let alone discussed and there is no mention of the general measurement and use of deformed xenoliths to quantify strain gradients in deformed granites. Much of the theoretical treatment of strain comes from the late 1960s and there is no acknowledgement for example that "flow" strains can be compounded simple and pure shears. This particular deficiency leads to the conclusion that low angles between fabrics and the contacts of adjacent undeformed granite are the result of "intense simple shear strains" without any independent evidence for such an assertion. The book therefore is rather out-of-date and it accepts almost in totality the conclusions of Cloos that "flow fabrics" are generated by movement of magma into spaces without any critical discussion of this. The alternative view, that regional tectonics can have an important role in generating pre-full crystallization "flow" fabrics in granites is only briefly considered with respect to the Sierra Morena plutons (the work of Brun and Pons) and it is unfortunate that this is not more fully contrasted with the Cloosian view throughout the book. Finally, the author draws about 80% of the examples from the Pyrenean Querigut complex and one must question whether such a geographically biased data set can be considered adequate for what is presented as a general text book.

Donny Hutton.

Durham, U.K.

Correlation not quite global

Leonov, Yu. G. & Khain, V. E. (Editors) 1987. *Global Correlation of Tectonic Movements*. John Wiley & Sons, Chichester. 286 pp. Price £45.00.

This much promising title covers a collection of 14 papers by 29 authors—a product of IGCP Project 107 *Global Correlation of Phases and Epochs of Tectogenesis* (1975–1980). It must be said, first, that the title is not entirely appropriate: all of the papers but one concern Eurasia alone, and almost exclusively treat the Alpine belt and its Cenozoic movements. The distribution of authors is rather one-sided, too: only two of the papers came from Western Europe and only one of them deals with this region. Even the elaboration of the Euroasiatic Alpine Chain exhibits gaps: the type localities of the western Alps (apart from inclusion in a paper on Italy), the Pyrenees, a substantial part of Carpathians, Crimea, Caucasus, the orogens of Turkey and of Middle Asia. (Some of these regions were considered but in terms of tectono-gravitational or volcanic processes.) The substance and organization of individual chapters are inconsistent. Along with an introduction to the problems of the correlation of tectonic movements (by the Editors of the volume) there are two general chapters rather loosely connected with the book's subject, and regional chapters based on tectonic units (Carpathians, Himalayas), as well as on geographical regions (Balkan Peninsula, Eastern Asia, Cuba) and on particular countries (Italy, Hungary). Some of these chapters analyse the tectonic–magmatic–paleogeographical evolution, and others are more specific, for example on olistostromes or volcanism.

Another reason for the impression that individual parts of the volume have not been co-ordinated enough are the differences in data presentation. For example, the series of paleotectonic maps, introduced in the Preface as one of main goals of the Project, entered only a few of the papers. In some chapters, even a tabular list of local tectonic events is lacking, as well as the lack of comparisons with other regions. In addition to that, the geochronological scales used by the authors differ substantially even for younger periods (for example, Miocene: 24–5, 23–5, 22.5–5, 23–10 My) as well as does stratigraphical nomenclature (for example that for the Neogene).

In spite of the 7 years since the Project finished, the authors do not seem to have studied their companion papers, because there is no apparent attempt to discuss and compare the material, even as far as different approaches to the same region are concerned (compare for instance Schwan's and Săndulescu's analyses of Balkan regions). The list of such shortcomings is extensive. One can easily understand the reasons of at least part of the inhomogeneities and gaps in the volume. Nonetheless they are a serious drawback for a book on *correlation*.

I have no doubt that individual chapters will contribute substantially to the international effort to correlate various geological develop-

ments. Among the regional papers a review of Cenozoic olistostromes of the Alpine belt by I. G. Scherba shows that along a great part of this belt, from the Pyrenees to Caucasus, the development of tectono-gravitational phenomena ("mixtites" as they are called by M. G. Leonov in an accompanying paper) was synchronous and took place in six phases, fitting well with the phases of Stille. M. Săndulescu, starting from a well-documented analysis of evolution of Balkan tectogens came to the conclusion (which seems to represent the majority of other authors) that synchronism and heterochronism of compressional events are complementary rather than exclusive features, since these events occur within some correlatable periods, but they are not ubiquitous—their deformational effects are often very limited in space. Naturally enough, an analysis of Mesozoic tectonics and magmatism over vast areas of the Eastern Asia (M. S. Nagibina, Yu. G. Gatinsky, G. A. Grinberg, C. S. Gusev & V. I. Kovalenko) has brought a less harmonious picture—simultaneous compression (folding) and tension (subsidence) in different places. In the same chapter there is an interesting attempt to explain the parallelism of tectonic activity in mobile belts and inside continents, but the shortcomings are: no list of radiometric data, poor legibility of some figures, the lack of summary conclusions and the somewhat one-sided bibliography (only nine non-Russian sources, including only one Chinese).

The chronology of tectonic processes in Italy by R. Malaroda is a single paper with such a broad chronological scope (from Precambrian) and the only one whose essence is contained in such a comprehensive correlation table. It is a pity that this erudite study is devoid of more general inferences and is of a paleodynamic background. Some problems arise from the two separate and mutually isolated papers about relatively small sections of the Outer Carpathian arc: Czechoslovakian by D. Vass, Z. Stráník & I. Krystek and Polish by N. Oszczypko & K. Żyto. The first is devoid of any radiometric data and the bibliographic sources are exclusively local: even a comparison with the neighbouring, Polish part of Western Carpathians is lacking. In the second there is an obvious need for tabulation of the events and the maps are misleading because they do not demonstrate "tectonic activity at the beginning of the Oligocene" (disregarding the palinspastics). In this paper the continuous character of tectonic evolution deserves attention as distinct from more episodic development in the light of other papers. The chapter on middle and late Alpine phases in Hungary (G. Császár, J. Haas, J. Halmaj, G. Hámor & L. Korpás) is in fact a review of the geological history of this country in the given time-span, performed mainly by means of 14 ingenious, clear maps. They are completed with a correlation table, but unfortunately without data on isotope chronology.

It is obvious why the relative precision of analyses of European tectogenes could not have been equalled by the review of the Himalayan orogeny (B. N. Raina, U. C. Pati & N. Srimal), which is limited mainly to the Indian part. However, a series of maps and sections as well as a survey of selected, more recent published opinions will be valuable for readers not acquainted with the complex problems of the tectono-magmatic evolution of Himalayas. It is a pity that the authors did not illustrate their review with a schematic map of the geotectonic development of that part of the globe.

The volume closes on a different tone—with a paper by A. V. Lukyanov on self-excited oscillations in geological systems. This specific question, investigated by the author for a dozen years, has been presented mainly with the help of non-tectonic examples. Those concerning rhythmic sedimentation seem to be most important; however, possible analogies to large-scale tectonic phenomena, although promising, so far look rather distant and have not been explained by the author. No doubt, theoretical and methodological aspects of the correlation of tectonic movements deserve a special treatment, which should be executed against the background of recent problems of stratigraphical correlation (so expanded in recent years).

To point out formal defects in a volume composed of translations may seem over-critical. However, there is a limit of tolerance, which I feel has been exceeded in the case of *Global Correlation*. Only a few examples of the various mistakes and omissions can be given here: $\alpha\beta$ mixtites instead of $\gamma\beta$ mixtites in Table 1 (p. 29); supposed Miocene–Quaternary mixtites in Outer Carpathians shown in the map on p. 31 and absent in the table on p. 33; missing locality of sections (quoted on the figures) on p. 74; early Oligocene (25 m.y.) instead of early Miocene on p. 77; missing legend to Fig. 11 on p. 113; unexplained letter symbols in Fig. 1, p. 120; Albanian transgression instead of Albian transgression on p. 176; lack of titles of figures on pp. 201–209; and numerous distortions of the authors' addresses. Many of the maps are of dubious value to the reader due to missing or faint topographic description; for instance those on pp. 14, 126, 214–217, 219, 220. Not