BOOK REVIEWS

WYLLIE (P. J.), editor. *Ultramafic and Related Rocks*. New York and London (Wiley), 1967. xvii+464 pp., 120 figs. Price £10·55 ($22·50).

Hess (1955, *Geol. Soc. Amer. Spec. Paper 62*) commented upon the apparent variance between experimental work and the field evidence in relation to temperature and mode of emplacement of ultrabasic rocks. This book goes a long way towards reconciling and explaining many conflicting interpretations. To review and comment in detail upon each of over forty contributions on ultrabasic rocks would require a much lengthier review article, and in selecting certain aspects of the book the reviewer inevitably reveals his own preferences and prejudices. Indeed, the book contains its own review, written by the editor in the last section of the final chapter, which provides a lucid and comprehensive summary of the other contributions and of the history and hypotheses of ultrabasic petrogenesis. There are over thirty authors who contribute various sections to twelve chapters [M.A. **19**–227]. Each chapter stands independently and is prefaced with a useful introduction/synopsis by the editor. Overlap of subject matter between chapters is both inevitable and, in the reviewer's opinion, useful in making each chapter intelligible without continuous cross-reference to others.

Chapter 1 (pp. 1–18) is a brief petrographic outline and survey of nomenclature, rock associations and ultrabasic mineral facies and stabilities. The use of the terms 'ultramafic' and 'ultrabasic' varies throughout the book, the former being preferred by North American authors although some also use 'ultrabasic'. As used in the book the terms are generally interchangeable since most mineralogically ultramafic rocks are chemically ultrabasic in composition.

Succeeding chapter headings are based upon mode of occurrence, a division that in general works quite well: 2 (pp. 19–49) Ultramafic rocks in layered intrusions; 3 (pp. 50–82) Olivine-rich rocks in minor intrusions; 4 (pp. 83–134) Zoned ultramafic rocks; 5 (pp. 135–72) Alpine-type ultramafic rocks; 6 (pp. 173–202) Deformation of Alpine ultramafic rocks; 7 (pp. 203–49) Origin of Alpine ultramafic associations; 8 (pp. 240–78) Kimberlites; 9 (pp. 279–326) Alkalic ultrabasic rocks, kimberlites, and carbonatites; 10 (pp. 327–49) Mafic and ultramafic nodules; 11 (pp. 350–80) Geochemistry; 12 (pp. 381–416) Petrogenesis of ultramafic and ultrabasic rocks; References (pp. 417–46); Author and subject indexes (447–64).

In Chapter 2 Jackson describes the ultramafic rocks of the Stillwater, Great Dyke, and Bushveld intrusions. All originate via gabbroic or basaltic magmas of tholeiitic type and the author places particular stress on the importance of cumulus minerals in petrogenetic interpretations. Layering has resulted from combinations of gravity settling, convective overturning, and repeated injection whereby 'old' magma was displaced by 'new'.

Drever and Johnston in Chapter 3 compare ultrabasic facies associated with alkaline and tholeiitic dolerites. Preconcentration of olivine crystals in basic magma occurred before emplacement of many alkaline sills. The authors suggest that whereas undifferentiated tholeiitic magma appears to be injected regionally, the upward migration of alkaline magmas seems to be arrested within the crust where precipitation of olivine occurs. Simkin describes differentiated picritic sills in Skye. The intruding magma carried olivine in suspension but gravity settling cannot explain its present distribution. Hydrodynamic migration of olivine crystals away from the margins during flow, coupled with some vertical density stratification, would explain the olivine-poor marginal phases and vertical changes in mineralogy.

Chapter 4 on zoned ultramafic rocks shows that the 'chapter by mode of occurrence' produces overlap, in this case between Chapters 2 and 4. Examples from Alaska are described by Irvine and Taylor, while Gass gives an account of the Troodos area in Cyprus. It is difficult to see why the latter contribution was not placed in Chapter 5 dealing with Alpine-type ultramafic associations. Chapters 5, 6, and 7 deal with various aspects of Alpine-type ultramafic rocks. Their association with orogenic belts and resulting deformation and metamorphism often present intractable field and petrogenetic problems. It is evident that many such ultramafic bodies have a complex history both at the magmatic stage and during subsequent lower-temperature hydrothermal phases producing several 'intrusive' episodes. 'Cold' intrusion may account for the lack of thermal aureoles, a mechanism supported by surface extrusion of plastic flowing serpentinite breccias (Dickinson, 1966, *Bull. Geol. Soc. Amer.* **77**). Thayer's contribution points out that ultramafic rocks cannot be considered apart from the basic volcanics, gabbros, diorites, and granophyres of the calc-alkali magma series. Jahns describes tectonically emplaced ultramafic rocks set in the Appalachian regional metamorphic environment and Ragan describes intrusion of dunite in the Washington Cascades as essentially solid material rather than as a crystal mush. O'Hara deals with rocks of the garnet-peridotite facies occurring among gneisses and schists of amphibolite or hornblende granulite facies. They are apparently restricted to rocks of Europe metamorphosed during the Caledonian orogeny and O'Hara distinguishes them mineralogically and chemically from xenolithic garnet-peridotites and eclogites of kimberlite pipes.

The structure and microfabrics of some serpentinites from the Piedmont of Pennsylvania are described by Lappin who attempts to correlate them with original flow-deformation, later deformations associated with serpentinization, and still later tectonic events. Similar studies on the petrofabrics of some Norwegian dunites are presented by Lappin who suggests intrusion by vortex-like movement about a sub-vertical *b*-axis. Raleigh describes the experimental deformation of ultrabasic rocks and minerals. From room temperature to 300 °C specimens of serpentinite become ductile at pressures greater than about 3 kb, yielding at stress differences of about 8–12 kb. The reduction in strength with temperature is not greatly different from other rocks at 5 kb up to 600 °C.

Green describes metamorphic aureoles around peridotites of the Lizard and elsewhere. At the Lizard the metamorphism affects olivine-normative basic foliated amphibolites in which green hornblende gives way to brown hornblende–pyroxene assemblages and hypersthene–augite pyroxene-granulites towards the peridotite. The granulitic rocks locally become mobile enough to intrude the peridotite. [High temperature brown titaniferous hornblende-pyroxene-plagioclase-granulites (metagabbros) adjacent to, and mobilized by, the peridotite ancestor of the Ballantrae serpentinite were described by Bloxam in 1955, *Geol. Mag.* **92**.]

Chapters 8 and 9 are on kimberlites and their associated rocks. Not unexpectedly contributions to these and the succeeding Chapter 10 on mafic and ultramafic nodules overlap. Kimberlites, including their geochemistry, are reviewed by Dawson and those of the U.S.S.R. are described by Davidson. There is also a section on kimberlites from Arizona by Watson. Alkaline pyroxenites are described by Upton and alkaline assemblages from Quebec by Gold. The former author concludes that the ultrabasic rocks are usually formed by fractional crystallization of alkalic undersaturated magmas such as olivine melilitite. Gold concludes that fractionation of the standard primary alkali basalt produced the assemblage peridotite–pyroxenite–gabbrodiorite–syenite. Eckermann proposes that the separation of immiscible carbonate globules decreases the lime content of a parent melilite basalt or alnöite yielding a kimberlite magma and a carbonatite fraction. Franz and Wyllie describe some experimental results from the system $CaO–MgO–SiO_2–CO_2–H_2O$ that support a very fluid carbonate magma. Genetic links between carbonatite and kimberlite are also indicated by the coexistence of high-temperature magnesian silicates in lower temperature carbonatitic liquid.

Chapter 10 on mafic and ultramafic nodules includes a world-wide review of peridotitic inclusions and their host rocks by Forbes and Kuno. The peridotite-bearing basalts clearly define arcuate belts, with circumoceanic and oceanic belts prevailing. The origin of the peridotite inclusions appears to be related to the genesis of basaltic magma within the crust. From a single crater in Japan, Kuno describes a suite of nodules which can be arranged according to the depth of their supposed source regions: andesite (surface); granodiorite (upper crust); gabbro (lower crust); pyroxenite and peridotite (top of mantle); and garnet-peridotite (below peridotite in the mantle).

Davidson ascribes a much shallower depth to many garnet-peridotites and eclogite nodules found in kimberlite. He found wide variations in the mineralogy and chemistry of xenoliths and constituent minerals, which lead him to question an origin in the mantle. Evidence from drilling in Czechoslovakia suggests that they may have come from granulites and migmatites of the basement complex. In contrast O'Hara considers that basalts originate in the mantle, fractionate during ascent, and that their ultramafic inclusions are related to this process.

Chapter 11 considers the geochemical aspects and a contribution by Goles reviews the trace element content of ultramafic rocks. Differences are noted among trace element contents of Alpine-types, nodules, and their host basalts. Taylor lists data for stable isotopes of H, C, Si, S, and O from meteorites and ultramafic rocks. The uniformity of ^{13}C and ^{18}O contents of carbonatites and the similarity in $^{18}O/^{16}O$ ratios of pyroxenes from gabbros, peridotites, and carbonatites suggests that they are related. Hurley discusses the significance of $^{87}Sr/^{86}Sr$ and $^{87}Rb/^{86}Sr$ ratios. Ultramafic zones in stratiform intrusions have basalt-like $^{87}Sr/^{86}Sr$ ratios as might be expected.

Other data suggest that Alpine-type ultrabasic rocks either separated in the latter half of the Earth's history and subsequently rose to the surface, or that they are residual accumulates from some very early Rb/Sr enrichment process, which was followed by a separation of sialic crust in the early Archean.

Murthy and Stueber discuss the variation of K/Rb, which in basalts shows systematic changes with varying K but not in eclogite inclusions, ultrabasic inclusions, and Alpine-type intrusions. They conclude that the upper mantle zone is characterized by low K/Rb. The residual nature of the Alpine-type peridotites seems almost certain, with fractionation removing alkalis to the crust.

Chapter 12, in addition to Wyllie's excellent summary, includes a section by MacGregor in which he proposes an upper mantle composed of a two-pyroxene peridotite with a spinel facies overlying a garnet facies. He suggests that seismic discontinuities in the upper 200 km of the mantle are the result of variations in the Al_2O_3 content of the pyroxenes. This is further supplemented by O'Hara who shows the changes in mineralogy of two fixed ultrabasic compositions in response to changes of temperature, pressure, and Al_2O_3 in the pyroxenes. A petrographic grid is presented showing compositional requirements of clinopyroxenes coexisting with orthopyroxene and olivine in an Al_2O_3-saturated environment. An analysed clinopyroxene can be plotted on the grid giving an estimate of the equilibrium temperature and pressure.

The whole book, contents and the way they are presented, sets a very high standard and constitutes an authoritative account of ultrabasic rocks and the frequently contrary views about their petrogenesis.

T. W. Bloxam

Gass (I. G.), Smith (P. J.), and Wilson (R. C. L.), editors. *Understanding the Earth: A Reader in the Earth Sciences*. Horsham, Sussex (Artemis Press), 1971. 355 pp., 243 figs. Price £3·50 (boards), £2·10 (paper).

This book was written primarily as a set book for the Foundation Course in Science of the new Open University and has aimed at showing that the Earth sciences are mentally stimulating and conceptually demanding. The editors have been able to call on a galaxy of talent, and in addition to chapters on the Earth's surface features, there are authoritative statements on measuring geological time (S. Moorbath), the Chandler wobble (M. Chinnery), and the Earth's composition (P. G. Harris), magnetic field (Sir Edward Bullard), and internal heat (J. H. Sass). The book opens logically with a chapter on minerals and rocks (K. Cox) though one is surprised to find cordierite classed as a member of the amphibole group; other early chapters include those on the Earth–Moon system (Z. Kopal), meteorites (B. Mason), and the primitive Earth (P. Cloud, Jr.). The environments in which ancient rocks are inferred to have formed, from comparison with sediments accumulating today, are fully discussed (E. K. Walton) and the oxidation: polarity paradox, which seems to stand in the way of a theory that could account for reversed magnetization in rocks, is described (P. J. Smith). During the last decade there has been a revolution in the Earth sciences,