COMPARATIVE PLANETARY MINERALOGY: CHEMISTRY OF MELT-DERIVED PYROXENE, FELDSPAR, AND OLIVINE. J. J. Papike, Institute of Meteoritics, Department of Earth & Planetary Sciences, University of New Mexico, Albuquerque, NM 87131-1126, U.S.A.

INTRODUCTION. The purpose of this study is to provide some comparisons of the chemical compositions of pyroxene, feldspar, and olivine that crystallized from melts originating in differing planetary environments (chondrules, Earth, Moon, Mars, and Vesta). Because these melts formed from chemically distinct planetary reservoirs and because they experienced differing intensive thermodynamic parameters, the minerals that crystallized from these melts should reflect these differing conditions.

The data for terrestrial basalts is presented as averages for seven sample suites: Archean, Columbia Plateau, ocean floor, Hawaiian, island arc, Keweenawan, and Rio Grande. Therefore, although a small number of points will be plotted on the following data displays for terrestrial basalts, they represent 1263 pyroxene, 269 olivine, and 708 feldspar analyses [1]. The details concerning these basalt suites are reported in BVSP [1] while a specific discussion of the silicate mineralogy is reported by Papike [2]. The data for lunar mare basalts and lunar highland melt rocks are tabulated in the appendix to Chapter 5 (lunar samples) [3]. Data for the silicate minerals in martian rocks are tabulated in Chapter 6 [3]. Chemical data for pyroxene and olivine in chondrules are from the Semarkona ordinary chondrite, which is a good example of an unequilibrated chondrite containing chondrules with phenocrysts that still record melt-mineral partitioning uncompromised by re-equilibration [3]. The pyroxene data for 4 Vesta is from six unequilibrated eucrites (Pun and Papike, [4]), and the feldspar data is from Table HED-4, Chapter 4, [3].

PLAGIOCLASE FELDSPAR. Figure 1 is a plot of K versus Na content. The data array shows interesting groupings with martian plagioclase plotting at higher Na and K, terrestrial plagioclase plotting in an intermediate position, and plagioclase from the Moon and 4 Vesta plotting at the lowest Na and K contents. This is an interesting result because it demonstrates the utility of minerals as geochemical recorders, an important attribute when considering planetary regolith samples or small non-representative lithic fragments. In this case, the basaltic melts reflect the relative volatile budget of planetary mantle reservoirs and the plagioclase, which crystallized from these basalts, also records this information. A number of previous studies have discussed the volatile content of the sampled planetary bodies (e.g. Drake et al., [5]) and their results are consistent with these observations.

OLIVINE. Figure 2a is a plot of Al versus $X_{Fe}$. Basically, it shows that small amounts of Al can substitute into the olivine crystal structure. Perhaps the most obvious feature of this diagram is the very low Al content of chondrule olivine; in most analyses Al is below detection. Figure 2b is a plot of $Cr$ versus $X_{Fe}$ for olivine and appears on the same diagram as Figure 2a for comparison. Whereas the Al content of Semarkona chondrule olivine is very low, Cr is quite high relative to olivine from other planetary basalts. Perhaps a major contributing factor to this systematic is that much of the Cr is in the reduced $Cr^{2+}$ valence state which is compatible with the olivine structure. In a study of chromium partitioning between olivine and melt, Huebner et al. [6] concluded that most Cr in olivine is present as $Cr^{3+}$. However, a study by Schreiber and Haskin [7] concluded that the high concentrations of Cr in lunar olivines are a direct result of high concentrations in the parent melts, not of an affinity for $Cr^{2+}$. Sutton et al. [8] addressed the issue of the valence state of Cr in olivine directly by using X-ray absorption near edge structure (XANES) to study olivine from lunar mare basalt 15555. Their results showed that Cr is predominantly $Cr^{2+}$ in olivine and $Cr^{3+}$ in pyroxene. Of most relevance to this discussion are the results of Sutton et al. [9] who used microXANES techniques with a synchrotron x-ray fluorescence microprobe to study the Cr oxidation state in olivine from chondrules including Semarkona. The main conclusions are that both $Cr^{2+}$ and $Cr^{3+}$ are present but Semarkona chondrule olivine has a higher $Cr^{3+}/Cr^{2+}$ than olivine from the ALH77307 chondrite. A recent paper by Hanson and Jones [10] examines the systematics of $Cr^{3+}$ and $Cr^{2+}$ partitioning between olivine, liquid, and spinel. This study shows that olivine does not discriminate strongly between $Cr^{3+}$ and $Cr^{2+}$ and their Ds can be similar.

PYROXENE. Figure 3 displays the Mn, Fe compositions for pyroxenes. The trajectories through the data for each planetary reservoir show a decreasing Mn/Fe ratio in the sequence Semarkona chondrules > 4 Vesta > Mars > Earth > Moon. Apparently the most important factor controlling the slope of these trajectories is the Mn/Fe ratio of the accreting materials, which appears to be correlated with distance from the sun. Oxygen fugacity and metal separation appear to have a secondary effect. The slightly higher Mn/Fe ratio for terrestrial basalts compared to lunar may reflect core formation on Earth after the “giant impact” which allegedly separated terrestrial material to combine with impactor material to form the Moon. Alternatively, the impactor material may have had a lower Mn/Fe ratio.
**CONCLUSIONS.** This brief review of the comparative chemistry of feldspar, olivine, and pyroxene from planetary melts demonstrates that these minerals are powerful recorders of the geochemical and petrologic processes on different planetary bodies. Some specific important information obtained from electron microprobe data on these phases is: 1. The planetary mantle sources have variable Na contents with Mars > Earth > Moon and 4 Vesta. 2. High Cr abundances in olivine phenocrysts from Semarkona chondrules indicate high Cr activity in the melt and high Cr$^{2+}$/Cr$^{3+}$ with Cr$^{2+}$ favoring olivine and Cr$^{3+}$ favoring pyroxene. 3. Mn/Fe ratios in pyroxene show decreasing values in the sequence Semarkona chondrules > 4 Vesta > Mars > Earth > Moon. The major factor controlling these ratios appears to be the Mn/Fe of the accreting material, with Mn/Fe increasing with distance from the sun. A secondary factor is core formation which perhaps explains the higher Mn/Fe of terrestrial basalts relative to lunar.

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