GRANULITE XENOLITHS FROM THE GERONIMO VOLCANIC FIELD, SE ARIZONA: EVIDENCE FOR A HETEROGENEOUS PROTEROZOIC LOWER CRUST BENEATH THE SOUTHWESTERN U.S.;

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Knowledge of the composition and structure of the deep parts of the continental crust is vital to understanding crustal evolution. Information inferred from examination of medium- to high-pressure granulite facies terrains exposed at the earth's surface suggests that the lower crust in continental shield areas has, on the average, an intermediate composition. However, these studies are based predominantly on Archean rocks and are probably not representative of lower crustal lithologies in more recent geologic time (1). Chemical and isotopic analyses of granulite xenoliths from the Geronimo Volcanic Field (GVF) indicate that the lower crust beneath the southwestern U.S. is markedly heterogeneous and more mafic than most recent estimtes of the average lower crustal composition (1 & 2).

THE GVF GRANULITES--The GVF xenoliths occur in 9 - 0.26 my alkalic basalts. All are enriched in LREE relative to HREE, but two chemical groups are apparent (Figs. 1 & 2). One group consists of mafic granulites having low levels of total REE ($Ce_N$ 6-41 x chondrites), variable LREE enrichment ($Ce_N/Yb_N$ 1.8-8.0), positive Eu anomalies and low Rb/Sr ratios (<0.01), indicative of plagiclase cumulate precursors. This group, which includes both one-pyroxene (Al-cpx + plagioclase + Al-spinel $\pm$ apatite) and two-pyroxene granulites (cpx + opx + plag + magnetite $\pm$ ap), is compositionally heterogeneous. The two-pyroxene granulites range from 46-54% $SiO_2$ and 0.43-0.55 Mg/(Mg+0.85Fe); the one-pyroxene granulites have more restricted mafic compositions (Mg# 0.71-0.74; $SiO_2$ 49-52%). Granulites of this group have a limited range of $\delta D$ (-98 to -91°/$_{oo}$; $H_2O$ 0.08-0.37 wt%), but the one-pyroxene granulites have lower $\delta^{18}O$ (6.5 to 6.7°/$_{oo}$) than the two-pyroxene granulites (7.7to 8.5°/$_{oo}$). Granulites of the second group have intermediate major element compositions and are all two-pyroxene granulites (cpx + opx + plag + Kspar + mg + ap). These have higher total REE ($Ce_N$ 54-59 x chondrites; $Ce_N/Yb_N$ = 4.2-5.2), negligible Eu anomalies and higher Rb/Sr ratios (0.08-0.11). The $\delta^{18}O$ value for the only sample presently analyzed from this group is intermediate between values for one- and two-pyroxene meta-cumulates, while $\delta D$ values are distinctly higher (-84 to -69°/$_{oo}$), and $H_2O$ contents are an order of magnitude lower (<0.004 wt%). This group has major and trace element characteristics consistent with derivation from metamorphosed quartz monzodiorite precursors. Major and trace element models confirm that the two major groups of GVF granulites are not cogenetic.

ARCHEAN VS. PROTEROZOIC LOWER CRUST--Archean high-grade (granulite facies) terrains are typically bimodal associations of tonalitic gneisses and mafic to ultramafic gneisses (often as ultramafic-mafic $\pm$ anorthosite layered complexes); Metasediments are, in general, volumetrically minor. The tonalitic gneisses dominate in these associations, and have strongly fractionated LREE/HREE ($Ce_N/Yb_N$ typically 9 - 15) and small positive Eu anomalies. The average composition of these terrains is intermediate (ca. 61% $SiO_2$; Fig. 2). In contrast, Proterozoic and Phanerozoic granulite xenoliths scavanged from the lower crust are dominated by mafic rocks with the chemistry of gabbroic cumulates (e.g. GVF and other xenolith localities

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in the SW U.S., Lesotho, Massif Central, central Hoggar, Chile; Fig. 2). Metasedimentary compositions comprise a considerably greater proportion of the xenolith suite, while siliceous orthogneisses (tonalites, trondhjemites) are rare. Average compositions of the lower crust indicated by these suites is more mafic (ca. 56% $SiO_2$).

These differences suggest that Archean and post-Archean lower crust have significantly different compositions and imply a change from underplating predominantly tonalitic magmas to underplating mafic magmas and metasediments to the base of the continental crust at the Archean/Proterozoic boundary.

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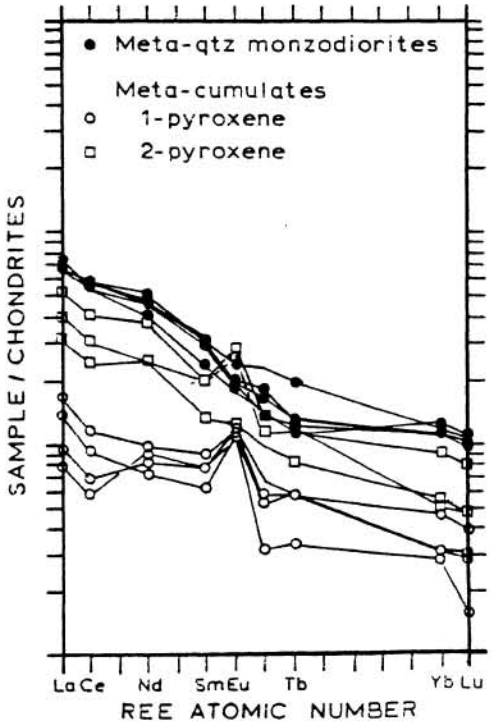


Fig. 1 Chondrite normalized REE patterns for GVF granulites.

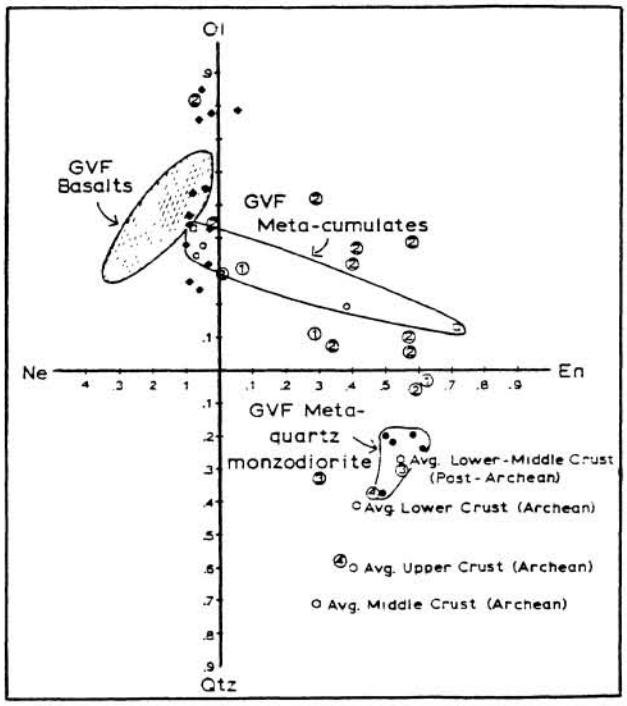


Fig. 2 Degree of silica saturation of GVF granulite xenoliths represented by normative mineralogy. The sum of normative olivine, nepheline, quartz, enstatite, diopside and corundum is recalculated to 100. Diopside and corundum project into and out of the plane repsectively. GVF metacumulates = open squares and circles. Solid diamonds are Al-augite series ultramafic xenoliths (GVF; San Carlos, refs. 3, Kilbourne Hole, Ref. 4). Number-filled circles are granulite xenoliths from other localities: 1 = Patagonia (ref. 5), 2 = Australia, 3 = Kilbourne Hole and 4 = The Thumb (refs. 6 and 7).

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