APHYRIC Ti-RICH BASALT FROM 74221.2. M. R. Martinez1,2, K. Mueller2, D. C. Barker3, D. Nyarwaya2, D. Luna2, A. M. Shipman2,4, and J. K. Meen2,4, 1Department of Mechanical Engineering, University of Houston, Cullen College of Engineering, 4722 Calhoun Rd., Houston TX 77204 USA (martinehenriquez@hotmail.com), 2Texas Center for Superconductivity, University of Houston, Houston Science Center, 3201 Cullen Blvd, Rm. 202, Houston, Texas 77204 USA, 3Department of Earth and Atmospheric Sciences, University of Houston, Science & Research Building 1, 3507 Cullen Blvd, Rm. 312, Houston, Texas 77204 USA, 4Department of Chemistry, University of Houston, Lamar Fleming Jr. Building, 3507 Cullen Blvd, Houston, Texas 77204 USA (jmeen@uh.edu).

Abstract: An approximately 500 µm grain in 74221.2 tells a story of several events in the evolution of the magma at this site. Armalcolite was first formed and was then overgrown with ilmenite. The compound crystals were physically disrupted and incorporated in a liquid that crystallized at least olivine and plagioclase at the highest temperatures. On cooling, the liquid co-crystallized ilmenite, olivine, plagioclase, and clinopyroxene and ultimately generated a silica-saturated and K- and P-rich liquid. This crystallized (or almost so) rock was disrupted and a tiny piece included in the regolith.

Introduction: Barker and Snow [1] separated and analyzed volcanic glasses from soil aliquot 74221.2 from the top 10 cm of regolith on the rim of Shorty Crater collected during the Apollo 17 mission. In an accompanying paper [2], we describe glasses separated from the same sample and that have surfaces consisting of thin crystals of olivine, ilmenite, and plagioclase (so the grains appear dark grey or black in reflected light). These glasses cooled more slowly than those described by Barker and Snow but still are dominantly glass. This paper looks at an aphyric basaltic sample from 74221.2 that was apparently brought to the near-surface as a liquid carrying phenocrysts and which cooled in the near-surface environment sufficiently slowly to exhibit internal differentiation. The fragment was incorporated into the regolith as a totally or near totalmente solid clast. It has been designated in-house as AS22.

Sample Preparation and Analysis: AS22 was swept up in the sample preparation described in [2]. The grain has undulose surfaces and is, externally, generally similar in appearance to the black glasses described by [2]. No rough areas of minerals ascribed to crystallization from a volcanic gas were seen on the surface of AS22 (cf. 2). On sectioning and polishing this clast, immediate differences from the glasses were obvious. The other clasts so far studied from 74221.2 are dominated by glass and contain quench crystals of olivine and ilmenite. This sample is aphyric and polycrystalline with grains ranging from ≈100 µm down to sub-micron intergrowths (Figure 1). Analysis of grains was using a JEOL JXA8600 electron microprobe using on-line Geller software to manipulate the x-ray wave-length-dispersive spectrometer results and using natural mineral grains as standards for elemental analysis.

Mode and Mineral Chemistry: The clast is ≈500 µm across and is densely crystalline except for a hole in the lower central portion (Figure 1). The most distinctive mineral species are the rimmed grains of oxides that are scattered through the upper part of Figure 1. The cores with darker grey scale are crystals of armalcolite, (Fe,Mg)Ti_2O_5, that is enclosed within a brighter ilmenite, FeTiO_3. The armalcolite grains are all <100 µm long and many of them have ilmenite rims that are of similar dimension. In some cases, small armalcolite grains have relatively huge ilmenite rims. While each armalcolite has an ilmenite rind at least in part, not all ilmenites grains have armalcolite cores. Small ilmenite grains are intergrown with silicate grains in the finer areas of AS23 and this, together with the lobate edges of some of the larger grains indicate that the liquid continued to crystallize ilmenite to relatively late stages of evolution. Rutile was not observed in this clast.

Two olivine grains (center and upper left) are the largest grains in AS22. Each has an armalcolite-ilmenite composite grain intergrown with it. The olivine grains are very idiomorphic and are apparently continuous with late stage olivine of the fine-grained areas. There are many smaller olivine grains so, again, the liquid continued to crystallize olivine over a wide interval.

Clinopyroxene and plagioclase do not form large crystals and most of these minerals are intergrown with ilmenite and olivine. Some of the plagioclase occurs as blades.

Although not resolvable in Figure 1, the area of the clast which is finest grained is in the center and includes, as well as olivine, plagioclase, ilmenite, and clinopyroxene, small regions rich in Ca and P which, although too small and irregular for unique analysis, are presumablyapatite crystals. Other regions have high Na and K and are likely to be alkali feldspar rich and other regions are definitely silica. Despite an almost perfect example of silica-saturated fractional crystallization, no grains of orthopyroxene were located.

The armalcolite grains are universally enriched in Ti with Ti near 2.1 atoms of 3 total for Ti+Fe+Mg. There is very little Mg-Fe zoning with Mg being 40-47
% of (Mg+Fe). Ilmenite has a small Mg component (Mg# near 6) and is near (Fe,Mg)TiO3.

Olivine shows rather more zoning – the variation in back-scattered electron density across the “O” in the olivine label on Figure 1 shows that the core is Mg rich. The highest Mg# in that grain (and the highest in AS23) is about 74 in olivines that contain 1500-1600 ppm Cr. The lowest Mg# are 66 with 800 ppm Cr. The broadly linear compositional analysis is consistent with a simple fractionation model.

Plagioclase also exhibits compositional variation with the highest An# of >90 (max. 93) and the lowest being 80. The potassium content of almost all plagioclase grains is 0.08-0.1% but, in the finer grained areas it rises to as high as 0.5% (An#≈80).

Clinopyroxenes have Mg# as high as 68 and as low as 40. There is a broad range in Cr content with 5000 ppm Cr in the more magnesian pyroxenes and <2000 ppm Cr in the least magnesian. The trend in Cr-Mg# is so broad that a simple fractionation model is probably not applicable.

Processes in a Grain of Sand: Despite the small size of this basaltic piece, several processes are inferred in the creation of this grain. A precursor liquid originally crystallized armalcolite which was overgrown by ilmenite, a well-known reaction in low-f(O2) Ti-rich lunar basalts. The fact that ilmenite does not completely surround the armalcolite in each grain and that silicate minerals are in contact with the armalcolite suggests that there was physical disruption of the Ti-rich material and the composite grains were incorporated as phenocrysts (xenocrysts?) in the liquid. The high Mg# of olivine adjacent to composite oxide grains suggests crystallization of the olivine as a phenocryst in fairly stable conditions. Plagioclase cores may also be phenocrystic. The liquid underwent fractional crystallization with a lower-temperature liquid retained in different parts of the clast. Small amounts of silica-saturated and K- and P-enriched liquids were the last to crystallize to fine-grained regions internal to the clast.

Most of this crystallization presumably occurred in a magma body somewhat larger than the remaining 0.5 mm grain and the holocrystalline (or almost so) clast was then physically separated from its parent body and incorporated in the regolith. It is possible that the very last crystallization was in situ.