

Basaltic regolith sample 12003,314: a new member of the Apollo 12 feldspathic basalt suite?

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1. Introduction

Three main basaltic suites (olivine, pigeonite and ilmenite) are recognised as having been sampled at the Apollo 12 landing site [1,2,3]. A fourth suite (feldspathic basalts) has been proposed, which is comprised of only one sample (12038) [3,4,5]. 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].

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].

2. Methods

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 [8]. Minor and trace element mineral chemistries were determined by laser ablation ICP-MS using a New Wave 213 nm laser ablation system coupled to an Agilent 750a quadrupole-based ICP-MS [9].

3. 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).

Plagioclase content and bulk Al₂O₃ (16.7±0.1 wt%) of ,314_D is higher than any other Apollo 12 basalt, however, the coarse grainsize of the sample means that the modal mineralogy and bulk composition may not be truly representative of the parent basalt.

Major and minor element concentrations in the ,314_D pyroxene are comparable to those reported for 12038 [4,11] and the pigeonite basalts 12021, 12031 and 12039 [4,11,12,13; Fig. 2]. The early forming pyroxene in 12038,263_A are less Mg- and Ti-rich than those in ,314_D. REE abundances of pyroxene and plagioclase in ,314_D are also in good agreement with those measured in 12038,263_A (Fig. 3).

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].

4. Discussion

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 [e.g. 5,15-28] indicate that 12038 may be older (3.28 Ga) than the other Apollo 12 basalts (3.18-3.20 Ga; Fig. 4). If this is the case, and the feldspathic basalt flow underlies those of the other three suites (Fig. 5), then the scarcity of feldspathic basalt samples could be due to a lack of craters large enough to excavate this material (Fig. 6).

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 ⁴⁰Ar-³⁹Ar 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.

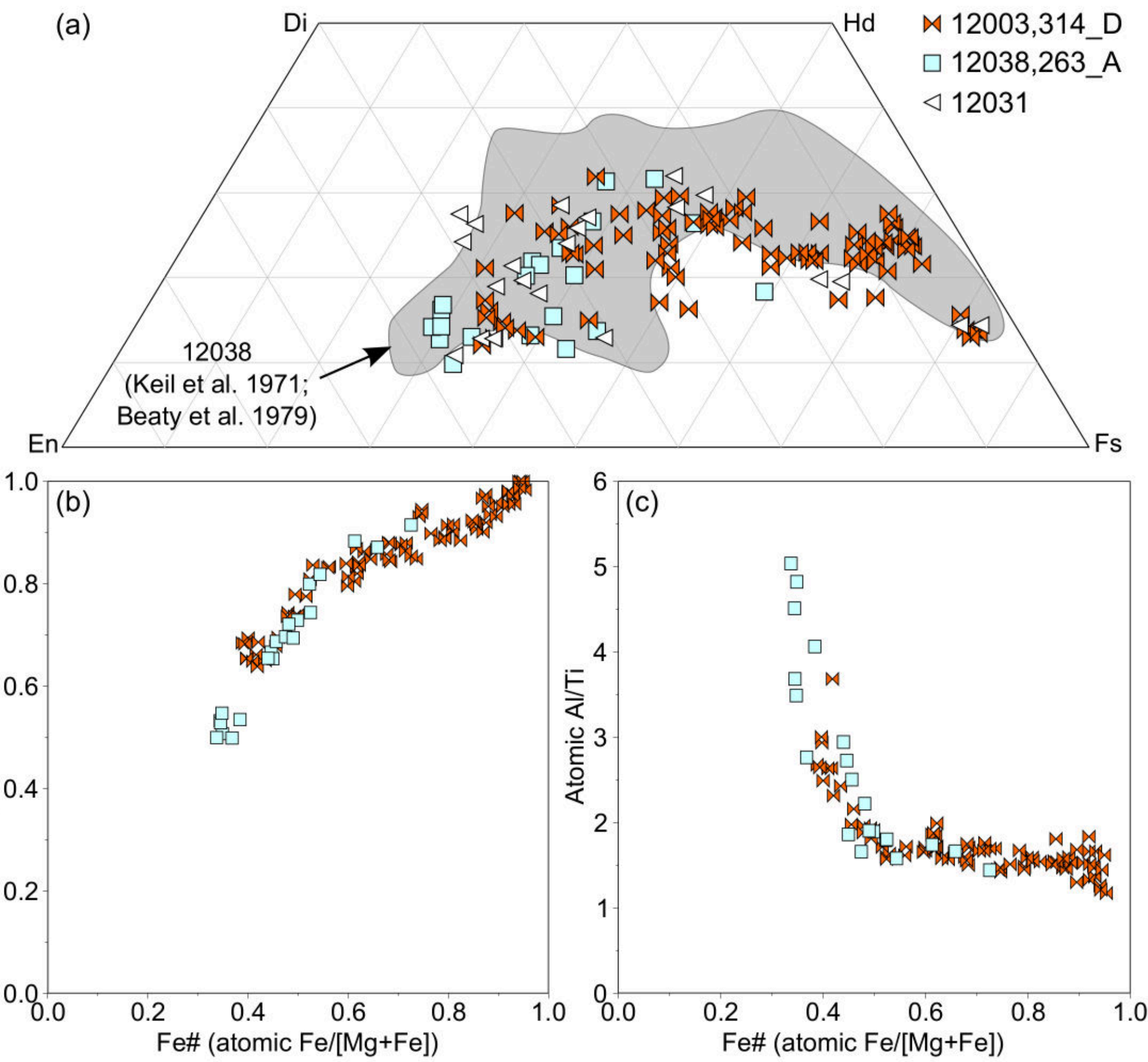


Figure 2: (a) Pyroxene compositions within 12003,314_D compared with those of the feldspathic basalt 12038 [4,10] and the pigeonite basalt 12031 [4]. Fe# (atomic Fe/[Mg +Fe]) plotted against (b) Ti# (atomic Ti/[Cr+Ti]) and (c) atomic Al/Ti for pyroxenes in 12003,314_D and 12038,263_A.

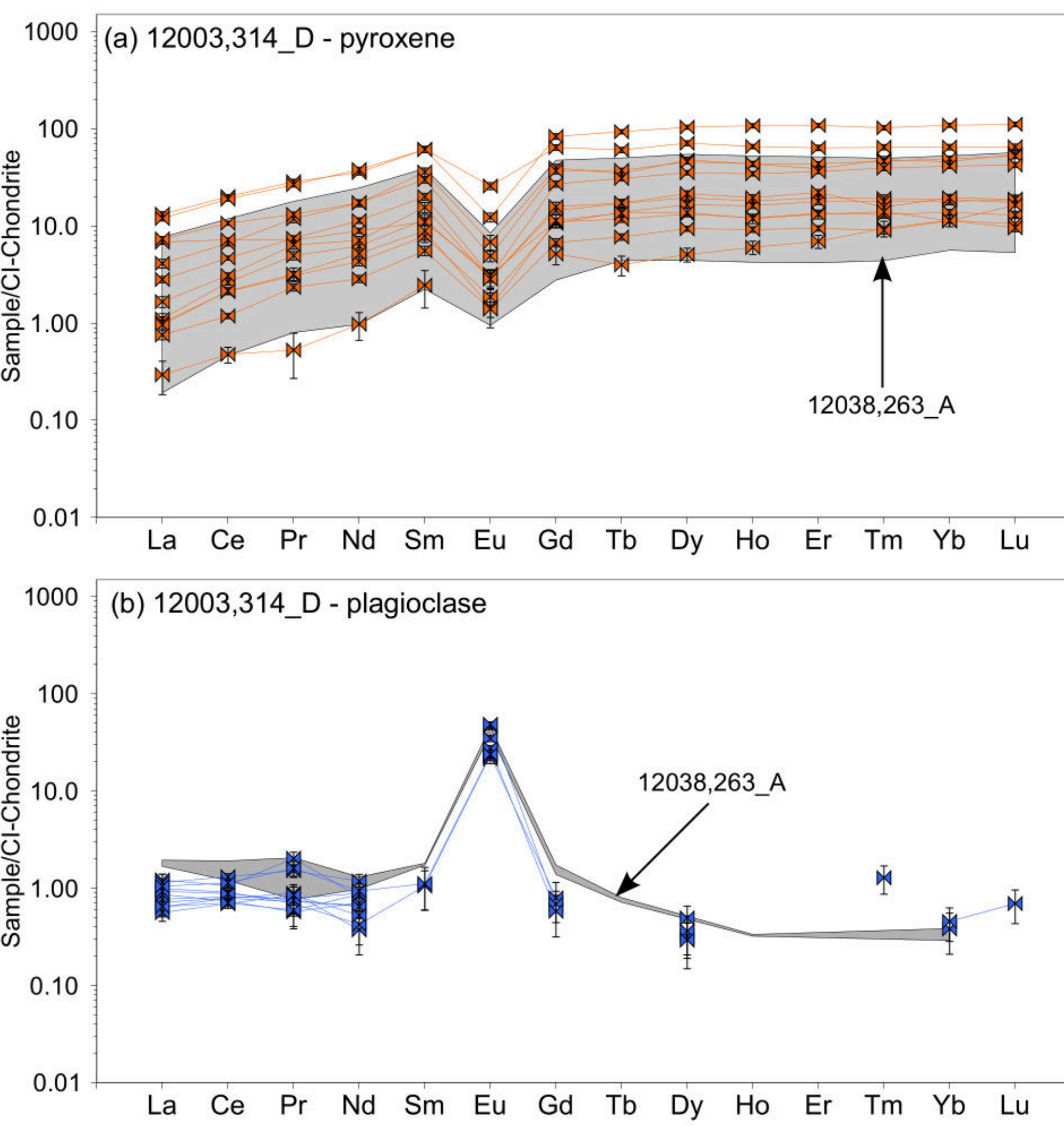


Figure 3: Chondrite normalised [10] REE patterns for (a) pyroxene and (b) plagioclase within 12003,314_D. REE values are compared with those obtained from a sample of 12038. Error bars represent 1σ errors.

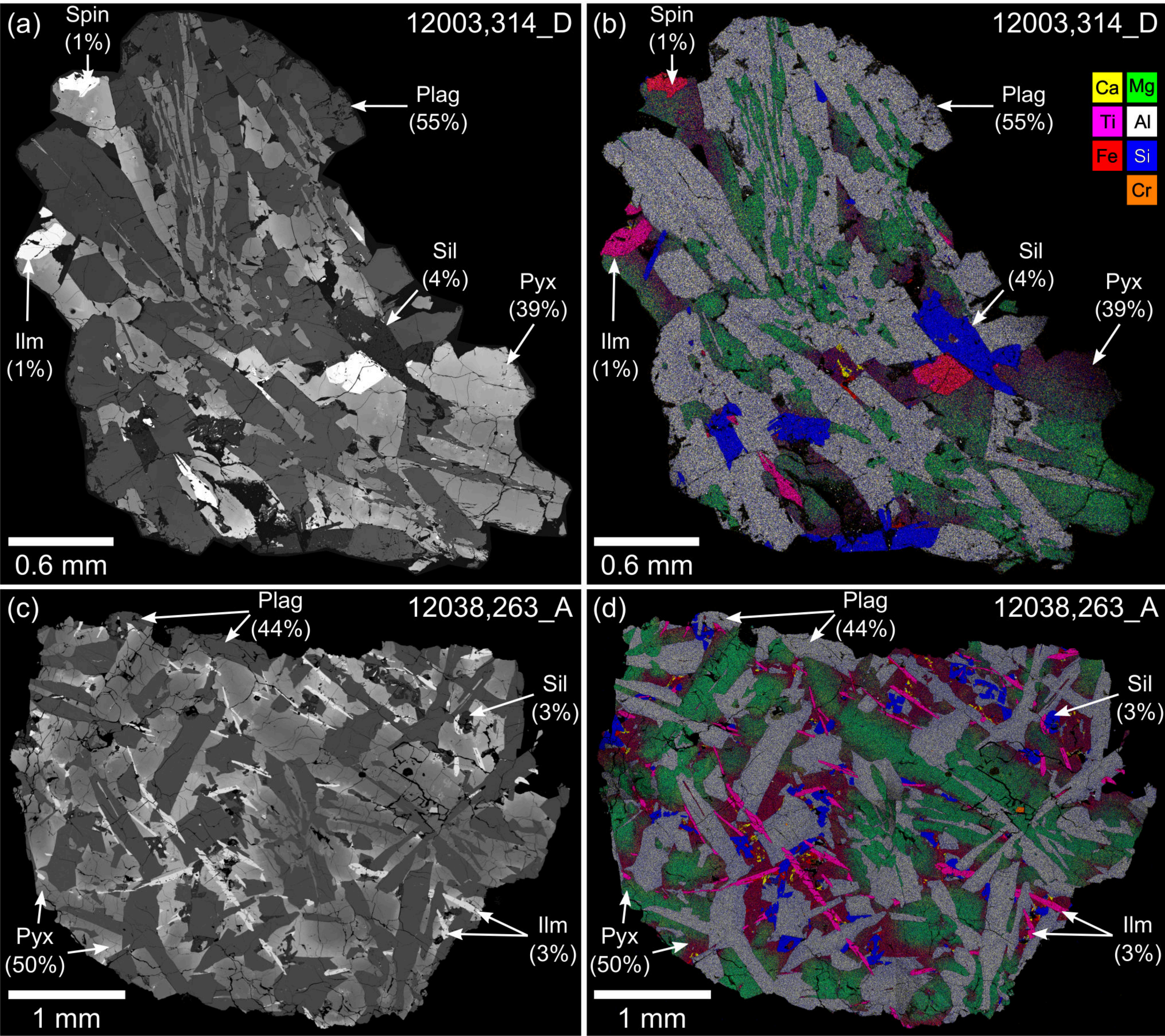


Figure 1: (a) BSE and (b) false colour element maps of 12003,314_D. Examples of major and minor phases have been indicated along with their modal abundances. BSE and element maps of the feldspathic basalt 12038,263_A (c,d) are also shown for comparison.

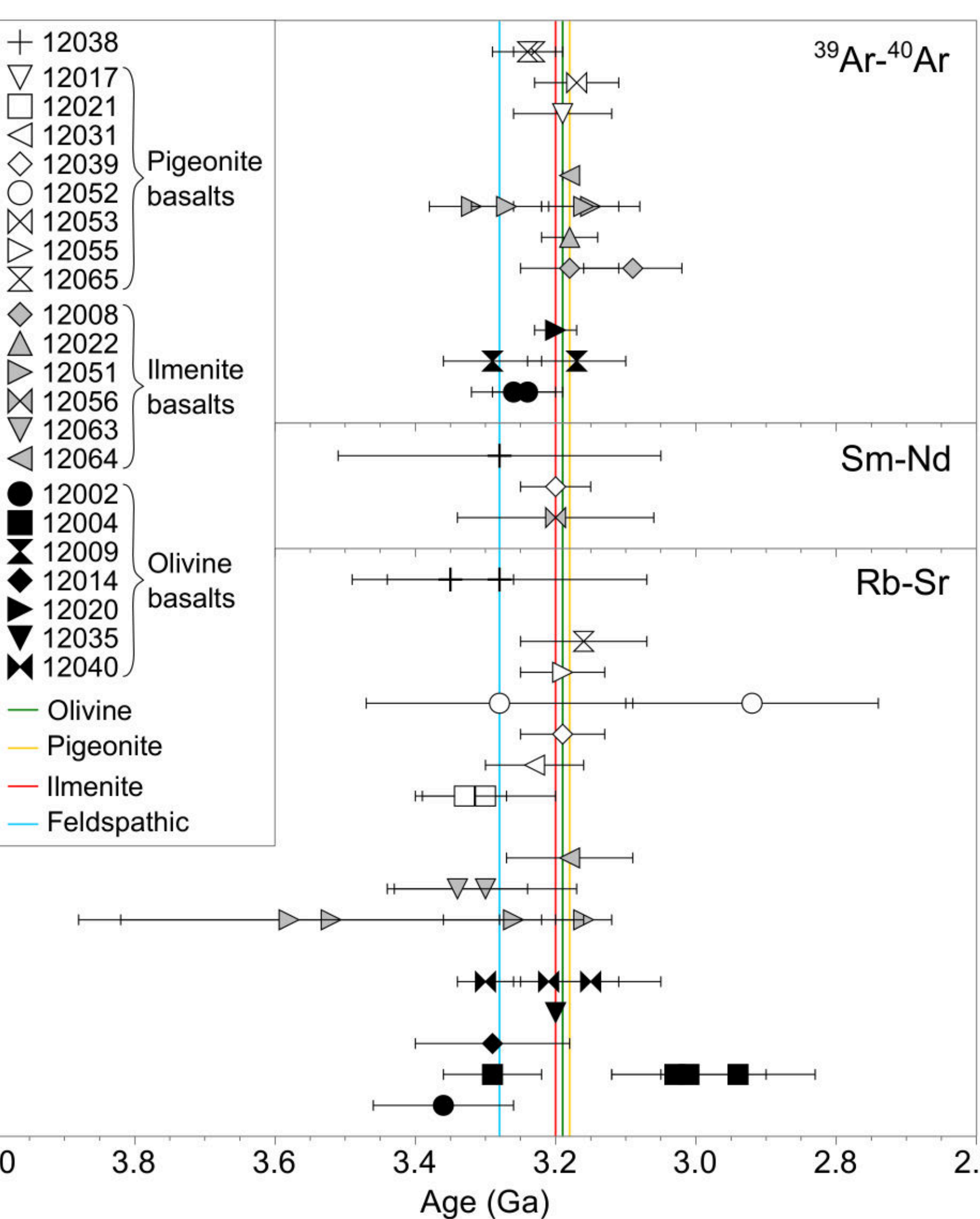


Figure 4: Ages of Apollo 12 basalts as determined by previous investigators using ³⁹Ar-⁴⁰Ar, Sm-Nd and Rb-Sr radioisotope dating methods [5,15-27]. Colored lines represent weighted-average ages calculated for each of the basaltic suites by [28].

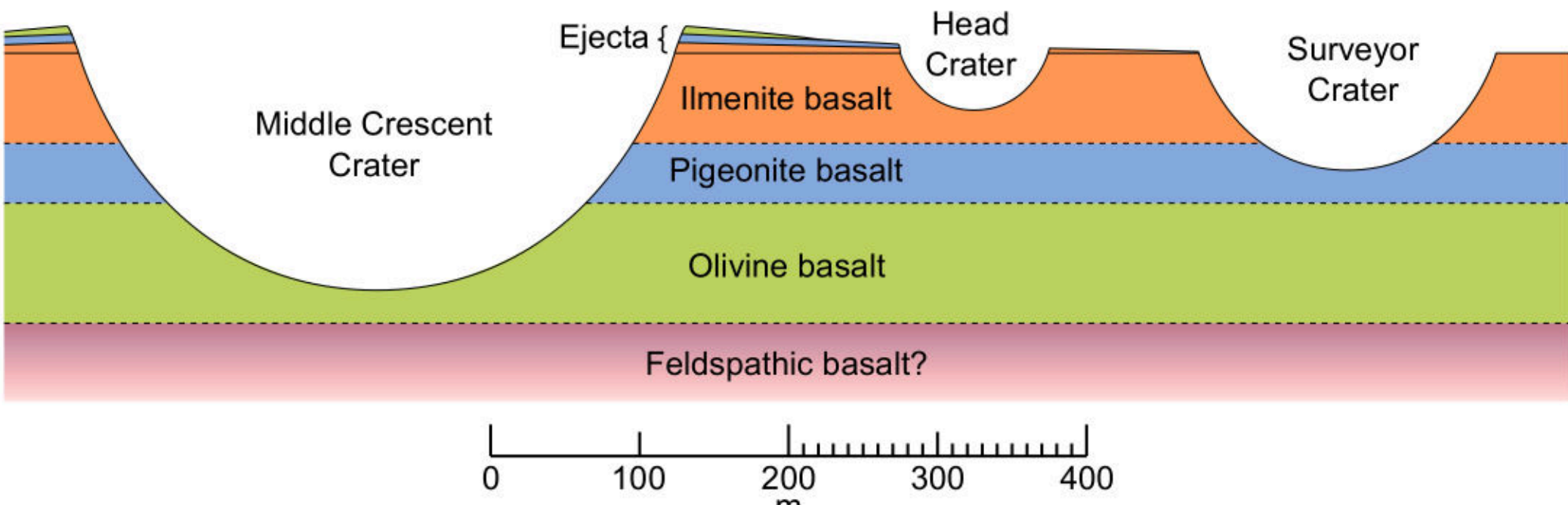


Figure 5: Simplified cross-section of Apollo 12 site, indicating stratigraphic sequence as inferred by [2] and the estimated excavation depths of the three largest craters at the landing site. Scale is approximate with a ~2× vertical exaggeration applied.

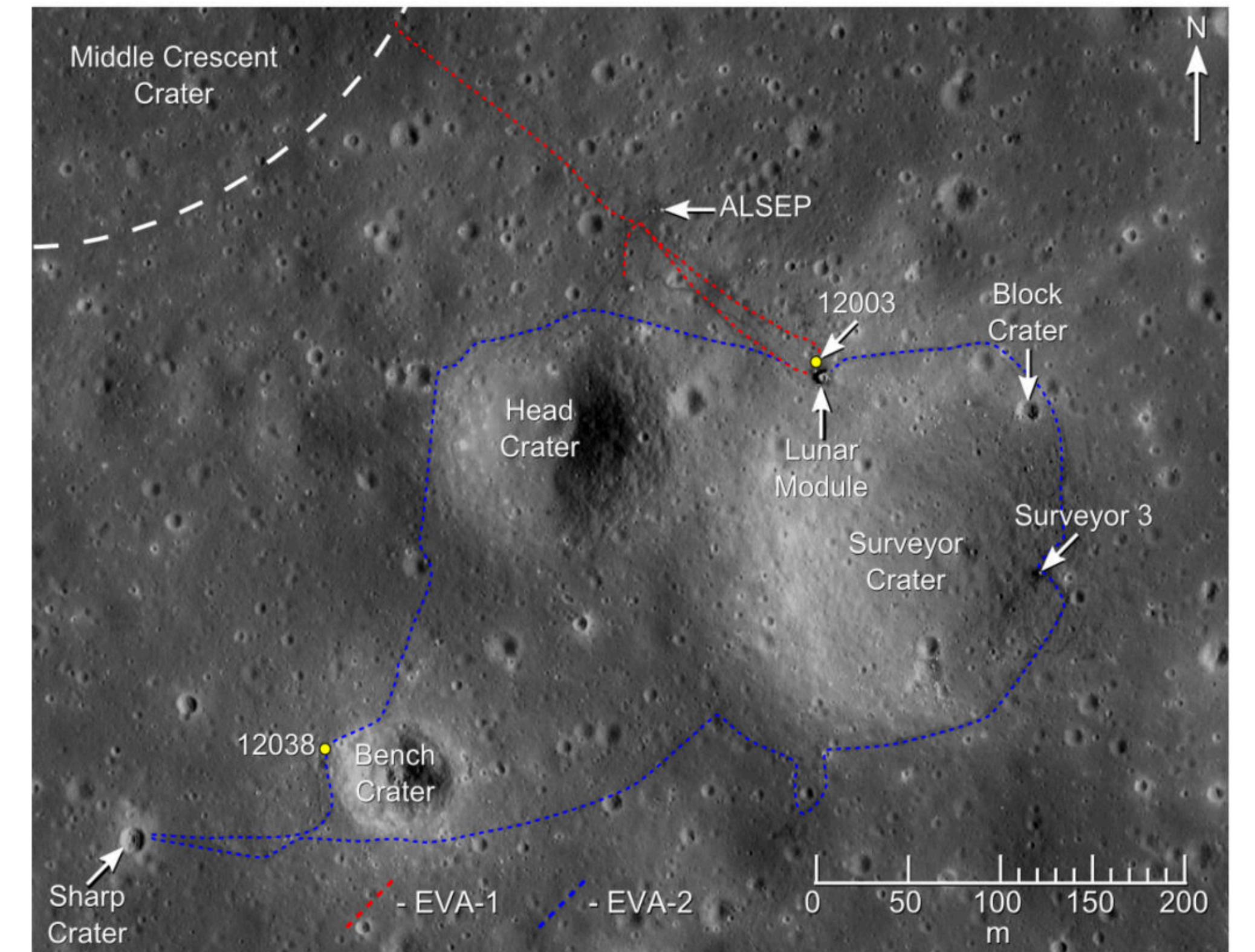


Figure 6: Map of the Apollo 12 landing site indicating the collection locations for the regolith sample 12003 and the feldspathic basalt 12038. Background image from the Lunar Reconnaissance Orbiter Narrow Angle Camera frame M175428601R (NASA/GSFC/Arizona State University).

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