Garnet peridotite xenoliths in a Montana, USA, kimberlite

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In Montana, USA, one diatreme within a swarm of subsilicic-alkalic diatremes (Hearn, 1968) contains common xenoliths of granulite, and rare xenoliths of spinel peridotite and garnet peridotite. The main diatreme is 270 by 370 meters, with a rounded irregular shape partially controlled by preexisting faults. The border of the diatreme contains a short ring dike of igneous monticellite peridotite and slices of higher wall rocks of early Eocene age, similar to the occurences of descended slices in other Montana diatremes which do not contain deep-seated xenoliths. A nearby xenolith-bearing subsidiary dike is in part massive with apparent igneous texture and in part fragmental with pelletal texture. Micas give K/Ar ages which are too old, as a result of excess argon or xenocrystic origin; fission-track dating will probably show a late-middle Eocene age similar to the other diatremes. Such an age is toward the end of widespread subsilicic- to silicic-alkalic igneous activity in north-central Montana.

Although many North American kimberlites contain characteristic xenocrysts probably derived from garnet peridotite, xenoliths of garnet peridotite are extremely rare and have been reported from only two diatremes in Utah and one in Colorado. Six relatively unaltered garnet peridotite xenoliths from Montana range from 2.5 cm diameter to 23x18x12 cm. All six contain garnet lherzolite mineral assemblages, although diopside is less than 0.5 percent in two. The garnet peridotites show distinctive textures: four are granular (either unsheared, or showing necklace texture of thin zones of fine-grained olivine surrounding large strained olivines) and two are highly sheared (large rounded to augen-shaped crystals of garnet, strained olivine, orthopyroxene and clinopyroxene in a fine-grained groundmass of granulated olivine and orthopyroxene, giving a banded appearance). Phlogopite, which is probably primary in part, occurs as rims around garnet, as veins, and as isolated grains in granular xenoliths, but is absent from sheared xenoliths, similar to phlogopite distribution reported by Boyd and Nixon (1973) for Lesotho garnet peridotite nodules.

Olivine and orthopyroxene show a restricted compositional range, $Fo_{90.5}$ to Fo_{94}, $En_{90.5}$ to En_{94}. Clinopyroxenes range from $Wo_{47}En_{50.5}Fs_{5.5}$ (granular xenolith) to $Wo_{32.5}En_{59.5}Fs_{8}$ (sheared xenolith). CaMgFe compositions of garnets from five xenoliths plot within the same fields as Lesotho garnets from sheared and granular lherzolites respectively. Garnet in one Montana lherzolite is strongly pyropic, $Ca_{3}Mg_{89}Fe_{7}$. Cr_2O_3 of xenolith garnets ranges from 0.7 to 7.8 percent. Five of six analysed garnet megacrysts, up to 4 cm diameter, have MgFe similar to xenolith garnets, but with more restricted range of Ca; their Cr_2O_3 ranges from 0.7 to 2.1. An ilmenite megacryst is typically magnesian with composition $Il_{48}Gk_{41}He_{11}$.

Equilibration temperatures and depths of the six garnet lherzolite assemblages, estimated from pyroxene compositions as discussed by Boyd (1973) and corrected for FeO by the method of Wood and Banno (1973), range from 920°C, 106 km to 1315°C, 148 km (fig. 1). The xenoliths show increasing amount of shearing with greater depth. Temperature-depth points for the Montana xenoliths suggest a geotherm which is similar in slope to the steep portion of the Lesotho geotherm, and is considerably steeper than the normal shield geotherm. The steepened geotherm defined by the xenoliths, coupled with deformation textures, could indicate their origin from the low-velocity zone in Eocene time, with increased temperature due to the inter-related processes of continental drift and magma generation. Preservation of textures of intense shearing requires active deformation of dry rock and rapid transport of xenoliths to the surface.

Xenolith data show that this diatreme was derived from a depth of at least 148 km, and the associated igneous rock (monticellite peridotite) indicates that the diatreme is related to ascent of a potassic gas-rich magma from upper mantle depths. Such magmas are involved in the genesis of many, but not all, kimberlites elsewhere in the world. The close relationship of kimberlite, carbonatite, and the monticellite peridotite-alnöite suite may define the spectrum of fluids responsible for transport of heterogeneous materials from upper mantle depths to near-surface levels where the resultant mixtures were emplaced as kimberlite.

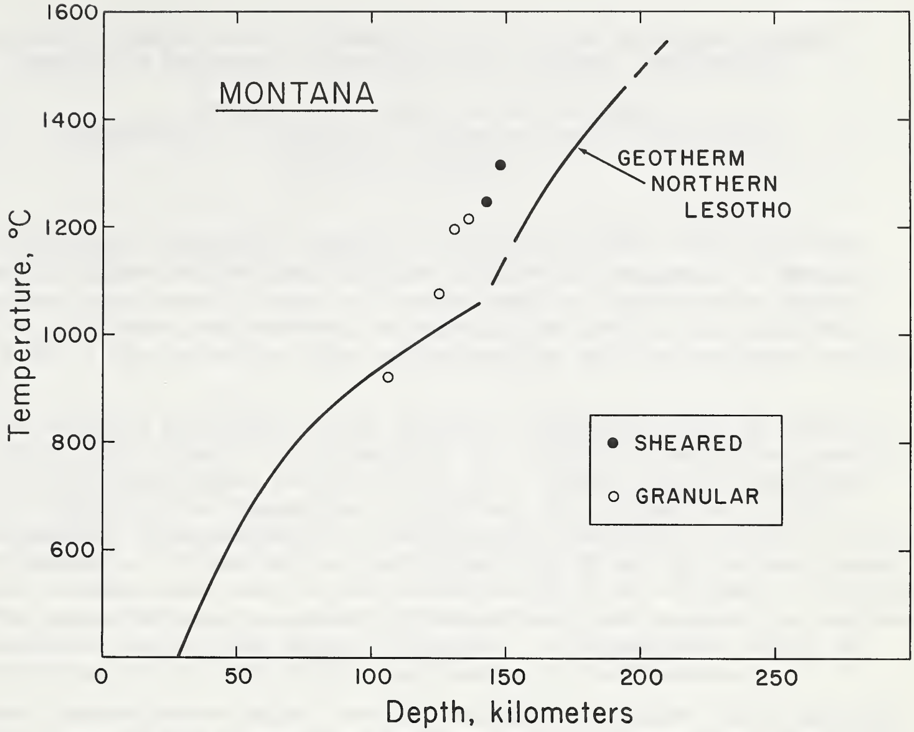

Fig. 1 Estimated temperatures and depths of equilibration of six garnet peridotite xenoliths from Montana, with the pyroxene-determined geotherm for northern Lesotho (Boyd and Nixon, 1973) for comparison.

References

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