EXTRACTION OF METEORITIC METALS FROM LUNAR REGOLITH

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Introduction: We have begun a series of new experiments, the aim of which is to develop methods of magnetically separating meteoritic metals from lunar soil. To our knowledge, no other attempts have been made to accomplish this. The task is daunting because meteoritic metals are not the only magnetically-susceptible materials in lunar soil. It is known [1] that pure metallic iron exists in the soil in the form of nanophase iron globules ($npFe^0$) in the rims of soil grains, and that lunar soil as a whole seems to be magnetically susceptible [2]. Moreover, while the amount of pure meteoritic metal increases with decreasing grainsize, the amount of$npFe^0$ also increases with decreasing grainsize[3-5].

Experimental Set-up: Our experiments involved placing magnets of various strengths at varying distances from a lunar soil sample which was immersed in isopropanol (IPA). In most tests, magnets were arranged in a horizontal plane at the height of the side arm of a modified Dean-Stark apparatus, which was filled with isopropanol to a level slightly higher than the magnets. The stopper of the side-arm held a piece of carbon tape. The configurations were maintained for 30 minutes to an hour, after which the carbon tape was removed and prepared for Scanning Electron Microscope (SEM) examination. Four different magnet configurations were used.SEM studies were performed and the amounts of meteoritic metal and $npFe^o$-rich grains were determined by grain counting.

The configurations, samples used, run numbers, and data obtained are given in Table 1.

RESULTS:

Magnet Configurations	Samples	Run #	Meteoritic Metal Grains	# of Grains with $npFe^0$
Test 1:- Twomagnets immersed in IPA with sample	Size-fractionated dust (median diameter 3.0 micrometers) from lunar soil 14003, 96.	Strong magnet	50	251
		Weak magnet	16	88
Test 2:- One magnet outside the glassware	Size-fractionated dust (median diameter 3.0 micrometers) from lunar soil 14003, 96.	1	4	14
		2	7	6
Test 3:- One magnet at 3.5 cm from glassware	Size-fractionated dust (median diameter 3.0 micrometers) from lunar soil 14003, 96.	1	7	6
Test 4:-Four magnets (two stronger,two weaker)	Size-fractionated dust (median diameter 3.0 micrometers) from lunar soil 14003, 96.	1	0	0
		2	0	0
	Material ground to a median size of 2.2 micrometers from lunar soil 14003,96	1	155	22
		2	0	0
		3	11	14
		4	0	0
	Size-fractionated dust (median diameter 1.5 micrometers) from lunar soil 14003, 96.	1	61	9
		2	2	2
		3	4	2
		4	5	4
	Bulk sample 12003,182 (median diameter 16.5 micrometers).	1	9	2
		2	n.d.	n.d.
		3	11	8

Discussion: Nano-phase iron particles in the samples were distinguished by their spherical shape with a strong iron signature in the sample. The $npFe^0$ globules were less than 30 nanometers diameter and approximately spherical in shape.

Test 1:- Use of 2 Magnets Immersed in IPA with Sample: During the first test, both the strong and weak magnets collected more grains with $npFe^0$ than grains of meteoritic metal. Moreover, the second run collected fewer total particles than the first; however, the relative amounts collected were similar (17 to 15% meteoritic metal as a percentage of total grains counted).

Test 2: Use of a single magnet outside the glassware: In the second test, we saw slightly more meteoritic metal (22% of the total).

Test 3: Use of a magnet at 3.5 cm:- In the third test, 54% of the grains were meteoritic material (Figure 1 and 2)and 46% were $npFe^0$-enriched grains (Figures 3 and 4).

Test 4: Use of fourmagnets (2 stronger and 2 weaker): The first attempt with this configuration was unsuccessful because most of the meteoritic material and npFe0-enriched grains had already been removed. It was visually apparent that the sample was lighter in color than the starting material, thus we decided to try other materials with this configuration. Material ground to a median size of 2.2 micrometers from lunar soil 14003, 96 was used[6].

For the first run with this new material, the particles collected consisted of 88% meteoritic metal. In the second run, few grains were found, possibly because the carbon tape was in contact with the sample for an insufficient amount of time. There were also particles in this sample that were not lunar-like. We determined that some contamination had occurred from the SEM as well as from the process of removing the carbon tape with tweezers. In the third run, the percentage of meteoritic metal was 44%; however, the overall particle count was also much reduced in this case (25 grains instead of 177 seen in the first run). This was confirmed by the total absence of grains collected on the carbon tape in run 4.

We next used another size fraction from 14003, 96; in this case with a median diameter of 1.5 micrometers. In this case, on run #1, 87% of the grains were meteoritic metal. We observed again the reduction in the total number of grains after the first run, and the simultaneous decrease in the percentage of meteoritic metal seen in the samples.

The final sample used with this configuration was bulk soil 12030,183, median diameter 16.5 micrometers. In the first run, fewer particles were collected than had been seen in other "first runs". In other cases the sample had produced significantly more grains when it was first used. In this case, the first run collected only 11 particles—however the percentage of meteoritic metal was again quite high: 82%. We obtained no data from the second run because the carbon tape was torn during removal from the glassware. On the third run, again only a few grains were collected (19); and in this case, the percentage of meteoritic metal was 58%, a reduction which is consistent with the other samples. It should also be noted that this sample had the largest median diameter of any of the samples tried. This may in part explain the dearth of small particles on the carbon tape.

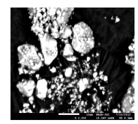

Figure1:- SEM image of meteoritic Iron.

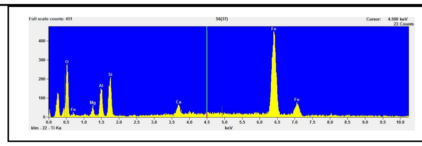

Figure2:- Corresponding spectra of the image on the left.

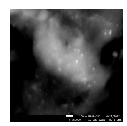

Figure3:- SEM image of $npFe^0$

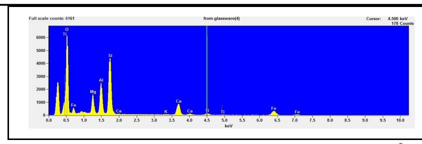

Figure4:- Corresponding spectra of the $npFe^0$.

Conclusions: -

Experimental results indicate promise for the extraction of meteoritic metals from lunar regolith. However, more work is needed to refine the technique and understand more about the variables that affected our results.

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