

**BASALTIC REGOLITH SAMPLE 12003,314: A NEW MEMBER OF THE APOLLO 12 FELDSPATHIC BASALT SUITE?** J. F. Snape<sup>1,2,3</sup>, L. Alexander<sup>2,4</sup>, I. A. Crawford<sup>2,4</sup>, and K. H. Joy<sup>2,5</sup>, <sup>1</sup>Planetary and Space Sciences, The Open University, Milton Keynes, MK7 6AA, U.K. ([joshua.snape@open.ac.uk](mailto:joshua.snape@open.ac.uk)), <sup>2</sup>Centre for Planetary Sciences at UCL-Birkbeck, London, <sup>3</sup>Department of Earth Sciences, University College London, <sup>4</sup>Department of Earth and Planetary Science, Birkbeck College, University of London, <sup>5</sup>SEAES, University of Manchester.

**Introduction:** Three main basaltic suites (olivine, pigeonite and ilmenite) are recognized as having been sampled at the Apollo 12 landing site [1,2,3]. In addition to these, a fourth suite (feldspathic basalts) has been proposed. Four samples have previously been identified as feldspathic basalts [1,2,4], however, subsequent analyses have demonstrated that only one of these (12038) is truly distinct from the other Apollo 12 basalts [3,5]. As such, it has been suggested that the feldspathic basalt(s) may represent material introduced to the site as impact ejecta rather than a local basaltic flow [3].

In this study we present results of a petrologic analysis of a basaltic chip (12003,314) collected as part of a regolith sample near the lunar module. A sample of 12038 was also analysed for comparison. This work forms part of a larger integrated petrologic and radioisotope dating study of basaltic diversity at the Apollo 12 site [6,7].

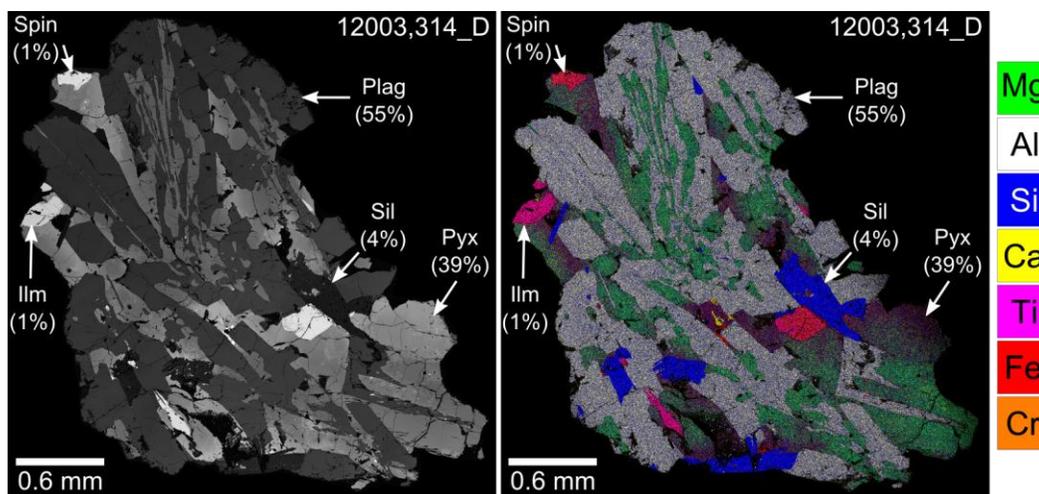
**Analytical Techniques:** The samples (12003,314\_D and 12038,263\_A) were analysed with a JEOL JXA-8100 electron microprobe. Back scattered electron (BSE) images, elemental maps and bulk sample composition were obtained with an accompanying Oxford Instruments EDS probe and INCA software package. A more detailed description of these techniques is given in [8]. Major and minor element mineral chemistries were measured with an integrated WDS system. Minor and trace element mineral chemistries were determined by laser ablation ICP-MS with a simi-

lar analytical procedure and instrument setup as described by [9].

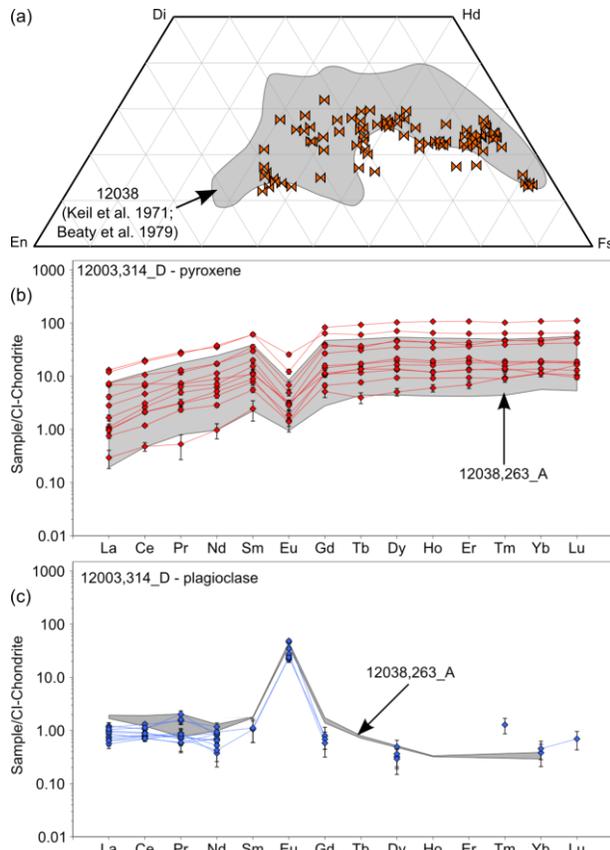
**Results:** 12003,314\_D is a coarse-grained (0.2-1.1 mm) subophitic sample composed mostly of plagioclase (55% by mode) and pyroxene (39%) which form graphic intergrowths (Fig. 1).

**Major phases.** The plagioclase in ,314\_D forms large (~0.1-1.3 mm) elongated crystals ( $An_{87-93}$ ). These have REE abundances between 0.3-49  $\times$ CI values and nearly flat chondrite normalised (cn) [10] rare earth element (REE) patterns with positive Eu-anomalies ( $La_{cn}/Lu_{cn} = 2$ ;  $Eu_{cn}/\sqrt{[Sm_{cn} \times Gd_{cn}]} = 26$ ; Fig. 2c). Pyroxene in ,314\_D exhibits prominent zoning from more magnesian to more Fe-rich compositions ( $Wo_{12-32} En_{4-53} Fs_{30-83}$ ; Fig. 2a). The pyroxene grains have REE abundances between 0.3-111  $\times$ CI values and positive chondrite normalised REE patterns and negative Eu-anomalies ( $La_{cn}/Lu_{cn} = 0.03-0.53$ ;  $Eu_{cn}/\sqrt{[Sm_{cn} \times Gd_{cn}]} = 0.1-0.4$ ; Fig. 2b). The REE abundances of the ,314\_D pyroxenes increase significantly in the more Fe-rich areas (Fig. 2b).

**Minor phases.** The minor phases in ,314\_D include silica, spinel and ilmenite (Fig. 1). Large (0.1-0.6 mm) crystals of a silica polymorph are common throughout the sample (4% by modal abundance). Spinel is the next most abundant phase in ,314\_D (1%) and forms subhedral ulvöspinel crystals (~0.1-0.3 mm;  $2Ti_{89-92} Al_{4-5} Cr_{4-7}$ ; Fig. 1). The largest of these contains small (~10-30  $\mu$ m) exsolved grains of ilmenite. Ilmenite is also present (1% by modal abundance) as separate



**Figure 1:** BSE and false colour element map of 12003,314\_D. Examples of major and minor phases have been indicated along with their modal abundances.

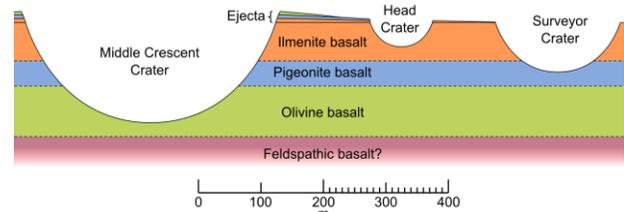


**Figure 2:** (a) Pyroxene compositions within 12003,314\_D compared with those of 12038 [4,10]. Chondrite normalized [10] REE patterns for (b) pyroxene and (c) plagioclase within 12003,314\_D. REE values are compared with those obtained from a sample of 12038.

subhedral crystals (~0.03-0.30 mm; Fig. 1).

**Discussion:** Although the plagioclase content and bulk  $\text{Al}_2\text{O}_3$  ( $16.7 \pm 0.1$  wt%) of ,314\_D is higher than any other Apollo 12 basalt, the coarse grain size of the sample means that the modal mineralogy and bulk composition may not be truly representative of the parent basalt. The major and minor element concentrations in the ,314\_D pyroxene are within the range of those reported for 12038 [11,4] and the pigeonite basalts 12021, 12031 and 12039 [11,12,4,13]. REE abundances of pyroxene and plagioclase in ,314\_D are also in good agreement with those measured in 12038,263\_A (Fig. 2b-c). Both [11] and [14] report the presence of ulvöspinel in 12038. As in ,314\_D, this is described as containing exsolved ilmenite [13]. The Fe# and Cr# of the 12038 and ,314\_D ulvöspinel are very similar, however, those in ,314\_D have higher Ti# [11,14].

Identification of further feldspathic basalts, in addition to 12038, would strengthen the case for a feldspathic basalt suite local to the Apollo 12 site. Previous studies of have provided a range of crystallisation



**Figure 3:** Simplified cross-section of Apollo 12 site, indicating stratigraphic sequence as inferred by [2] and the estimated excavation depths of the three largest craters at the landing site. Scale is approximate with a  $\sim 2\times$  vertical exaggeration applied.

ages for samples from each suite [e.g. 15,16,5]. Weighted-average ages calculated by [17] indicate that 12038 may be older (3.28 Ga) than the other Apollo 12 basalts (3.18-3.20 Ga). If this is the case, and the feldspathic basalt flow underlies those of the other three suites (Fig. 3), then the scarcity of feldspathic basalt samples could be due to a lack of craters large enough to excavate this material.

The classification of 12003,314 as a feldspathic basalt could be strengthened by determining its crystallisation age. Indeed, part of the ongoing work in this project involves  $^{40}\text{Ar}$ - $^{39}\text{Ar}$  radioisotope dating of a sub-split (12003,314\_B) of the sample. However, given the range and uncertainty of previous crystallisation ages obtained for Apollo 12 basalts, this is unlikely to provide a completely unambiguous answer. A more definitive test would be the acquisition Sr, Nd and Sm isotopic compositions for the sample such as those which were used to differentiate 12038 from other Apollo 12 basalts [5].

**Acknowledgments:** We thank Drs. Andrew Beard and Andrew Carter for their assistance with electron microprobe and laser ablation ICP-MS analyses.

**References:** [1] James O. B. and Wright T. L. (1972) *Bull. Geol. Soc. Am.*, 83, 2357-2382. [2] Rhodes J. M. et al. (1977) *LPS IX*, 1305-1338. [3] Neal C. R. et al. (1994) *Meteoritics*, 29, 334-348. [4] Beatty D. W. (1979) *LPS X*, 115-139. [5] Nyquist L. E. (1981) *EPSL*, 55, 335-355. [6] Snape J. F. et al. (2011) *LPS XLII*, Abstract #2020. [7] Alexander L. et al. (2011) *MAPS*, 74, Abstract #5084. [8] Snape J. F. et al. (2011) *LPS XLII*, Abstract #2011. [9] Joy K. H. et al. (2011) *GCA*, 75, 2420-2452. [10] Anders E. and Grevesse N. (1989) *GCA*, 53, 197-214. [11] Keil K. et al. (1971) *LPS II*, 319-341. [12] Weill D. et al. (1971) *LPS II*, 413-430. [13] Shearer C. K. et al. (1989) *GCA*, 53, 1041-1054. [14] Simpson P. R. and Bowie S. H. U. (1971) *LPS II*, 207-218. [15] Papanastassiou D. A. and Wasserburg G. J. (1971) *EPSL*, 11, 37-62. [16] Compston W. et al. (1971) *LPS II*, 1471-1485. [17] Snyder G. A. et al. (1997) *GCA*, 61, 2731-2747.