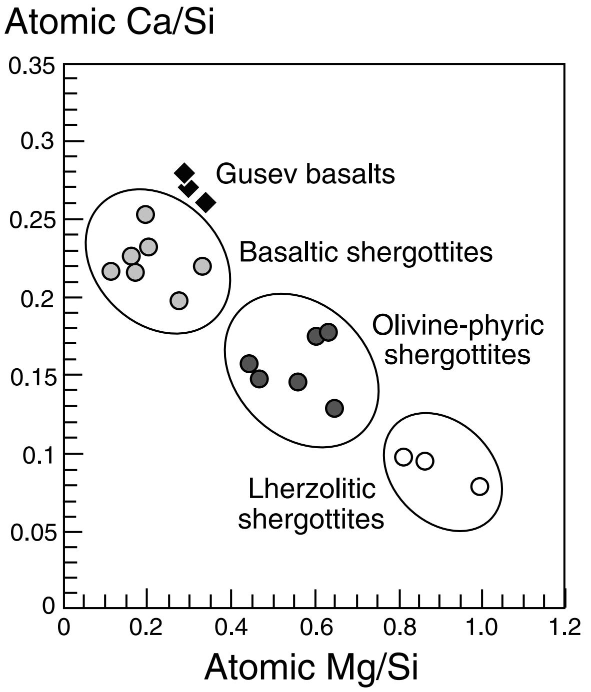

Figure 17. Chemical classification diagram for Martian meteorites [after *Oura et al.*, 2003], illustrating a compositional difference between Gusev basalts and olivine-phyric shergottites.

Moon. There are no obvious volcanic edifices nearer to Gusev, so we cannot specify the source of these flows. Whatever their source, the volcanic units surrounding Apollinaris and the plains unit within Gusev have Hesperian [*Milam et al.*, 2003] or Early Amazonian to Hesperian model ages [*Kuzmin et al.*, 2000], significantly older than olivine-phyric shergottites. Morphological data and crater counts from orbital imagery suggest that lavas flooded Gusev at ~3.65 Ga, postdating other materials such as putative sediments emplaced by Ma'adim Vallis [*Greeley et al.*, 2005].

[48] The differences in composition and age appear to rule out any direct petrogenetic relationship between Gusev picritic basalts and shergottites. However, it seems clear that undepleted Martian mantle sources have produced primitive magmas over much of post-Noachian time.

6.3. Are Rocks Formed From Primitive Magmas Widespread on Mars?

[49] There are conflicting views about whether the Martian crust is dominated by basalt [*Wyatt and McSween*, 2002; *McSween et al.*, 2003] or contains significant amounts of andesitic rocks [*Bandfield et al.*, 2000a; *Hamilton et al.*, 2001]. Even the basalt-only advocates, however, have not argued that primitive basalts might be abundant. Primitive, mantle-derived magmas are uncommon on Earth, because most magmas experience fractionation and sometimes contamination with crust en route to the surface. In identifying primitive magmas, even olivine-rich basaltic rocks can be misleading, because they may be fractionated basalts containing cumulus olivine. Yet, the very limited surface exploration of Mars by rovers and the probable biased sampling of the surface by Martian meteorites may have both found instances of rocks formed by solidification of primitive, olivine-rich magmas. The identification of other olivine-bearing volcanic materials from orbital thermal emission spectra further suggests that primitive magmas may not be unusual. Picritic basalts may even be common, because Martian weathering under acidic conditions preferentially attacks olivine [*Hurowitz et al.*, 2006; Schröder et al., manuscript in preparation, 2006] and disguises such rocks under alteration rinds, as observed at Gusev.

7. Summary

[50] Volcanic rocks excavated from craters on the floor of Gusev Crater are uniform in composition. These picritic basalts share many similarities with olivine-phyric shergottites, including the following:

[51] 1. Intermediate to ferroan olivine compositions: Gusev basalts contain olivines with average compositions in the range Fo_{60-40}; shergottites contain normally zoned olivines ranging from Fo_{84} to Fo_{25} (zoning within individual meteorites is more restricted) with normative olivine compositions of ~Fo_{65}.

[52] 2. Olivine modal abundances ranging up to 20–30 volume%.

[53] 3. Coexisting minerals that include low-calcium and high-calcium pyroxenes, plagioclase of intermediate composition, iron-titanium-chromium oxides, and phosphate.

[54] 4. Porphyritic textures produced by olivine megacrysts.

[55] 5. Similar nickel-magnesium and chromium-magnesium systematics.

[56] 6. Major element bulk-rock compositions that are multiply saturated with olivine, orthopyroxene, and spinel at mantle pressures, suggesting they are primitive magmas.

[57] A number of differences are also apparent:

[58] 1. Textures: Gusev basalts have abundant vesicles and vugs, suggesting eruption with high volatile contents.

[59] 2. Chemical compositions: Gusev basalts have higher Al_2O_3 and Na_2O contents, reflected in higher plagioclase abundances than in shergottites, and they do not plot with shergottites on a Ca/Si versus Mg/Si classification diagram.

[60] 3. Age: Gusev basalts appear to be Hesperian or Early Amazonian, whereas olivine-phyric shergottites have radiometric ages that are significantly younger (Late Amazonian).

[61] Examination of orbital thermal emission spectra provides a global context for olivine-rich basaltic rocks. Such rocks, containing intermediate to ferroan olivine with abundances up to 30%, appear to be widely distributed within the ancient highlands of Mars. The existence of younger picritic basalts, although clearly demonstrated by olivine-phyric shergottites, has not been confirmed by spectroscopy, probably because young volcanic terrains in Tharsis and Elyssium (likely sources for shergottites) are obscured by dust cover. Nevertheless, primitive olivine-rich basalts of various ages have now been suggested by rover exploration at Gusev Crater, studies of Martian meteorites, and orbital remote sensing. Given that weathering processes under acidic conditions preferentially destroy olivine and