TYPE, CHEMISTRY, ^{40}Ar-^{39}Ar AND COSMIC RAY EXPOSURE AGE OF NEW APOLLO 17 BASALTIC REGOLITH FRAGMENTS

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Introduction: Serenitatis basin presents 29 spectrally different compositions on its surface [1], but the chemical diversity of the lava flows below is not known. Thus, a complete understanding of mantle evolution beneath this basin cannot yet be constrained. Apollo 17 basalts are divided into high- and very-low-Ti compositions with the high-Ti representing the majority. The range in ages obtained for volcanic samples is 3.75-3.65 Ga [2] and from crater counts of the whole basin ~3.9 and 3.6 Ga [1]. Acquiring chemical composition, mineralogic and chronologic data from different lava types is needed. Here we present textural, chemical composition and isotopic ages of 7 Apollo 17 2-4 mm regolith fragments. These were collected from impact ejecta of Shorty, Steno and Camelot craters. In principle, the ejecta from these small craters come from depths greater than any of the drill-cores collected by the Apollo 17. Hence, these fragments potentially sampled material from underlying lava flows and intercalated regolith. Conversely, this regolith is likely to include local and regional material (from other flows within Mare Serenitatis). The analytical results on our samples are compared with remote sensing data and literature data to later be used in models to evaluate mantle source(s) under the Serenitatis Basin.

Analytical Tehcniques: A JEOL JXA 8500A with field emission ***EMP*** was used to obtain BSE images and major mineral major element compositions (11 mm working distance, 15 keV power and 15 nA current). Bulk composition was estimated using spectral image data obtained with a JEOL JSM-6390 ***SEM*** (LaB_6 filament to obtain spectral images; 20 keV, beam current = 10-15 nA). The spectral data were analysed using the open toolbox "iSpectra" [3] to obtain accurate mineral maps. The bulk composition was then calculated using the mineral mass fraction (phase volume x density) and chemical compositions. Trace element compositions for each mineral phase were obtained using a Thermo Element XR ***LA-ICP-MS*** [4]. These were also used to estimate the bulk composition of the samples. All data are then compared with literature data [5]. A Thermo Scientific Argus VI mass spectrometer was used for ***Ar-Ar*** age determination via the IR-laser step-heating technique. The CRE-age derived using ^{38}Ar production rate calculated based on the bulk chemistry of each basaltic fragment.

Type and chemical composition (Table 1&2):

⇒ *74244,12 (Fig.1a)*: pyroxene-porphyritic high-Ti basalt, pyroxene ($En_{31-46}Wo_{27-46}Fs_{16-42}$), plagioclase ($An_{81-85}$) and ilmenite with armalcolite cores.

⇒ *75063,13 (Fig. 1b)*: olivine-porphyritic high-Ti basalt, sub-variolitic texture, contains olivine (Fo_{69-73}), plagioclase (An_{85-88}), and ilmenite of various sizes.

⇒ *71063,7 (Fig. 1c)*: high-Ti dolerite (phases >1mm); olivine (Fo_{56-71}), pyroxene (En_{36-69} $Wo_{6-26}Fs_{25-41}$), plagioclase (An_{93-96}) and ilmenite.

⇒ *75063,5 (Fig. 1d)*: high-Ti olivine dolerite with 2 size domains. The coarser domain is 0.5-1 mm. It is composed of plagioclase (An_{89-92}), olivine (Fo_{33-52}), pyroxene ($En_{32-45}Wo_{9-35}Fs_{33-53}$), and ilmenite.

⇒ *71064,12 (Fig. 1e)*: vitrophyric high-Ti basaltic melt with 50-200 µm olivine crystals (Fo $_{72-76}$) and ~10 µm chromite. Potentially an impact melt of predominantly mare material.

⇒ *74243,41 (Fig. 1f)*: vitrophyric high-Ti basalt with olivine (Fo_{64-73}) and armalcolite phenocrysts. Potentially an impact melt composed of mare material.

⇒ *71063,6 (Fig. 1g)*: very low-Ti (VLT) basaltic melt composed mostly of matrix with olivine xeno/phenocryts (Fo_{65-70}), and a matrix of zoned pyroxene ($En_{41-64}Wo_{8-39}Fs_{17-32}$), plagioclase ($An_{85-87}$) and minor chromite. Based on its texture and phenocrysts, it is probable that this fragment is an impact melt likely composed of mare material.

The bulk REE profiles for all samples (Fig. 2) show the same trend as literature data corresponding to a depletion in the LREE and a relative enrichment in the HREE. Fragments 71064,12 and 74243,41 show a negative Eu-anomaly and have a pattern similar to type A, and U (gabbroic) Apollo 17 basalts [5]. Fragment 71063,6 shows a stronger negative Eu-anomaly and the REE pattern resembles that from Apollo 17 type D to VLT basalts [6]. Fragment 71063,7 shows a steeper LREE depletion and a very slight negative EU-anomaly. Fragments 74244,12, 75065,5 and 75063,13 have the same REE pattern and a slight positive Eu-anomaly.

^{40}Ar-^{39}Ar and CRE age: Argon extraction was done by the IR-laser step heating technique, and the number of heating steps for bulk sample varied from 20 to 32. All data were corrected for blank, discrimination, decay of the short-lived nucleaogenic nuclides (^{37}Ar and ^{39}Ar). Ages reported (Table 1) were obtained from Ar-release spectra, inverse or normal isochron. When necessary further cosmogenic and/or trapped Ar corrections were also considered. ^{40}Ar-^{39}Ar age and CRE-ages are reported in Table 1; apart from fragment 71063,6 with an age of ~2.86 Ga, all others fall within the age range previously determined for Apollo 17 basalts, 3.96-3.68 Ga.

Table 1: *TiO_2 content, texture, type and Ar-data summary.*

Sample	TiO_2	Type	Texture	Ar-Ar age (Ga)	error (Ga)	CRE-age (Ma)	error (Ma)
71063,6	0.5	impact melt?	ophitic	~2.860	-	310.2	0.6
71063,7	11.4	1B	cumulate	3.699	0.038	112.2	0.3
71064,12	10.9	impact melt?	quench/ spinifex	3.960	0.01	138.3	0.3
74243,41	10.0	impact melt?	quench melt with armalcolite & ülvospinel phenocryts	3.702	0.008	227.1	0.4
74244,12	12.6	C	Pyroxene, ilm porphirytic	3.568	0.014	441.7	0.2
75063,5	14.2	1B	coarse plagioclase poikilitic	3.679	0.038	237.1	0.4
75063,13	15.8	1A	olv, ilm porphiritic subvariolitic	3.555	0.024	155.3	0.2

Table 2: *Bulk composition best estimation for the 2-4 mm Apollo 17 basaltic fragments*

	71063,6 (wt%)	71063,7 (wt%)	71064,12 (wt%)	74243,41 (wt%)	74244,12 (wt%)	75063,5 (wt%)	75063,13 (wt%)
SiO2	47.9	39.1	40.0	39.4	40.6	36.5	33.0
TiO2	0.5	11.4	10.9	12.8	12.6	14.2	15.8
Al2O3	11.4	7.6	9.8	8.6	10.5	11.2	11.3
Cr2O3	0.8	0.4	0.4	0.4	0.4	0.4	0.3
FeO	15.8	19.7	19.0	18.7	15.7	17.8	27.9
MnO	0.3	0.3	0.3	0.3	0.2	0.2	0.4
MgO	12.4	11.7	8.2	8.7	8.3	9.9	3.4
CaO	10.9	9.7	11.0	10.7	11.1	9.1	8.4
Na2O	0.2	0.3	0.4	0.5	0.5	0.5	0.4
K2O	0.01	0.02	0.05	0.07	0.03	0.02	0.01

Preliminary comparison of sample bulk composition with remote sensing data: The mare units considered are the larger flows of [7] due to the large pixel size of the K-map (CE-2 & LP) and the location of the smaller flows being in the mixed region near the rim of Serenitatis Basin. FeO and TiO_2 values were determined from Clementine data. Initial connparison of bulk sample composition and orbital data show higher K content for the latter. Further assessment will be performed.

Summary: The Apollo 17 basaltic regolith fragments show an overal range of chemical compositions similar to those reported earlier. Fragments 74244,12, 75065,5 and 75063,13 showing a slight positive Eu-anomaly suggest a potential change in the source region that will be further investigated. The ^{40}Ar-^{39}Ar age range of 3.96-3.68 Ga also suggests a longer period of volcanism than previously observed.

References: [1] Hiesinger et al. (2011) Geol.Soc. of America Sp. Pap. 477, 1-51. [2] Paces J.B. et al. (1991) GCA 55, 2025-2053. [3] Liebske (2015) Microsc. Microanal. 21, 1006–1016. [4] Sliwinski et al. (2015) J. Petrol. 56, 2173–2194. [5] Mare Basalt Database http://www3.nd.edu/~cneal/Lunar-L/. [6] Ryder G. (1990) MaPS 25, 249-258. [7] Hiesinger et al (2000) JGR 105, 29239-29275.

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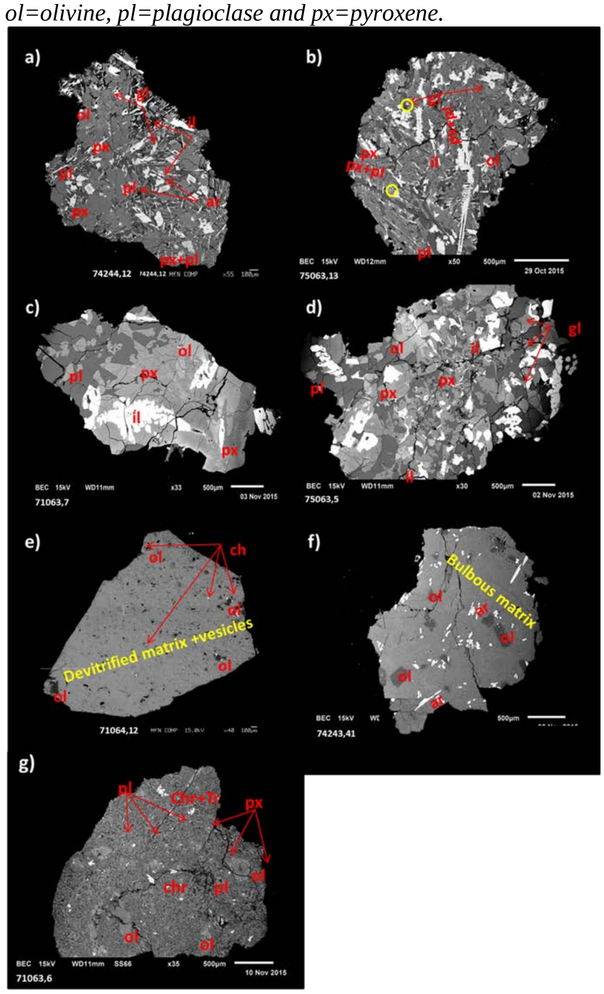
Figure 1 *BSE images of 71063,6, 71064,12, 75063, 5, and 75063,13. These are characterized by different textures /cooling regimes. ch=chromite, gm=groundmass il=ilmenite, ol=olivine, pl=plagioclase and px=pyroxene.*



Figures 2: *REE pattern for the seven Apollo 17 regolith basaltic fragments.*