LOWER CRUSTAL GRANULITES AND ECLOGITES FROM LESOTHO & SOUTH AFRICA

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Nodules of granulites and "crustal" eclogites occur in many kimberlites around the edge of the Kaapvaal craton, but are apparently absent in pipes within the craton. In most Lesotho pipes this nodule suite is dominated by basic gnt + cpx + plag ± opx granulites, with smaller numbers of eclogites, gnt pyroxenites and intermediate/acid granulites. Two-pyroxene granulites are common at Monastery Mine, and spinel peridotites occur at Lipelenang and Ngopetseu. The early Archean Kaapvaal craton is bordered by younger mobile belts, apparently formed by reworking of the older rocks. The garnet granulite suite may have formed in connection with the reworking process.

Major- and trace-element analyses of 22 nodules show that the basic granulites and eclogites are essentially olivine-basaltic in composition, with minor normative Ne or Hy (Table 1). The garnet pyroxenites, in contrast, are typically Hy-normative. The absence of modal plagioclase in the eclogites and gnt pyroxenites is controlled mainly by bulk composition; only rocks with $>35\%$ normative (An + Ab) and $<45\%$ normative ol + px contain modal plagioclase. The continuous variations in bulk chemistry and in the proportions of gnt + cpx + opx + plag within the suite strongly suggest that the rocks of the garnet granulite-eclogite-gnt pyroxenite suite have formed by metamorphism of related rocks under similar P-T conditions.

Microprobe data for >50 rocks also demonstrate the consanguinity of the gnt granulite suite. Clinopyroxenes from all types of garnetiferous rocks generally have Jd/Ts $> \frac{1}{2}$, and thus are typically eclogitic (Fig. 1). Jd/Jd+Ts is roughly proportional to Ab/Ab+An in the coexisting plagioclase (An=5-77%); Jd ranges up to 30%. The common difference in Jd/Jd+Ts between cpx from eclogites and cpx from granulites collected *in situ* probably reflects cpx-plag reequilibration during normal uplift/cooling cycles. Garnets in all rock types fall in both the Class B (eclogites in gneiss) and Class C (eclogites in blueschist terranes) fields (Fig. 2). High-S (3.5-6.8% SO_3) scapolite occurs in six samples.

The eclogites studied here are distinct in garnet composition (Fig. 2) and K_D (gnt/cpx) from the type "griquaites" (= mantle eclogites) of Roberts Victor Mine and similar rocks elsewhere, but resemble the gnt granulites in these and other respects. Published analyses of "griquaite" minerals from Kao and Sekameng suggest that these rocks are similar to ours and are probably of crustal origin. Distinction between crustal and mantle eclogites may thus be possible on the basis of mineral chemistry.

P and T were estimated by using empirical calibrations of element partitioning between gnt+cpx (Råheim & Green 1975), gnt+opx (Wood 1974) and cpx+plag (Currie & Curtis 1976) in samples where two or more of these pairs are present. Most suitable samples of the gnt granulite suite yield P-T estimates between 550-700°C and 5-13 Kb, implying an origin in the lower crust (Fig.

3). From seismic data on adjacent regions, measured densities of the nodules, and data on the relative abundances of nodule types, we estimate that the lower crust consists of 40-70% basic granulite + eclogite + pyroxenite, and 60-30% intermediate/acid granulite.

Seven Fe-rich gnt pyroxenites give P estimates in the range 20-35 Kb (Fig. 3), and may represent an important rock type in the uppermost mantle. However, the opx of the gnt pyroxenites shows a good inverse correlation of Al with FeO (up to 26%), so that P increases with FeO. There is thus a strong possibility that the high P values reflect an imperfect calibration of the opx/gnt geobarometer for Fe-rich compositions, and that the gnt pyroxenites are part of the crustal suite. T estimates (cpx/opx: Wood & Banno 1973) for three Monastery pyroxene granulites range from 795-885°C; estimates for three Lipelenang spinel lherzolites fall between 825-850°C. Cpx/opx temperatures for cpx+opx+gnt assemblages are higher than other T estimates for these rocks, casting doubt on the usefulness of the cpx/opx thermometer at low T.

A geotherm based on our crustal P-T estimates lies closer to an oceanic geotherm than to the "Shield" geotherm (Fig. 3), suggesting that the latter is only valid for the deeper parts of the upper mantle beneath Lesotho. The present-day heat flow in the Karroo basin is high, and is consistent with the elevated geotherm suggested by our data. The high T at lower-crustal depths during mid-Cretaceous time presumably was a consequence of the Karroo volcanic activity. The Monastery pyroxene granulites apparently crystallized at temperatures above our crustal geotherm. These rocks, and some garnet granulites giving anomalously high T estimates, may have equilibrated in the aureoles of Karroo-period gabbro plutons.

Table 1
Average Rock Compositions

	gnt granul. (10)	eclog. (2)	gnt pyroxen. (4)
SiO_2	47.6	42.0	47.3
TiO_2	1.0	1.4	1.1
Al_2O_3	16.8	12.6	9.4
Fe_2O_3	1.8	2.3	3.2
FeO	8.0	16.0	9.1
MnO	0.1	0.4	0.2
MgO	7.6	9.3	13.9
CaO	10.4	11.5	12.1
Na_2O	2.9	1.0	1.6
K_2O	0.9	0.4	0.1
P_2O_5	0.2	0.1	0.2
H_2O	1.6	1.3	1.2

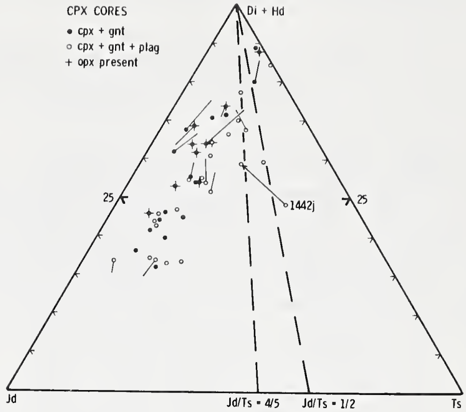

Fig. 1. Cpx chemistry. Short lines connect cores (symbols) with rims, where zoning is present.

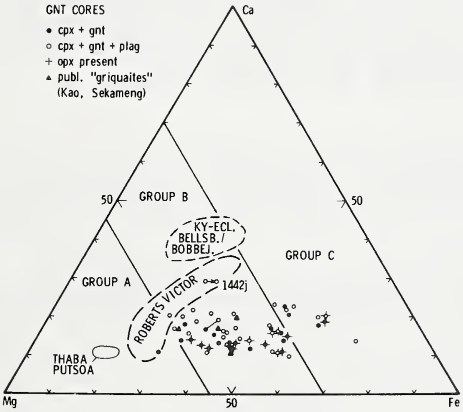

Fig. 2. Gnt chemistry.

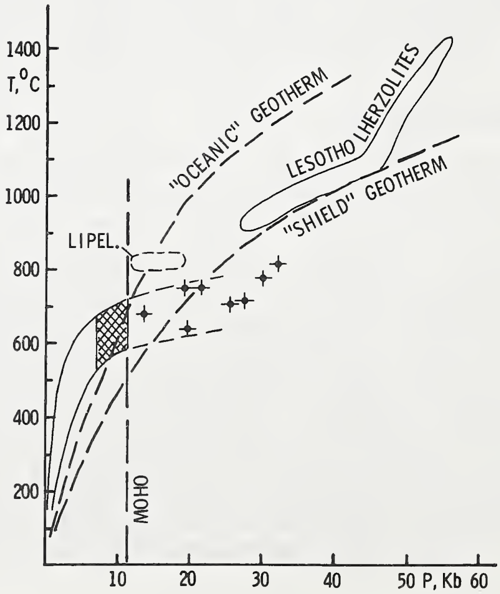

Fig. 3. P-T estimates. Cross-hatched field contains 24 of 31 P-T estimates (cpx/gnt+cpx/plag) on rocks of the gnt granulite suite. Crossed dots are high-Fe, low-Al gnt pyroxenites.