A PETROLOGICAL AND GEOCHEMICAL ANALYSIS OF LUNAR BASALTIC FINES 12070,891 AND 12030,187.
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Introduction: The Apollo 12 mission landed in the Eastern region of Oceanus Procellarum. Crater size-frequency distribution measurements by [1] indicate that some of the youngest lava flows occur within the Oceanus Procellarum region and it is, therefore, possible that some younger, exotic fragments have been sampled by the Apollo 12 mission. Most basalts from the Apollo 12 site can be grouped into three main basaltic suites: olivine, ilmenite and pigeonite, based on their mineralogy and bulk composition [2,3,4]. However, care needs to be taken as many small samples are not representative of their parent rocks [4].

As part of a larger study of the diversity of basalts at the Apollo 12 site, we present new petrological and geochemical results for two basaltic fragments: 12070,891, a basaltic fine (2.2 x 2.0 mm) from the mature contingency soil sample (I_s/FeO = 47), and 12030,187, a basaltic fine (2.4 x 2.3 mm) from an immature soil sample (I_s/FeO = 14) collected close to the ALSEP site. In addition to the bulk chemical properties of these samples we use major, minor and trace element mineral chemistry to compare these samples with other basalts at the Apollo 12 site.

Methods: Samples were analysed with a JEOL JXA-8100 electron microprobe with an Oxford Instrument INCA energy dispersive system (EDS) to produce back scattered electron (BSE) images. Bulk chemical compositions were calculated from multiple EDS raster beam analyses (RBA) and corrected for differences in phase densities in accordance with [5]. This method has been previously tested on known compositions and found to be in good agreement [6].

Element maps were obtained with a Cameca SX100 electron microprobe at the Natural History Museum, London. Trace element analyses of mineral phases were obtained using laser ablation inductively coupled plasma mass spectrometry (LA-ICP-MS).

Results: Both samples are highly porphyritic with large phenocrysts of olivine and pyroxene set in a fine-grained vitrophyric groundmass containing ilmenite, plagioclase and minor silica (Fig. 1). Spinel is present in both samples, often wholly or partially enclosed by olivine, indicating early crystallisation. Sample 12070,891 contains normal zoned pyroxene with a soda-straw texture, indicating rapid cooling (Fig. 1).

Bulk Chemistry. Both samples are low-Ti basalts (bulk rock 1-6 wt% TiO_2), typical of basalts at the Apollo 12 site [7]. The bulk chemistry of the samples indicates that 12070,891 (Mg# 42) is typical of pigeonite basalts (Mg# <46 [4]), whilst 12030,187 (Mg# 49) is typical of olivine basalts (Mg#>46 [4]).

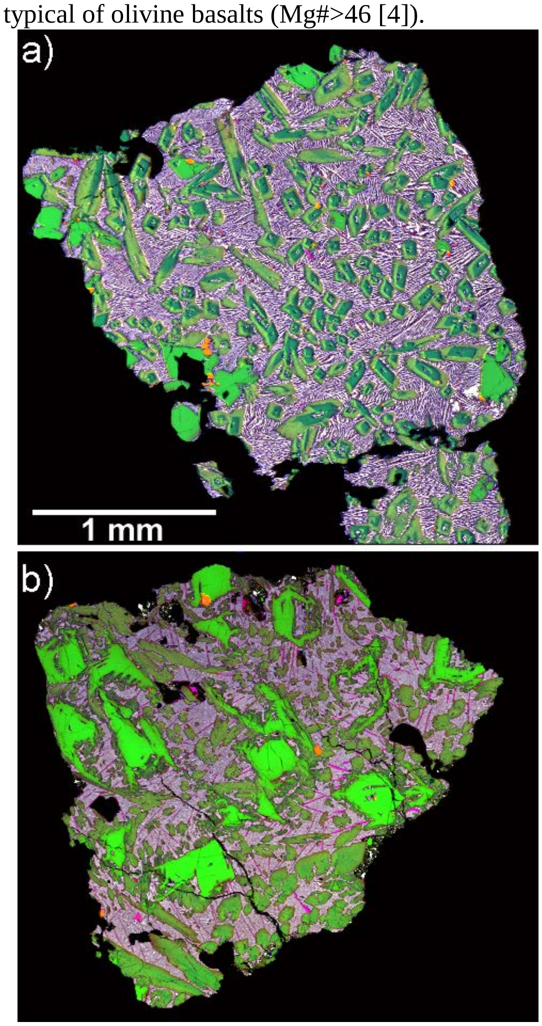

Figure 1. False colour element maps of a) Sample 12070,891, showing strong zoning and soda-straw texture of pyroxene phenocrysts, and b) Sample 12030,187 showing abundant skeletal and eroded olivine and pyroxene phenocrysts. Colours represent concentrations of different elements: Si = blue, Fe = red, Mg = green, Ca = yellow, Al = white, Ti = pink and Cr= orange.

Chemistry of mineral phases. Pyroxene compositions are varied for both 12070,891 (Wo_{6-39} En_{9-68} Fs_{22-74}) and 12030,187 (Wo_{10-46} En_{4-50} Fs_{20-70}), but there is no extreme rim Fe-enrichment (Fig. 2). Pyroxene in 12030,187 exhibits high Wo contents in the rims of some larger crystals and in the groundmass pyroxene. Both samples have pyroxene that exhibit relatively shallow negative Eu-anomalies ($Eu_{cn}/\sqrt{[Sm_{cn} \times Gd_{cn}]}$ = 0.18 to 0.76 for 12070,891 and 0.2 to 0.6 for 12030,187. Olivine Fo range from 55 to 72 in 12030,187 and 42 to 70 in 12070,891, within a typical range for mare basalts. Both samples show a wide range of Ni in olivine (2129 to 2648 ppm for 12070,891 and 1936-2958 for 12030,187), typical of olivine and pigeonite basalts and Ti/V ratios also vary from core to rim (3 to 23 in 12070,891; 2 to 43 in 12030,187). Plagioclase An contents are relatively low in 12070,891 compared with other Apollo 12 samples, ranging between 82 and 90. In addition, there is no correlation between Mg# and An# in plagioclase in this sample. REE abundances show positive Eu-anomalies. Plagioclase is too fine-grained in 12030,187 for accurate chemical analysis. Spinel in both samples range from chromite to ulvöspinel following a typical mare basalt fractionation trend.

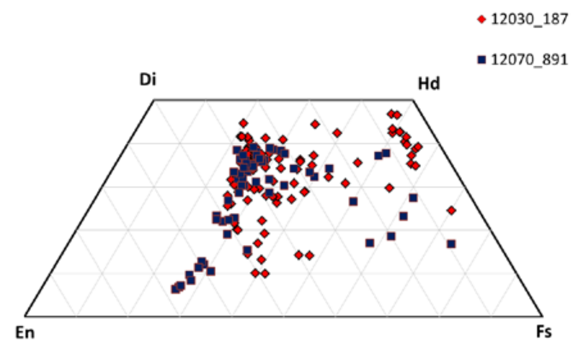

Figure 2. Pyroxene compositions in 12030,187 and 12070,891.

Source lava flows: Various methods have been used to distinguish between different Apollo 12 basalt groups. It has been suggested [8] that olivine trace element compositions discriminate between the groups. In particular, Ti/V ratios can apparently distinguish between ilmenite basalts and the other basalt groups. The samples in this study have a wide range of olivine Ti/V ratios, but the most primitive core measurements have Ti/V ratios of 3 for 12070,891 and 2 for 12030,187, and Sc contents of up to 14 ppm (Fig. 3). This indicates that they are not ilmenite basalts, but are either olivine or pigeonite basalts, confirming inferences made from the bulk chemistry of these samples.

Apollo 12 samples are normally classified according to their bulk chemical properties, but it can be difficult to do this due to the problems of representativeness of small samples. For these vitrophyric samples we can reconstruct the equilibrium parent melt Mg# using the composition of the most primitive olivine [9,10,11] and appropriate mineral-melt Kd values [12]. This gives a modelled bulk rock Mg# of 44 (using olivine Mg# 70) for 12070,891 and 46 (using olivine Mg# 72) for 12030,187. Thus, we model the bulk rock Mg# and olivine Mg# with reasonable accuracy, which suggests that olivine was in equilibrium with the melt as represented by the bulk rock composition. Therefore, measured bulk compositions of the samples are likely to be representative of the parent melts despite the small sample sizes. From a combination of the bulk chemical properties and mineral chemistries of these grains, sample 12070,891 is most similar to pigeonite basalts from the Apollo 12 site, while sample 12030,187 likely represents an olivine basalt.

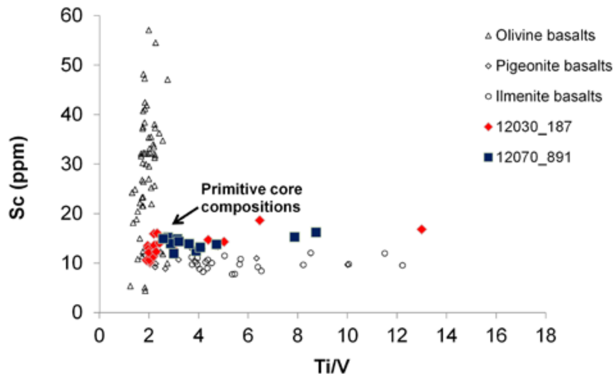

Figure 3. Olivine compositions. Sc (ppm) vs. Ti/V in olivine phenocrysts. Comparative data from [7].

Future work: Further work, including Ar-Ar dating of the samples will further help to constrain the origin of these samples and others analysed as part of our wider study.

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