APOLLO 11-TYPE BASALTS FROM APOLLO 16: A NEW TYPE OF HIGH-Ti BASALT?

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Introduction: Sample 60639 is a 175.1 g rake sample collected near the Apollo 16 lunar module. It is a polymict fragmental breccia containing a variety of lithic clasts, including mare basalt, anorthosite, and a variety of impact-melt breccias (poikilitic, aphanitic, and glassy) [1]. A basalt clast from 60639 was examined by [2], who described the fragment as being chemically similar to subophitic textured Luna 16 basalts. A subsequent study [3] suggested that the major- and trace-element concentrations in the 60639 basalt clast indicated that it is similar to low alkali Apollo 11 and 17 high-Ti basalts. The basalt fragment 60639,2 (Fig. 1) is a coarse-grained mare basalt [4] with plagioclase laths ~300-500 microns in length [1] and is composed of approximately 5% olivine, 35% plagioclase, 5-10% ilmenite, and 50% pyroxene and accessory spinel [4].

The main objective of this study is to characterize newly discovered basalt clasts from 60639, as well as re-examine the previously studied 60639 basalt clast [3,4], with modern analytical methods. New mineral and whole-rock data augment the sparse petrographic dataset for basalts from the Apollo 16 landing site. We examine the previously studied thin-section 60639,2 [2] as well as two new thin-sections (Table 1) from basalt fragments we discovered in 2010. The additional thin-sections (,50 & ,52) are petrographically similar to ,2. In addition to the thin-sections, the whole-rock (WR) composition of 5 basalt chips as well as 2 breccia and 3 breccia-basalt mix fragments from 60639 (Table 1) were analyzed. WR split 60639,4 is the same sample reported by [3].

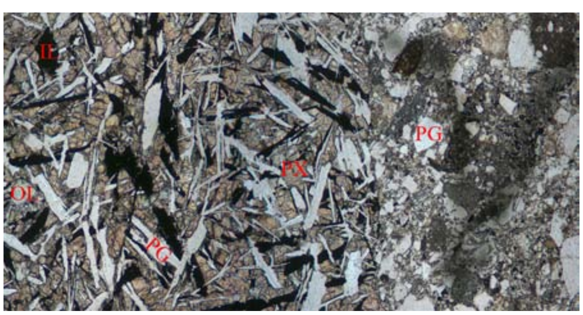

Fig 1. Plane-polarized light image of 60639,2 showing the basalt portion on the left and the breccia portion on the right with annotated crystals (IL=ilmenite, OL=olivine, PG=plagioclase, PX=pyroxene). Image is ~3 mm wide.

Subsample	Lithology	Type
,1	B	WR
,2	BX	TS
,4	B	WR
,44	B, BX	WR-2
,45	B, BX, X	WR-3
,48	B, BX, X	WR-3
,50	BX	TS
,52	BX	TS

Table 1. 60639 subsamples examined in this study with their sample type description: B= basalt, BX=basalt-breccia mixture , X=breccia, TS= thin-section, WR=whole rock. Numbers next to WR indicate the # of WR splits made from the subsample according to the lithology divisions.

Methods: *Mineral Phase Chemistry:* The chemical composition of ilmenite, pyroxene, olivine, and plagioclase phases are being determined for the three thin-sections (Table 1) from 60639, both from the breccia and basalt portions. Major-element analyses are performed with the JEOL JXA-8200 electron microprobe (EMP) at Washington University in St. Louis using a 5 µm spot size and 30-s on-peak counting times. Trace-element data are collected via Laser Ablation-Inductively Coupled Plasma-Mass Spectrometry (LA-ICP-MS) using a New Wave UP-213 laser ablation system coupled with a ThermoFinnigan Element2 ICP-MS at the University of Notre Dame. Trace element analyses use a repetition rate of 5 Hz, spot size 15-65 µm (depending on crystal size), and power range of 85-100% to maximize the corresponding fluence of ~16-20 J/cm^2. Plagioclases and pyroxenes were analyzed using Ca and NIST SRM 612 glass as internal and external standards, respectively. Ilmenite and olivine crystals were analyzed using the NIST SRM 610 glass and Ti and Mn abundances, respectively.

Whole Rock Chemistry: Major elements were determined via solution using a Perkin Elmer ICP-Optical Emission Spectrometry at the Center for Environmental Science and Technology (CEST) at the University of Notre Dame. Four standard reference materials (BIR-1, BCR-2, BHVO-1, BHVO-2) were analyzed as unknowns and a calibration curve was created using 6 solutions of known concentrations. Trace element abundance data were collected via solution-mode ICP-MS using the standard addition method (see [5]).

Results: *Mineral Phase Analyses:* Laser ablation work is scheduled on the three thin-sections from 60639. Preliminary results show that plagioclase grains from different thin-sections have similar major element compositions (Fig. 2a). Plagioclase grains from the breccia portions have higher An% and a wider spread in their Mg# than their basaltic counterparts; the average An% in breccia plagioclases (97.9%) is similar to the average An% of impact melt plagioclases from Apollo 16 (97.2%). Pyroxene grains are predominately augite (Fig. 2b) in composition with some crystals zoning to an Fe-rich pigeonite rim; some pyroxenes from ,50 and ,52 are enstatitic. Average composition of olivine grains from the basalt is 66.8% Fo and 70.4% Fo from the breccia (Fig. 2c).

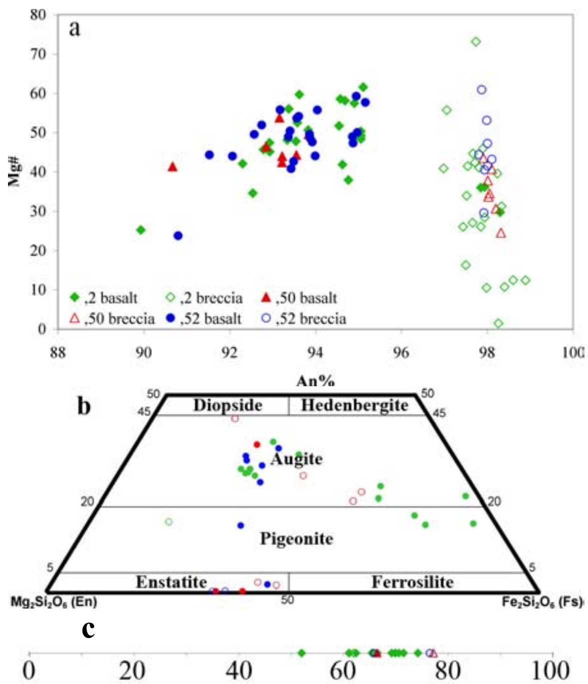

Fig 2. Major element data for mineral phases; color legend is shown in 2a. (a) An%-Mg# for plagioclases; (b) pyroxene quadrilateral plot; (c) olivine Fo content.

Whole-Rock Analyses: Preliminary results indicate that basalts from 60639 are similar in major-element composition to Apollo 11 basalts (Fig. 3), which is consistent with the findings of [3]; the combination of chemical composition and textural data is largely distinct from other previously analyzed Apollo 16 basalts [6] indicating that basalts from the Apollo 16 site likely represent ejecta from several localities. Although major element data is similar to Apollo 11 high-Ti basalts, 60639 does not fall easily within any of the defined high-Ti basalt groups (Fig. 4) described by [7], but appears to bridge the gap between group A and the group B basalts.

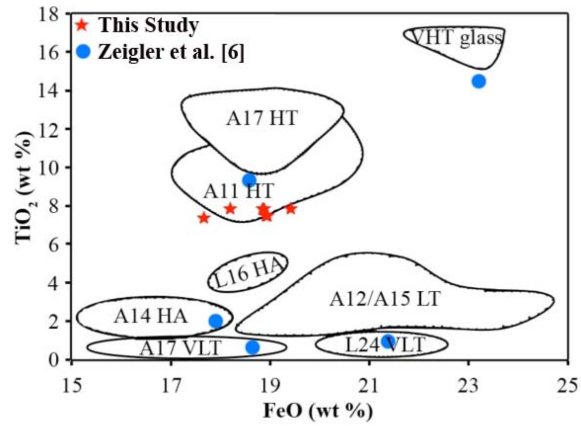

Fig 3. WR major element data for mare basalts suggests that the 60639 basalt clasts are similar to Apollo 11 high-Ti basalts; figure modified from [6].

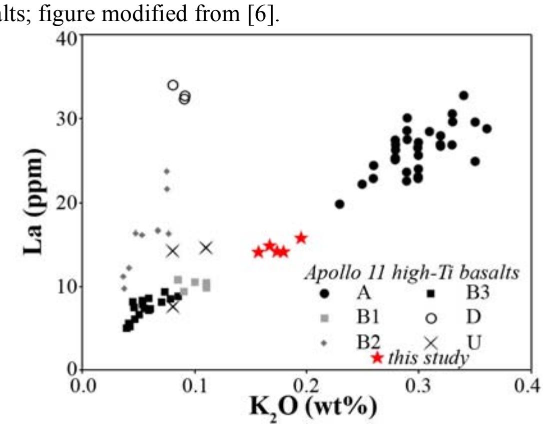

Fig 4. Whole rock data of 60639 basalt clasts from this study in comparison with Apollo 11 high-Ti basalt groups suggesting that is the 60639 basalts are distinct from the Apollo 11 basalts; figure modified from [7].

Preliminary Conclusions: Mineral compositions for the different thin- sections are similar to each other, with the exception of pyroxene where 60639,2 does not appear to contain any enstatite. This suggests that the three basalt clasts were likely ejected from the same locality. Whole rock data indicate that although there are similarities with Apollo 11 high-Ti basalts, the 60639 basalt clasts represent a new type of high-Ti basalt.

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References: [1] Ryder G and Norman M (1980), *NASA Cur. Branch Pub. 52*, JSC 16904. [2] Dowty E et al., (1974), *PLPSC., 5th,* 431-445. [3] Murali AV et al. (1976), *LPSC, 7th*, 583-584. [4] Delano JW (1975), *PLPSC 6th*, 15-47. [5] Neal CR (2001) *JGR, 106*, 27865-27885. [6] Zeigler R et al. (2006), *MAPS, 41*, 263-284. [7] Jerde EA et al. (1994), *GCA, 58*, 515-527.