Book Review: ***Introducing Tectonics, Rock Structrures and Mountain Belts*** by Graham Park. Dunedin Academic Press, Edinburgh. 2012. Paperback, 132 pp. Price £14.99. ISBN 978-1-906716-26-4

This is the complete and fully referenced review, an edited version of which was published in The Edinburgh Geologist*, No. 53 (Spring 2013), 23-25.*

The latest contribution to geological literature from Dunedin Press aims to '*share the excitement of discovering how the all-embracing theory of plate tectonics can help to explain the multitude of complexities revealed in the study of rocks*'. Its author, Graham Park, initiated the series in 2006 with *Introducing Geology* (2nd edition 2010). This latest and larger format book delves deeper into **s**mall and large scale tectonic structures and features, and is aimed at '*students and others interested in geology*'. Its remit is definitely challenging as the subject is wide ranging, and this publication falls between a textbook and a coherent literary document focused on a specific facet of geology. It avoids the use of mathematical formulae in explaining the theoretical basis of deformation, stress and strain, and the development of folds, fractures and fabrics, but this does not necessarily makes such concepts easier to understand. The author points out that he has been selective, guided by his '*subjective view of what is most important, and also a desire to keep the book reasonably short*'. As such the book can only skim across the surface of most topics – to confirm this just access some of the numerous teaching sites on the web.

The book first spells out the global framework linked to plate tectonics, then moves on to summarize traditional structural geology concepts, before describing the structure of igneous intrusions and gravitationally induced features. The last three chapters look at the tectonic interpretation of orogenic belts with examples taken from both modern (Jurassic and later) and ancient (Lower Palaeozoic and earlier) orogens. The author has tried to '*avoid the excessive use of terminology*', which can be a minefield for less expert geologists, students, and amateurs. An appendix containing classification tables for the basic terminology is followed by a fairly comprehensive glossary (with good text links), and some brief recommendations for further study.

The text is generally well-written, the layout good, and the illustrations suitably numerous and relevant, though unsurprisingly, several diagrams and some photographs are repeated from the earlier introductory book. Most of the diagrams are commendably simple, suitably colourful, and easy to understand, though some have minor errors; the standard of the photographs is disappointing. More importantly, there are numerous errors and inconsistencies in the text and diagram captions, notably in the cross-referencing between diagrams.

A problem with venturing into geologically deeper waters is that one needs to be a stronger all-round swimmer. Ideally, the author should be up-to-date with recent references, concepts and interpretations, and promote the current best-practice with regard to classifications, terminology, etc. The material presented should effectively synthesize this knowledge and experience. It is in these areas that I feel the book falls down somewhat. The reader could easily be misled into thinking that this is an up-to-date view of the subject, when in truth some descriptions, interpretations and definitions have long been superseded. A glance at the references cited for some of the diagrams (listed on pages x-xi) highlights this deficiency.

Perhaps the most glaring example is Figure 8.4 that portrays a model for cauldron subsidence and granite pluton emplacement in the Etive-Glencoe area. The interpretation was taken from a sketch in Johnstone (not Johnson as stated) 1966, which in turn followed the much earlier (1909) work of Clough and colleagues. Although this was ground-breaking over a century ago, more recent detailed fieldwork by Moore and Kokelaar (1998) and the U-Pb ages and geochemistry of Neilsen et al. (2009) throw significant new light on the volcanic and intrusive history of this area. For example, the main basaltic andesite lava outpourings in Lorn occurred at c. 425 Ma, the Glencoe Caldera formed at around 420Ma, and the constituent intrusions of the Etive Pluton and related dyke swarm were emplaced in stages between about 418 and 408 Ma. The timing and relationships suggest intrusion of separate magma pulses over a 17-20 Ma period rather than a single event lasting only a few million years.

Similarly, with regard to the Western Alps the author has chosen Ramsay (1963) as his source for the description of tectonic units and diagram (Figure 11.7). Although the data and interpretations are not seriously in error, Ramsay's paper predates the advent of plate tectonics. Park's description thus ignores the multitude of more recent summaries of the tectonic framework of the Alps, now based on the CROP-ECORS deep seismic data, sophisticated age determinations, and the much improved understanding of the Tethyan palaeogeography and tectonics, e.g. see Dal Piaz et al. (2003), Manatschal and Müntener (2009), Stampfli et al., (2002), Schmid et al. (2004), Handy et al. (2010). The Debelmas (1983) alpine cross-section figured here is some 20 years younger, but again outdated. Further examples are the Red Sea–Afar triangle–Gulf of Aden triple junction (Figure 3.9B), taken from Girdler and Darricot (1972), and the simple explanation of the Iceland hot spot (Figure 3.13), taken from Saemundsson (1974). The former has the plate boundary incorrectly positioned, and both fail to reflect the large amount of more recent work and the complexity of the geology. That said, there seems to be little consensus among current authors as to the nature of the Iceland plume, and whether the hot spot is presently fixed, or has been fixed, relative to the Mid-Atlantic ridge.

On looking at the individual chapters in more detail various other deficiencies become apparent. The description of the large-scale global tectonic framework is adequate but dated. The following summary and discussions of the theoretical aspects of deformation, stress and strain, and of the geometry, classification and models of faulting, folding and fabrics has changed little since their inception and are generally fine. However, the author gives short shrift to the importance of mylonites, and his classification of cleavages is somewhat arbitrary. The explanations for the formation of slaty cleavage and schistosity read much the same, with the significance of fabric recrystallisation and metamorphic reactions not clearly spelt out. Also note that schistose is a textural qualifier and schist not a recommended rock name in current metamorphic schemes. The chapter (No. 8) on the structure of Igneous Intrusions seems dated, whereas Chapter 9 on Gravitational Effects ranges widely from soil creep and landslips to glacier flow, salt tectonics, orogenic collapse, and mantled gneiss domes. Note that other large-scale gravitational

effects related to extensional faulting and continental margins are covered in Chapter 5 (Faulting).

The chapters on Orogenic Belts present further problems. It is still unclear as to the way in which many orogens have formed, even whether the crust has behaved like ‘crème brulée’ or a ‘jelly sandwich’. Much of the testing of orogenic models lies within the detail and the timing of deformation. The huge amount of work carried out on orogenic belts and the modelling of possible crustal scenarios points more and more to their individuality. Global positioning does at least allow us to document ongoing tectonic movements with considerable accuracy. I was disappointed that Park did not consider Taiwan, a currently developing orogenic belt, which has been the subject of much recent work. Instead, as examples of modern orogenic belts he presents rather simplistic descriptions of the central Himalaya, the Western Alps, and the Canadian Cordillera, based mainly on a single author’s interpretation, namely Searle et al. (2011), Ramsay (1963), and Coney et al. (1980) respectively. I feel that this is not the best way to inform (or excite) the reader - perhaps a more detailed description of a single belt would have been better.

For ancient orogenic belts Park has chosen the British Caledonides, the Grenville Belt and the Trans-Hudson orogen. The summary and model for the British Caledonides is moderately satisfactory but, like other authors, Park’s cartoon model (Figure 12.4) contains inconsistencies with its geometry and in the timing of events. Grampian deformation is shown affecting the Moine of the Northern Highlands, but in the text the impression is given that Scandian folding and metamorphism is dominant here. The Great Glen Fault is portrayed as only moderately dipping, but is in fact sub-vertical. The Lake District and Welsh deformation events are Mid-Devonian (Acadian) in age, but here are correlated with Southern Uplands events that occurred in the late Silurian to early Devonian. Also, the oft-quoted statement that the Dalradian Supergroup totals 20 km is repeated here. The combined sequence thickness may reach this figure, but certainly not in any one place – continental rupturing would have occurred in such circumstances. The description of Barrovian and Buchan metamorphism is rather meaningless without

metamorphic facies and related P-T information – what constitutes lower pressure, higher temperature?

The synthesis of the Grenville Belt is concise and follows Rivers (2009), who has spent a lifetime deciphering the orogen. Note that the dates for the Rigolet phase are 1009 - 980 Ma, not 1090 - 980 Ma as stated in the text. The related caption for Figure 12.8 is correct. The Trans-Hudson Orogen (THO), based on Corrigan et al. (2009), seems an odd choice, but serves as an Early Proterozoic example of orogenesis by amalgamation of varied continental fragments and the intervening arcs and supracrustal belts. Both the description of the THO and those of the succeeding Archaean Superior Province (1000 x 550 km) and the Nuuk part (175 x 75 km) of the North Atlantic Craton introduce a plethora of names; the descriptions then pose as many problems as they purport to resolve. Perhaps focusing on the well-documented Abitibi Belt (part of Superior Province) and the Nuuk area would have served the purpose better. The author's alternative explanation of the microcontinental 'Terrane model' of Friend and Nutman (2005) as representing thrust slices in the lower parts of an orogen is interesting, given the 'terrane' amalgamation model presented for the THO earlier, admittedly at a considerably larger scale. The many problems inherent in the phased generation of continental crust in the Archaean and Early Proterozoic are barely touched upon.

Throughout the book, some of the terminology used is subjective and rather dated. For example, should mio-geosynclines and granitisation be discussed here? Further, the classifications given in the Appendix for igneous, sedimentary and metamorphic rocks fail to follow the IUGS schemes, although they do reflect some erroneous popular usage. The igneous scheme is acceptable, if rather simple. Note that the highlighted terms alkali-granite (syenogranite?) and granodiorite are missing from the Glossary. The sedimentary scheme is also simple – but is the repetition of limestone deliberate, and should chert be inserted? Also, note that greywacke has been banished from accepted UK classification schemes, even though arenite and wacke are still the building blocks of the sandstone classification. The metamorphic scheme presented here perpetuates parochial terminology only really used in the Scottish Highlands (psammite, pelite, etc) and throws

in some textural terms (slate, schist, gneiss). Semi-psammite will be unknown even to many geologists, and marble is now regarded as misleading and obselete. In this context, a notable omission from the Appendix is a metamorphic P-T diagram to briefly explain the framework of metamorphic facies. As noted above, this creates problems in the understanding of Buchan and Barrovian metamorphism. Perhaps more significant for subduction-related tectonics, Eclogite Facies is mentioned on p 84, but little guidance is given to the reader to help their understanding of the real magnitude of the requisite high pressure and moderate temperature conditions? Perhaps a classification of fault rocks could also have been added, to reflect the large amount of recent and current work on this subject.

With regard to the diagrams, some have minor errors. but these rarely mislead or detract significantly, e.g. position of the Azores hot spot (Figure 3.12), the sinistral arrow on the δ structure (Figure 7.4E), Killie**k**rankie Schist (Figure 12.3C), Rocka**l** Plateau (Figure 12.6), the omission of Torngat Belt label (Figure 12.9). In contrast, the photographs are disappointing. Obviously, they need to be small given the space available, but many do not show good or even clear examples of the requisite structures. Hence, with regard to folding and fabrics, Figure 6.2 shows several rather similar looking chevron fold-type structures, and Figure 7.1 shows varied cleavages that the reader might struggle to discern – the indicative lines are certainly needed. The depiction of dykes in Figure 8.3 is also poor – and is the repetition of the 'bayonet' structure necessary? Only the aerial shots of the Lewis Glacier, Alaska and the folds of Bighorn County, Wyoming really generate excitement. When we reach the chapters on Orogenic Belts, there is a dearth of photographs, apart from a strangely orange image of the Loch Glencoul view. Yet, excellent images are available (check out www.alpengeologie.org) and undoubtedly would illuminate the sections on the Alps and Himalayas.

The book also contains numerous errors and inconsistencies, notably in the cross-referencing between diagrams, as well as more obvious typos or omissions. The list of sourced illustrations, cited on pages x-xi, patently does not take into account the renumbering of Figure 12.3 (A-F), presumably caused by the addition of the Glencoul

image (Figure 12.3B). Note that Gan et al. (2007), cited for Figure 11.4, is missing from the reference listing. The Coward and Dietrich (1989) reference on p. xi links to Figure 11.5 not 11.5A as stated. The cross reference in the caption to Figure 8.7 (Cone sheets, etc) should be to Figure 5.10 not 5.9 as stated. Caption errors include Figure 3.3, which should state that it shows magnetic pole positions for 200 **million** year-old rocks. Abitibi is in the Glossary and refers to Figure 12.11, but is absent from this diagram (≡ part of Wawa Superterrane).

The terminology is not only erratic, but in parts also inconsistent. For example, on pages 98-99, the many references to the Moine Thrust (+Belt/Zone) are given variable names and capitalization. The Lewisian complex (Lewisian Gneiss Complex) and the Torridonian Supergroup (Sleat and Torridon groups) are 'incorrectly' named, and the main component **events** of the Caledonian Orogeny are themselves termed Grampian orogeny and Scandian orogeny (nested orogenies?). Such bad habits may seem trifling to world-weary geologists but they should not be passed on to newer more impressionable readers.

In summary I cannot recommend this book, either for the student or interested amateur, or for the more informed reader. Its ambitious remit and good layout and illustrations cannot overcome the deficiencies spelt out above, particularly the use of dated references and interpretations, failings compounded in places by the subjective usage of geological terminology. To supplement such material I would advise the reader to consult a good text book, recent papers, or the internet, as indeed suggested by the author at the end of the book.

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