GRANULITE FACIES XENOLITHS FROM KILBOURNE HOLE MAAR, NEW MEXICO MAAR, NEW MEXICO, AND THEIR BEARING ON DEEP CRUSTAL EVOLUTION

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Introduction. Abundant quartzofeldspathic and mafic granulite facies xenoliths occur in the ejecta blanket at Kilbourne Hole maar, Dona Ana County, New Mexico. No rocks of such high metamorphic grade occur either in outcrop or in wells drilled into the Precambrian basement of the area (Denison et al., 1970). These xenoliths were incorporated into ascending magmas during the explosive volcanic eruptions that formed the maar and provide an opportunity to study samples of the earth's deep crust.

Xenolith Mineralogy. Anhydrous, sillimanite-bearing and orthopyroxene-bearing garnet granulites, charnockites, two-pyroxene granulites and anorthosite are the principal rock types represented in the deep crustal xenolith population. Garnet-bearing granulites have two distinct mineralogies: group 1 contains almandine-pyrope garnet, perthitic potassium feldspar(sanidine), quartz, $\pm$ plagioclase $\pm$ sillimanite, with ilmenite, rutile, zircon and graphite as accessories; group 2 contains almandine pyrope garnet, plagioclase, $\pm$ orthopyroxene $\pm$ quartz, with ilmenite and/or hercynite as accessories. Charnockites contain two pyroxenes, perthitic potassium feldspar(sanidine), plagioclase and ilmenite. Two-pyroxene granulites contain plagioclase and ilmenite in addition to pyroxenes. Anorthosite is the least abundant rock type and contains less than 2% orthopyroxene. The detailed chemistry of the xenoliths is given in Padovani(1977) and Padovani and Carter, 1977).

Variable amounts of partial fusion, due to heating and decompression during transport to the surface, produced melts which are now seen as inhomogeneous interstitial glasses or symplectites of either orthopyroxene-spinel-glass around garnet, or olivine-glass around orthopyroxene. The fusion occurred rapidly enough to have had little effect on the homogeneity of major phases and to have prevented mixing of melts on a microscale.

Discussion. The phases present in the garnet granulites, their chemistry and especially the absence of the hydrous phase, biotite, require that these granulites formed at temperatures greater than those necessary for the breakdown of biotite, and at pressures greater than those necessary for the breakdown of cordierite (Holdaway and Lee, 1977). This suggests minimum equilibrium P-T conditions of 5.4 kilobars and 700°C. Equilibrium temperatures of 750° to 1000°C are indicated from feldspar geothermometry (Stormer, 1975; Padovani, 1977; Padovani and Carter, 1977). Modal analyses of the percent rock melted indicate that there appears to be no direct relationship between visible melt and calculated temperature (Figure 1). Application of geobarometry to the garnet-plagioclase equilibria yields a pressure range corresponding to depths of 22 to 28 kilometers(Ghent, 1976; Padovani, 1977; Padovani and Carter, 1977). This is equivqlent to a geothermal gradient of about 30°/km beneath the southern Rio Grande Rift(Figure 2).

Similar application of feldspar and pyroxene geothermometry and geobarometry to the more mafic charnockites and two-pyroxene granulites support equilibration in a temperature-pressure regime similar to that of the garnet granulites(Stormer, 1975; Irving, 1974; Ross and Huebner, 1975; Padovani and Carter, 1977).

Conclusions. The garnet granulite xenoliths plot along the geotherm derived from heat flow and gravity measurements in the southern Rio Grande Rift implying that the mineral assemblages reflect the ambient geothermal gradient in the deep crust(Figure 2)(Decker and Smithson, 1975). The estimated range of P-T conditions for the mafic granulites agrees with that of the garnet granulites. Anhydrous, garnet-bearing granulite facies rocks may be constituents of the deep crust in tectonic environments similar to that of the southern Rio Grande Rift. The garnet granulites are probably residues after partial melting and extraction of felsic magmas in the lower crust. Such magmas would be rich in volatiles and would probably crystallize before reaching the earth's surface, enriching the intermediate crust in water and volatiles.

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References

Decker, E. R. and S. B. Smithson, Heat flow and gravity interpretation across the Rio Grande Rift in southern New Mexico and west Texas, J. Geophys. Res., 80, p. 2542-2552, 1975.

Denison, R. E., W. H. Burke, Jr., E. A. Hetherington and J. B. Otto, Basement framework of parts of Texas, southern New Mexico and northern Mexico, in: Symposium in honor of Ronald K. DeFord, West Texas Geological Society, p. 3-14, 1970.

Ghent, E. D., Plagioclase-garnet-Al_2SiO_5-quartz: a potential geobarometer-geothermometer, Am. Mineral., 61, p. 710-714, 1976.

Holdaway, M. J., Stability of andalusite and the aluminum silicate phase diagram, Amer. J. Sci., 271, p. 97-131, 1971.

Holdaway, M. J. and S. M. Lee, Significance of Fe-Mg cordierite stability relations on temperature, pressure and water pressure in cordierite granulites, in: The Earth's Crust, Geophys. Monogr. Ser., 20, AGU, Washington, D. C., ed. J. G. Heacock, in press, 1977.

Irving, A. J., Geochemical and high pressure experimental studies of garnet pyroxenite and pyroxene granulite xenoliths from the Delegate basaltic pipes, Australia, J. Petrol., 15, p. 1-40, 1974.

Kerrick, D. M., Experimental determination of muscovite and quartz stability with P_{H2O} P_{total}, Amer. J. Sci., 272, p. 946-958, 1972.

Luth, W. C., The influence of pressure on the composition of eutectic liquids in the binary systems sanidine-silica and albite-silica, Carnegie Inst. Wash. Yearbk., 66, p. 480-484, 1968.

Padovani, E. R., Granulite facies xenoliths from Kilbourne Hole maar and their bearing on deep crustal evolution, PhD dissertation, Univ. of Texas at Dallas, Richardson, Texas, 1977.

Padovani, E. R. and J. L. Carter, Aspects of the deep crustal evolution beneath south central New Mexico, in: The Earth's Crust, Geophys. Monogr. Ser., 20, AGU, Washington, D. C., ed. J. G. Heacock, in press, 1977.

Ross, M. and J. S. Huebner, A pyroxene geothermometer based on composition-temperature relationships of naturally occurring orthopyroxene, pigeonite and augite, in: Extended Abstracts, International Conference on Geothermometry and Geobarometry, 1975.

Stormer, J. C., A practical two-feldspar geothermometer, Amer. Mineral., 60, p. 667-674, 1975.

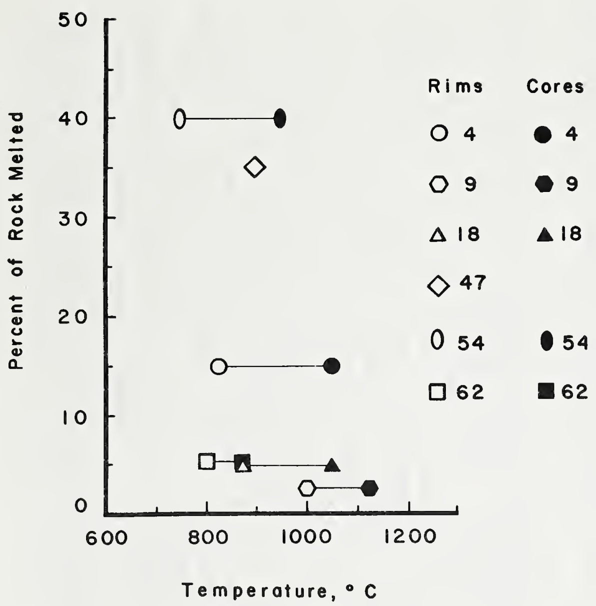

Figure 1. Percent of rock melted versus its temperature range calculated using the method of Stormer(1975). Open and closed symbols, respectively, represent temperatures calculated from electron microprobe analyses of the rims and cores of potassium feldspar(Padovani and Carter, 1977).

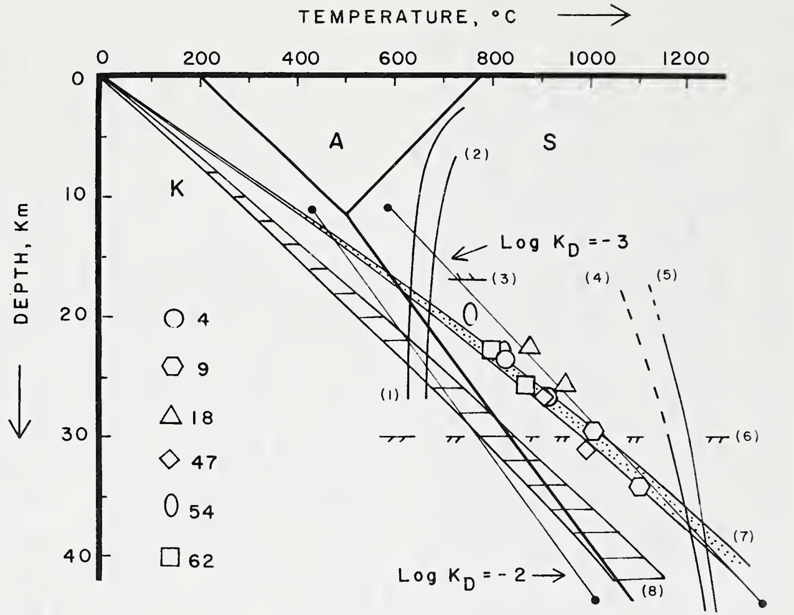

Figure 2. Temperature-depth plot showing the Al_2SiO_5 stability field(Holdaway, 1971) with respect to hypothetical K_D values for coexisting garnet and plagioclase according to Ghent(1976). The positions of garnet granulites were calculated using the methods of Ghent(1976) and Stormer(1975). Curves (1) & (2) = melting of granite at $P_{H2O} = 1\ P_{total}$ and $P_{H2O} = 0.5\ P_{total}$, respectively; (3) =minimum P-T conditions predicted by the data of Holdaway and Lee(1977); (4) & (5) = dry melting of sanidine-silica and albite-silica(Luth, 1968); (6) = base of crust in southern Rio Grande Rift(Decker and Smithson, 1975); (7) & (8) = the range of temperatures as a function of depth for surface fluxes(q_s) of 2.4 HFU for the southern Rio Grande Rift and of 2.0 HFU for the Basin and Range Province, respectively(Decker and Smithson, 1975). Temperatures were calculated from perthite-free sanidine rims.