SPINEL-BEARING IGNEOUS LITHIC FRAGMENTS FROM APOLLO 17 DOUBLE DRIVE TUBE 73001/73002.
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Introduction: As part of the Apollo Next Generation Sample Analysis (ANGSA) program, samples from previously unopened Apollo 17 double drive tube 73001/73002 are becoming available for study. The upper section, 73002, extends from the surface to a depth of ~18 cm. The lower section, 73001, is 33 cm long. They were sampled in 0.5-cm intervals in the Curatorial Facility at the Johnson Space Center; the >1 mm fragments were hand-picked and individually numbered, and the <1 mm fraction was sieved into multiple size fractions.

The double drive tube was collected at Station 3, within the "light mantle" deposit at the base of South Massif. Orbital data suggest that this deposit represents multiple landslide events that were triggered by movement along the Lee-Lincoln scarp [e.g., 1] or impact events [e.g., 2]. It contains a wide variety of lithologies, including mare basalts from the valley floor [3], Si-, K-rich felsites [4], and highland lithologies, presumably from the South Massif. Among the latter, anorthosites, troctolitic anorthosites, and noritic anorthosites are the most abundant igneous lithologies, followed by norites, gabbroic anorthosites, and anorthositic norites [5]. Rare types include olivine norite, anorthositic troctolite, and troctolite [5]. Thus, a very wide range of modal plagioclase:mafic silicate ratios is observed. Here, we focus on spinel-bearing magmatic lithic fragments found in the 250–150 µm fraction, including a suite of anorthosites with similar features that may represent an important rock type. Particles are classified based on the modal mineralogies and textures observed in the exposed planes of the thin sections and the classification scheme of [6].

Methods: Bulk <1 mm soils were received at the University of New Mexico (UNM) and sieved into six size fractions, then mounted in epoxy and polished. Particles were identified and classified through backscattered electron imaging and energy-dispersive analysis (both qualitative and quantitative) with a TESCAN Lyra3 scanning electron microscope at UNM equipped with an IXRF silicon drift energy-dispersive X-ray detector running Iridium Ultra software.

Results: The sample suite consists of four anorthosites, one troctolitic anorthosite, and a dunite.

Anorthosites. These samples are strongly dominated by calcic plagioclase, with sparse, isolated grains of mafic silicates and spinel. 73002,176 G50 (Fig. 1a) has discrete forsteritic olivine, Fo_{85}, ~20 µm across and finer, blebby forsteritic olivine, also Fo_{87}, interstitial to plagioclase and outlining some grains. Isolated spinel grains are 20–25 µm across except for one smaller grain (10 µm). The latter is poorer in Al_2O_3 and richer in TiO_2, Cr_2O_3, and FeO than the other grains (Table 1). Sample 73002,374 G38 (Fig. 1b) has sparse grains of very forsteritic olivine (Fo_{87}), Cr-rich (20 wt% Cr_2O_3, 13 wt% FeO) and Cr-poor (8.1 wt% Cr_2O_3, 11 wt% FeO) spinel, all ~15 µm across, and trace phosphate and ilmenite enclosed in plagioclase (An_{91}). Sample 73002,399 G53 (Fig 1c) also has sparse, isolated grains of forsteritic olivine (Fo_{88}) and spinel (10 wt% Cr_2O_3, 11 wt% FeO) enclosed in plagioclase (An_{88}). It also has merrillite (Mg-bearing phosphate) and Zr-armalcolite. Sample 73002,182 G119 (Fig. 1d) differs from the others in having pyroxene ($En_{54}Wo_{40}Fs_6$) and no olivine, and slightly more calcic plagioclase, An_{94}. The spinel grain size, ~20µm, and composition (12.6 wt% Cr_2O_3, 11 wt% FeO) are similar to those of the other anorthosites.

Troctolitic anorthosite. Sample 73002,374 G114 Fig. 1e) has Mg-Al spinel enclosed in olivine (Fo_{79}) and plagioclase (An_{93}). The spinel grains have Cr-poor cores (2 wt% Cr_2O_3, 15 wt% FeO) and thin, relatively Cr-rich (9 wt% Cr_2O_3, 16 wt% FeO) rims.

Dunite. Sample 73002,176 G26 (Fig. 1f) has very primitive mineral compositions, with isolated grains of very calcic plagioclase (An_{97}), near-endmember enstatite ($En_{92.1}Wo_{0.6}Fs_{7.3}$) and Mg-, Al-rich spinel (Table 1) enclosed in very forsteritic olivine (Fo_{94}). Unlike the few previously reported lunar dunites, it is neither cataclastic like 74215 nor chromite-bearing, like the dunite clast in lunar impact melt breccia NWA 11421 [7], and its olivine is more magnesian than either of those samples.

A plot of Mg# of mafic silicates against anorthite content of plagioclase in these samples (Fig. 2) shows that they all have Mg-suite affinities. The mafics are more magnesian than those in the ferroan anorthosite (FAN) suite and both the mafics and plagioclase are much less fractionated than the phases in the alkali suite. This is not surprising, as FANs and alkali suite rocks are rare at the Apollo 17 site. Unlike some other A-17 Mg-suite rocks and the NWA 11421 dunite [7], the present samples do not contain symplectic intergrowths.

Table 1. Representative energy-dispersive analyses of spinel in 73002,176 G50 and G26.

	G50 SP1	G50 SP2	G50 SP3	G50 SP4	G50 SP5	G26 SP1	G26 SP2
MgO	15.6	17.2	17.9	16.9	11.7	23.3	23.4
Al_2O_3	44.5	49.6	52.8	49.6	29.9	61.5	61.4
TiO_2	0.39	0.34	0.25	0.30	0.58	0.09	0.11
Cr_2O_3	22.9	17.5	14.5	18.1	37.0	7.34	7.22
FeO	16.1	14.8	14.1	14.8	20.3	7.18	7.42

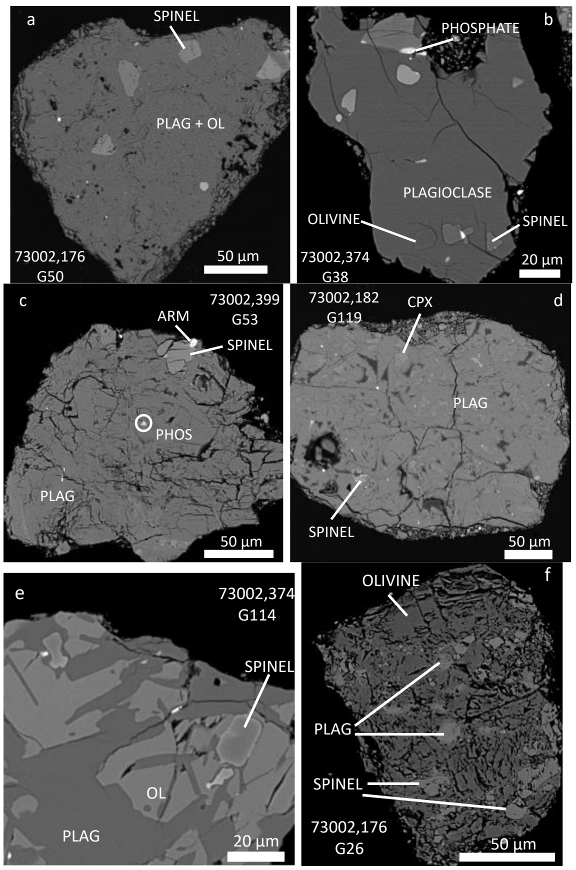

Fig. 1. Backscattered electron images of spinel-bearing lithic fragments. a) anorthosite from ,176. b) anorthosite from ,374. c) anorthosite from ,399. d) anorthosite from ,182. e) troctolitic anorthosite from ,374. f) dunite from ,176. ARM: armalcolite; PHOS: phosphate; CPX: clinopyroxene; PLAG: plagioclase; OL: olivine.

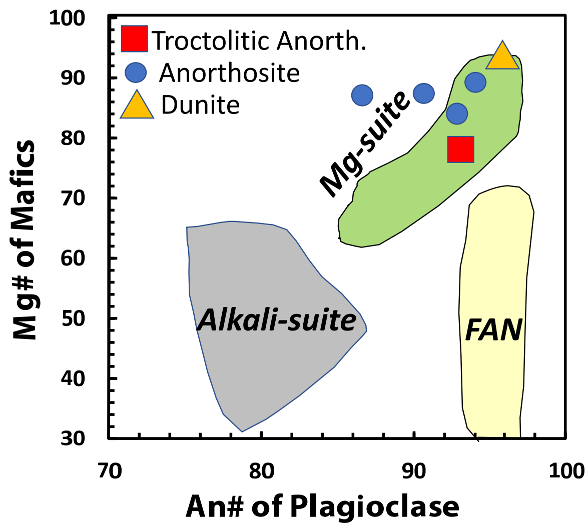

Fig. 2. Plot of Mg# (Mg/(Mg+Fe)) of mafic silicates vs. anorthite content of plagioclase in spinel-bearing igneous lithic fragments.

Discussion: This double drive tube has great potential for improving our understanding of the lithologies of the upper South Massif. It contains samples of lithologies, such as felsites and dunites, that are very rare among Apollo 17 samples and even the entire Apollo collection. The anorthosites discussed here have generally similar textures (Fig. 1a-d) and mineral compositions - calcic plagioclase, magnesian olivine, and three of the four have spinel with ~8-12 wt% Cr_2O_3 and FeO - suggesting they may be related.

Spinel has traditionally been considered an indicator of a deep, high-pressure formation environment, but its occurrence in relatively fine-grained rocks, in which pyroxene does not exhibit exsolution lamellae, such as those reported here and by [8,9], suggests that low-pressure origins are possible. A deep crustal origin cannot be ruled out, especially for the dunite, but shallow crustal origins and even impact origins must be considered as well.

References: [1] Schmitt H. (2017) *Icarus 298*, 2-33. [2] Lucchitta B. et al. (1977) *Icarus 30*, 80-96. [3] Simon S. B. et al. (2022) SSERVI NESF. [4] Shearer C. K. et al. (2022) SSERVI NESF. [5] Simon S. B. et al. (2022) Apollo 17-ANGSA Workshop, Abstract #2009. [6] Stöffler D. et al. (1980) *Proc. Conf. Lunar Highlands Crust*, 51-70. [7] Treiman A. H. and Semprich J. (2019) 50th LPSC, Abstract #1225. [8] Gross J. and Treiman A. H. (2011). *JGR 116*, E10009, doi:10.1029/2011JE003858. [9] Simon S. B. et al. (2022) *JGR 127*, doi:10.1029/2022JE007249.