Matching regolith breccia and soil compositions using Lunar Prospector data

MATCHING REGOLITH BRECCIA AND SOIL COMPOSITIONS USING LUNAR PROSPECTOR DATA

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Introduction: The Moon is a valuable body to better understand the early history of the Solar System. It preserves a geological record of the processes that have shaped the formation and evolution of the Earth-Moon system, and it is the only planetary body from which samples have been returned from known locations. These samples (some 382 kg returned by the Apollo and Luna 16, 20 and 24 missions) have shed light on the age and composition on the Moon [1] and have been used as "ground-truth" validation for remote sensing techniques [2-5]. However, these sample return sites are restricted to nine localities on the near side of the Moon and do not provide sufficient global knowledge to fully understand the Moon's origin and evolution.

An additional source of lunar material are lunar meteorites, which were ejected from the surface as result of an impact event. Petrologic and geochemical analysis of these meteorites, combined with orbital remote-sensing measurements, can reveal many new details about composition and geological evolution of the Moon [6-8].

Approach: We are undertaking an investigation of the source regions of lunar meteorites to determine the local geological context of these samples utilizing geochemistry data from the Lunar Prospector gamma-ray spectrometer. This instrument spatially resolved the abundance of major rock-forming elements (O, Si, Ti, Al, Fe, Mg, Ca,), as well as radioactive incompatible elements (U, Th and K), within the upper few tens of centimeters of the surface, and has produced global abundance maps of the composition of the lunar regolith.

Adapting a method [9,10] we have developed a new software application in the Python programming language that matches input elemental compositions with the 2 degree per pixel (i.e., 60 km per pixel) LP-GRS dataset [11]. The Python application is compatible with ArcGIS™ and produces a shapefile layer that allows for convenient visualization of the results.

Apollo landing site validation results: We first validated our approach by comparing the composition of the Apollo 11, 12 and 16 bulk regolith samples (Table 1 [12-18]) with the elemental abundances of FeO, TiO_2 and Th reported by LP-GRS [11]. The Apollo 15 and 17 areas were not selected due to their local geologic complexity (i.e. highland and mare surfaces are unresolved in the LP –GRS data); in the case of Apollo 14, the soil samples have average Th abundances that are larger than those reported in the LP-GRS dataset which prevented a direct comparison.

The method was found to give accurate results for the Apollo 11 and Apollo 12 sites (Fig. 1a and 1b). In both cases the pixels obtained match the landing sites. In the Apollo 16 case our software returns pixels in its vicinity however, not match the exactly place (Fig. 1c). This is because Apollo 16 sample is collected from a relatively localised area, whereas LP-GRS takes the average elemental composition from an area of 60 km per pixel.

Landing Site	FeO (wt. %)	TiO_2 (wt. %)	Th (ppm)
Apollo 11	16.34 ± 3.51	8.02 ± 0.52	2.12 ± 0.76
Apollo 12	14.63 ± 3.66	2.44 ± 1.06	7.01 ± 7.64
Apollo 16	4.95 ± 0.69	0.52 ± 0.11	2.36 ± 2.65
NWA 4472	9.26 ± 0.09	1.28 ± 1.0	6.99 ± 0.08
MET 01210	16.25 ± 0.305	1.48 ± 0.096	0.86 ± 1.0
DaG 400	3.67 ± 0.097	0.180 ± 0.006	0.23 ± 9.064

Table 1. Average landing site (Apollo 11, 12, and 16) bulk soil and regolith breccia compositions used for the validation exercise of this study. Also listed are the bulk rock reported compositions of three meteorites used during this study ± the analytical 1σ standard deviation of averaged measurements.

Lunar meteorite results: Once validated (Fig. 1), we then applied our method to seek regoliths on the lunar surface that are most similar to the bulk compositions of lunar meteorite regolith breccias Northwest Africa (NWA) 4472 [10,19], Meteorite Hills (MET) 01210 [6,9,20] and Dar al Gani (DaG) 400 [9], Table 1. These samples were selected as a test suite as they have previously had their source regions investigated [9,10], and they represent samples with a broad array of compositions.

NWA 4472 possible source regions were found to be located mostly within the Mare Frigoris, with some pixels in vicinity of Mons Caucasus and the Apollo 15 landing site around the edge of the Imbrium basin (Fig.2a). This agrees with the results obtained in previous work [10].

MET 01210 potential launch regions are mostly identified within the interior of Mare Crisium and Mare Fecunditatis, with some sparse pixels in Mare Serenitatis and the eastern side of Mare Tranquillitatis (Fig. 2b).

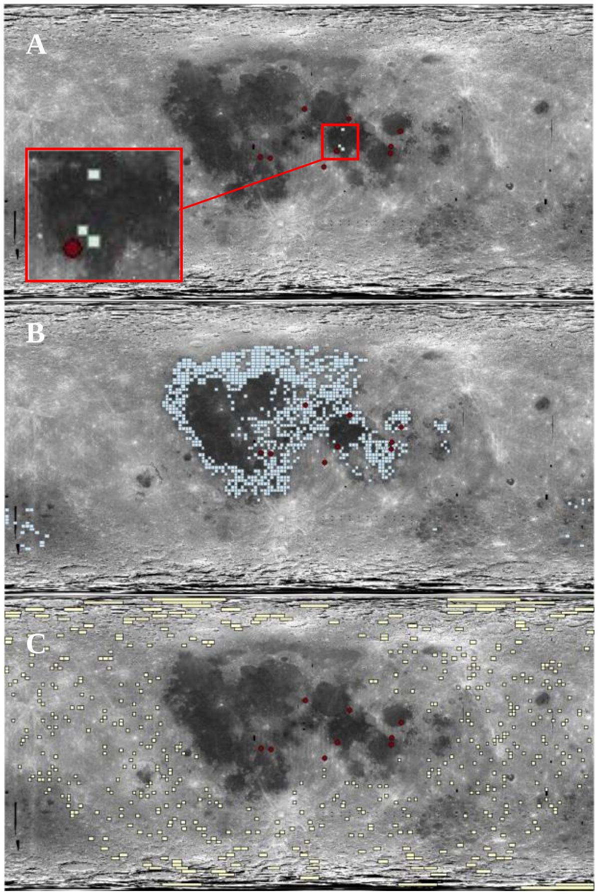

Figure 1. Identification of lunar regolith with similar compositions to Apollo 11 (A where close up is shown in inlay), Apollo 12 (B) and Apollo 16 (C) soils and regolith breccias. Matching compositions to the inputs in Table 1 are shown as pastel coloured 2° pixels. Apollo and Luna landing sites locations are denoted as red symbols. Underlying albedo image of the Moon is a Clementine image in a cylindrical projection.

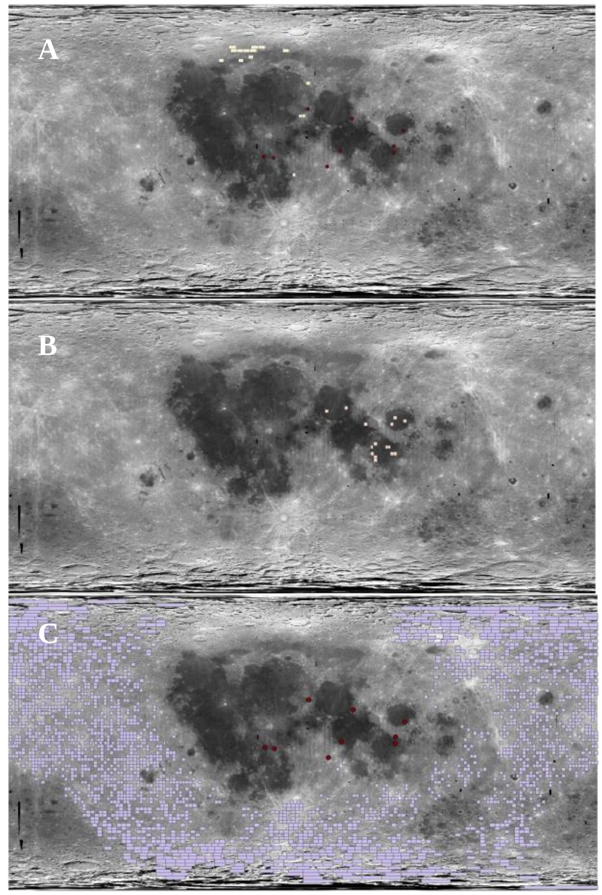

Figure 2 Identification of lunar regolith with similar compositions to NWA 4472 (A), MET 01210 (B) and DaG 400 (C) meteorites. Matching compositions to the inputs in Table 1 are shown as pastel coloured pixels.

Our software identifies many areas of the lunar highlands as a possible source of the meteorite DaG 400 (Figure 2c). Both results agree with previous investigation to the potential origin of this meteorite [9].

Future work: Once validated, we intend to apply our approach in a study of all known lunar meteorites to investigate their source regions and better place them within the context of the global geological diversity of the Moon.

References:

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