WHITLOCKITE-RICH BASALTS FROM 4-10 MM BOULDERS AT APOLLO 14: MINERALOGY AND PETROLOGY Gregory A. SNYDER and Lawrence A. TAYLOR, Dept. of Geological Sciences, University of Tennessee, Knoxville, TN 37996-1410.

Previous studies of small rock clasts and fragments from polymict breccias and soils have added immensely to our knowledge of lunar igneous processes and have led to the construction of a more complete picture of the evolution of lunar basalts. In this vein, soil "fall-apart" studies have been undertaken for samples from the Apollo 14 landing site. We report here a set of five 4-10 mm mare basalt "boulders" from soil 14256. These rocks exhibit a variety of textures and mineral-chemistry.

PETROGRAPHY: Four of the five basalts have distinct fine-grained granular textures, and the other (,39) exhibits a medium-grained sub-ophitic texture. All samples contain olivine, often subhedral, and occasionally as 0.05 to 0.1mm phenocrysts. Plagioclase is also ubiquitous as both large (0.1-1mm) blocky phenocrysts and as finer matrix or interstitial material. Pyroxene makes up a large proportion of the matrix in these rocks and is mostly low-Ca pyroxene, although a small proportion of high-Ca pyroxene is found in all samples. These rocks contain FeNi metal grains, abundant in the granular basalts and minor in the sub-ophitic sample. Whitlockite also is found in all of the granular basalts, but it is noticeably absent from the sub-ophitic basalt (,39). Minor apatite was found in two of the granular basalts as blocky subhedral grains. All basalts contain ilmenite, which typically exhibits a sieve-texture (enclosing mafic phases) when the grains are large (0.1-0.4mm) and is blocky to acicular when the grains are small (typically, 0.01-0.04mm, though they may be smaller). One sample (,38) also contains minor poikilitic badellyite in some larger ilmenite grains. K-Ba feldspars are found as minor fine-grained (0.05-0.1mm) interstitial material. Basalt 14256,40 contains an anhedral, interstitial patch of **sieve-textured zircon** (0.06 x 0.13 mm in size) with tiny inclusions of plagioclase and low-Ca pyroxene. This rock also contains 2-3% modal whitlockite, crystals of which are blocky to "puzzle-piece" in shape and 0.03 to 0.08mm in size.

MINERAL CHEMISTRY: The mineral chemistry of the five 14256 basalts is summarized in Table 1 and discussed below.

Table 1: Texture and ranges in mineral chemistry for analyzed 14256 basalts. SO = sub-ophitic; GR = granular.

SAMPLE	TEX	OLIVINE	PLAGIOCLASE		PYROXENE		ILMENITE
		Fo	An	Ab	Wo	En	Mg#
,36	GR		79-84	11-19	2-53	34-70	15-18
,37	GR	63-69	73-95	5-25	1-8	63-83	15-19
,38	GR	61-70	78-93	7-20	2-42	50-84	15-21
,39	SO	75-76	78-96	3-18	4-65	27-75	22-31
,40	GR	62-64	77-95	5-21	4-39	45-67	17-19

Olivine compositions exhibit little variation within each sample, but can be split into two separate groups which correlate with texture. Olivines from the sub-ophitic basalt sample (,39) are homogeneous and have the highest Fo of any sample (75-76). The granular basalts exhibit modest variability in olivine composition from Fo61 to Fo70. Figure 1 presents the pyroxene data. As can be seen, all samples (except possibly ,37) contain both high-Ca and low-Ca pyroxenes, but high-Ca pyroxenes are sparse. Many pyroxenes exhibit minor zoning from pigeonite-rich cores to more augite and diopside-rich rims. Compositions of plagioclases from all samples exhibit similar variability from An96 to An73. Plagioclases may exhibit extreme zonation where in contact with pyroxenes. One grain varies, core to rim, from An91 to An42. On average, though, variation from core to rim is 5-20 An units. The sub-ophitic basalt sample (,39) contains ilmenites which have the highest Mg# and MgO of all samples (22-31, and 6.3-9.8%, resp.). All ilmenites from the granular samples are more Fe-rich. FeNi metals analyzed from these basalts

Figure 1

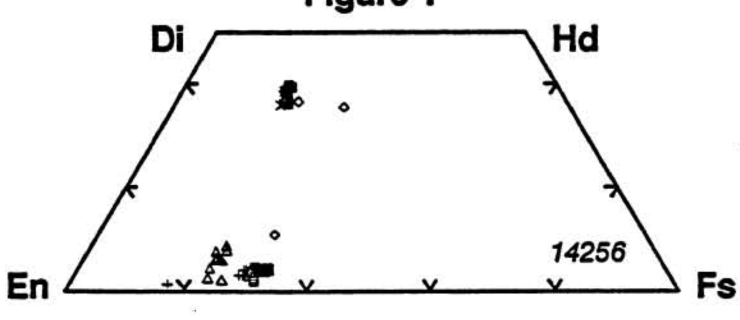
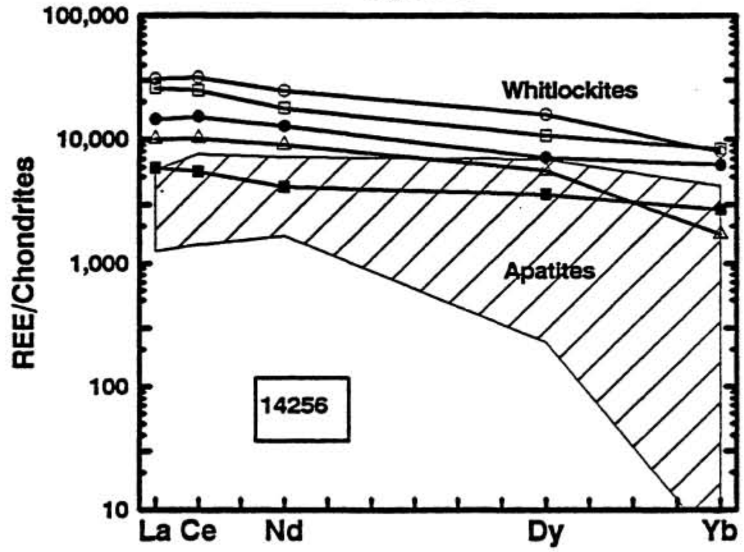


exhibit relatively little variation with Ni contents from 4-10 wt.% Ni. Ni/Co ratios are typically 10-20. Three native metal grains which occur in the interior of either olivine or orthopyroxene grains have low Ni and Co contents (<1% and <0.3%, resp.).

PHOSPHATES: Whitlockite is present and abundant in all rocks, except the subophitic basalt (,39). These whitlockites have REE in the ranges of La_2O_3 = 0.73-1.2, Ce_2O_3 = 2.1-3.1, Nd_2O_3 = 1.1-1.8, Gd_2O_3 = 0.50-0.79, and Yb_2O_3 = 0.17-0.24. F-apatites, with much lower abundances of the REE (by an order of magnitude), have been found in three samples, ,37 ,38 and ,40. Selected whitlockite and apatite REE patterns for these basalts are given in Figure 2. The patterns are not unlike those previously reported by Neal & Taylor [2]. Considering the high REE abundances in the whitlockites and the relatively large proportion of whitlockite in these rocks, it is to be expected that this phase will dominate the REE chemistry of the whole-rock (as indeed it does; see companion abstract on whole-rock geochemistry [3]). Liquids in equilibrium with these whitlockites were calculated using published whitlockite Kd's from Neal & Taylor [2]. These calculated liquids have much higher abundances of the REE (2-5x) than the actual basalts which contain the whitlockites. Therefore, the whitlockites are not in equilibrium with the whole-rocks within which they are found.

Figure 2



DISCUSSION: Considering the relatively primitive mineralogy of the granular basalts, as manifested by pyroxene, olivine, and plagioclase compositions (Table 1), the presence of late-stage minerals (K-feldspar, whitlockite, apatite, and zircon) is enigmatic. An interesting feature of these rocks is the large amount of whitlockite (up to 3%) and its elevated proportion relative to other late-stage interstitial phases. But for the large proportion of whitlockite, the bulk mineralogy and chemistry of the late-stage interstitial material is granitic. No known lunar granite contains phosphate in such profusion. Liquids in equilibrium with the whitlockite are more evolved (2-5x) than any basalt yet sampled. *The late-stage material found in these rocks could not all have been generated in one stage, either through extensive fractional crystallization of a basalt, or assimilation of granite.* However, the relative proportion of whitlockite to late-stage "granitic" minerals can be explained by the process of silicate liquid immiscibility.

Neal & Taylor [1] have shown that KREEP can undergo silicate liquid immiscibility (SLI), whereby it is effectively split into a K-fraction (high in K, Si, and Zr) and a REEP-fraction (high in REE, P, Fe, and Ti). The relative proportions of these two fractions after SLI would be about 4:1 (REEP-frac/K-frac) as dictated by known phase equilibria for the immiscible fields in basaltic systems [4]. This may account for the high proportion of whitlockite in the samples relative to "granitic" interstitial phases. It is proposed that the presence of K-Ba feldspars, zircon, and apatite represent the K-frac portion of SLI, and that the abundance of whitlockite (+ sieve textured ilmenite) represents the corresponding REEP-frac.

REFERENCES: [1] Neal et al. (1989), GCA 53, 529-541; [2] Neal & Taylor (1991), GCA, *submitted*; [3] Snyder et al. (1991), LPSC, this volume; [4] Roedder (1978), GCA 42, 1597-1617.