COMPARISON OF OLIVINE-RICH MARTIAN BASALTS AND OLIVINE-PHYRIC SHERGOTTITES.

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Introduction: Although initial deconvolutions of orbital thermal emission spectra of common Martian surface materials did not reveal the presence of magnesian olivine above the detection limit [1,2,3], recent deconvolutions that include more Fe-rich olivines in the spectral library suggest that this phase may be widespread and abundant in some locations [4]. The occurrence of olivine in some Martian basaltic meteorites is obvious, but its origin remains controversial. Crystals in olivine-phyric shergottites have been suggested to represent phenocrysts [5,6], xenocrysts [7,8], or restites from impact melting [9,10]. The occurrence of olivine-rich basalts (and olivine-bearing tephras) in Gusev Crater further confirms that this mineral is locally abundant on Mars. Compositional and textural comparison of Gusev basalts with olivine-phyric shergottites allows a more robust interpretation of the primitive character of these rocks and the nature of their mantle source region.

Identification and Characteristics of Gusev Olivine: Pancam, Mini-TES, and Mössbauer spectra obtained by the Spirit Rover all confirm the presence of abundant olivine in Gusev plains basalts (Humphrey, Adirondack, and Mazatzal) [11]. The calculated CIPW norm for the APXS composition of RATed Humphrey, the least altered of these rocks, indicates 26% olivine with an average composition of Fo52 [11]. The relatively Fe-rich olivine compositions for Humphrey and the other rocks are supported by Pancam, Mini-TES, and Mössbauer spectra (Fig. 1). A point count of an MI mosaic of Humphrey indicates 25% dark crystals (interpreted to be olivine [11]), in agreement with the normative proportion. At least one analyzed rock (Wishstone), interpreted to be a tephra, in the Columbia Hills of Gusev Crater contains olivine, as determined by Mini-TES and Mössbauer spectra.

Comparison with Olivine-phyric Shergottites: Fo52 is more Fe-rich than olivine in terrestrial basalts, but it overlaps compositions inferred from TES spectra (Fig. 1). Olivine compositions in Gusev basalts also overlap those of zoned megacrysts in some olivine-phyric shergottites, but are more Fe-rich than in other olivine-phyric and lherzolitic shergottites (Fig. 1). Normative olivine compositions for olivine-phyric shergottites (open circles in Fig. 1) are slightly more magnesian than Gusev basalts. Euhedral to subhedral olivine crystals in olivine-phyric shergottites have been interpreted as phenocrysts [12,13], based on their magnesian core compositions and on CSD measurements suggesting continuous cooling. However, olivine-phyric shergottites also contain some olivines with ragged and embayed grain boundaries, compositions more Fe-rich than in equilibrium with their bulk rock compositions, and ferroan reaction rims in contact with groundmass that indicate disequilibrium with the enclosing melt [8,13]. The controversy over the origin of olivines arises because different groups have focused on one or the other kind of grains. Taking all available compositional, textural, and CSD constraints into account, the most likely scenario is that most olivines are phenocrysts, but a (probably small) fraction of the large crystals are cumulus megacrysts or xenoliths [13]. A further complication is that some fraction of the earliest crystallized phenocrysts (~Fo83-86) have been lost from all but a few of these magmas [6,13].

A plot of Ni versus Mg (Fig. 2) shows that olivine-phyric shergottites have higher contents of both elements than do basaltic shergottites. Given the model above, this correlation can be interpreted to reflect the higher Ni and Mg abundances in primitive magmas, with the trend representing an olivine-control fractionation line. The composition of olivine may be approximated by the bulk analysis of Chassigny, an olivine cumulate.

The dark grains in microscopic images of Gusev basalts appear to be subhedral to anhedral crystals (Fig. 3) and could be either partly resorbed phenocrysts or xenocrysts. If they are xenocrystic, then the bulk rock compositions inferred from APXS analyses of RAT holes [11] may not represent picritic liquids. Subtraction of 25% olivine from the Humphrey bulk rock analysis yields a composition having ~50% silica that resembles basaltic shergottites, especially those like QUE94201 with higher plagioclase contents [14]. However, this calculation represents an extreme end-member, if these rocks contain both phenocrysts and xenocrysts.

Gusev basalts plot in Figure 2 with olivine-phyric shergottites. All three analyzed Gusev rocks have virtually identical chemical compositions [11]. It seems more plausible that the olivine megacrysts they contain are phenocrysts, because incorporation of xenocrysts would likely be random, producing a range of xenocryst proportions and bulk rock compositions. Olivine-phyric shergottites exhibit such a range in proportions (7-29 vol %) and compositions (Fig. 2).

If the comparison with olivine-phyric shergottites is valid, the olivine-rich basalts of Gusev probably contain only small amounts of xenocrysts, if any at all, and their composition [11] can probably be used to infer mantle properties. The modest measured abundances of incompatible elements (P, Ti, K) and presence of normative olivine plus hypersthene [11] suggest a depleted mantle source.

References:

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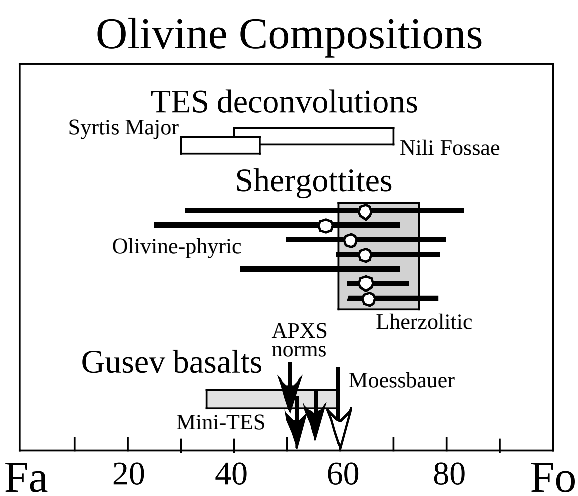

Fig. 1. Mars olivine compositions determined from deconvolutions of TES orbital spectra [4], microprobe analyses of olivine-phyric and lherzolitic shergottites (black bars and gray box, respectively), and Spirit rover instrument analyses of Gusev basalts [8]. Open circles are normative olivine compositions for olivine-phyric shergottites, calculated assuming Fe2+/Fe(total) = 0.84 [11].

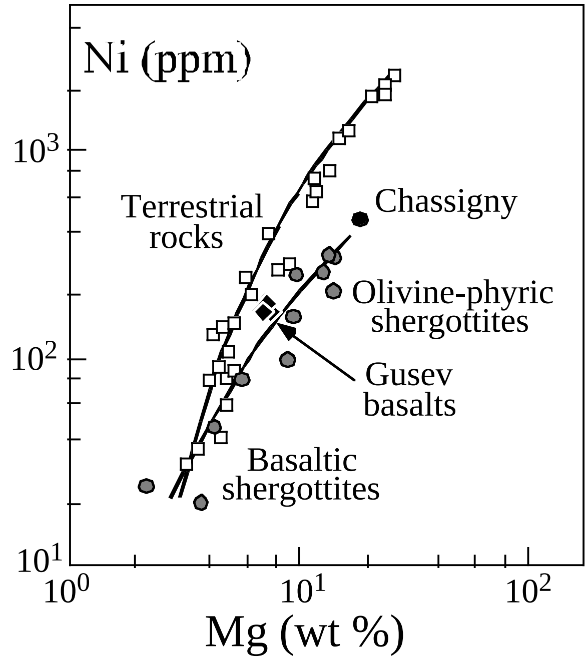

Fig. 2. Comparison of bulk Ni versus Mg contents of terrestrial rocks and shergottite meteorites (modified from [15]). Gusev basalts (diamonds) plot with olivine-phyric shergottites.

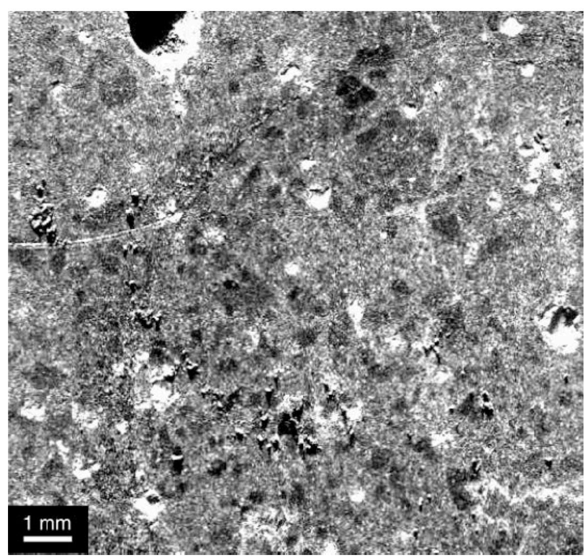

Fig. 3. Enhanced MI image of RATed Humphrey showing dark subhedral crystals, interpreted to be olivine crystals. These grains resemble some olivine megacrysts in olivine-phyric shergottites.