COMPARISON OF LUNAR AND MARTIAN SIMULANTS TO VOLCANIC ROCKS OF THE ATACAMA DESERT AND (PRE-)CORDILLERA REGIONS OF CHILE.

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Introduction: The main problem of the lunar and Martian simulants is that a single product with particular characteristics was produced with evident geochemical differences from the real lunar and Martian soils and then misused for many studies, which is inappropriate [1]. Appropriate simulants with similar geochemical characteristics to the lunar and Martian soils should be produced and then used for different purposes. Also, the first Martian simulants that were produced during the 90's are now outdated because quite distant from the geochemical values of the lunar and Martian soils. Another problem related to the misuse of the simulants is the lack of integration between engineering requirements and lunar (or Martian) studies [2]. Such a problem, of course, can be easily solved with a synergy of studies between scientists belonging to the fields of engineering, mining, geology, and planetary science.

Martian simulants: The widespread Martian simulant used by NASA so far was the Johnson Space Centre Mars One (JSC Mars-1), developed with the knowledge of the Viking Landers missions and obtained from the volcanic terrains of the Mauna Kea [3]. This simulant now has become outdated because shows different geochemical composition from the basaltic and andesitic terrains analysed on Mars by the Martian rovers. A new simulant from the Mojave Desert was proposed [4]. The Mojave Mars Simulant (MMS) was chosen for its inert hygroscopic characteristics and availability as whole rock, sand, and dust mined from the Tertiary Tropico Group (TTG) basalt [4].

Lunar simulants: The lunar simulant is the Johnson Space Centre One (JSC-1), which is a material that complements but does not replace the Minnesota Lunar Simulant (MLS-1) produced by the University of Minnesota [5]. Although the MLS-1 was a reasonable simulant of hi-Ti lunar mare composition, the major problem with MLS-1 was the difference of bulk chemical composition and mineralogy so that was abandoned by NASA; also JSC-1 revealed quite inappropriate for studies of hydrogen reduction of ilmenite because of its lack of ilmenite and it was dispersed free of charge [1]. The Japanese produced three simulants in the late 90's [6] plus the MKS-1 with unknown criteria [7]: the FJS-1 produced with basaltic lava from Mt. Fuji but with lower MgO content than lunar soils; the FJS-2 improved with olivine; and the FJS-3 with olivine and ilmenite. Although all these simulants contain 0.5 wt% of H_2O they are unsuitable for In Situ Resource Utilization (ISRU) investigations, water production by hydrogen reduction, because they are geochemically different from most lunar soils [1]. The Chinese simulant CAS-1 was produced from the trachy-basaltic scoria of the Jinlongdingzi volcano, China, and compared to the lunar sample 14163 retrieved by Apollo 14 astronauts in the Fra Mauro region of the Moon [7]. The Chinese NAO-1 lunar simulant was mined from a gabbro of the Yarlung Zangbo River in Tibet in order to match the lunar soil of the Apollo 16 landing site [8]. It was even stated that the CAS-1 is "essentially a duplicate" of JSC-1 in terms of bulk chemistry [1]. We compared the values of the Apollo 14 sample to the CAS-1, to a Jurassic back-arc sample (PR-11-179) taken in the Andes of northern Chile [9], and to those of JSC-1, FJS-1, and MKS-1. No one of the newer simulants can be considered as "essentially a duplicate" of the JSC-1. Evidently, the question **"**how good they are?**"** [1] is still actual and needs to be addressed. Actually, there are so many differences between the current simulants and their planetary counterparts that make them far from being duplicates. Besides the distance of values in major elements from the lunar soils, the Chinese and Japanese simulants proved also unsatisfactory for their mechanical properties (internal friction angle, cohesion, etc.), beyond those of the lunar regolith collected between 0 and 30 cm of depth in the lunar maria. So a new one was prepared at the Tongji University (TJ-1) from the ashes located at 20 km southwest of Jingyu County in China [10]. This simulant was prepared according to several criteria: 1) must contain olivine, pyroxene, plagioclase, and the content of glass must be relatively high; 2) bulk density ranges from 1.55 to 1.65 g/cm^3, specific gravity from 2.90 to 3.51 with a recommended value of 3.10, and void ratio from 0.9 to 1.0; 3) internal friction angle from 44 to 47°, cohesion from 0.74 to 1.1 kPa, and compression index from 0.01 to 0.1 under a pressure range of 12.5-100 kPa

[10].

Chilean available simulants: The sample PR-11-179, nearly equals the JSC-1 in number of values of major elements nearer to those of the Apollo 14 sample with respect to other simulants. The sample PR-11-179 gained a significant advantage over the NAO-1 simulant regarding the Apollo 14 sample. However, it obtained a significant disadvantage when compared to the Apollo 16 sample. To obtain a more homogeneous compositional comparison, a more specific sample coming from the region of Atacama was used. This time, a gabbro coming from plutonic rocks of the Chilean Iron Belt [11]. Although this gabbro brings no advantage over the NAO-1 regarding the Apollo 16, it is much better when compared to the Apollo 12 and 15 samples. The Chinese gabbro is of a composition so unusual that seems unbeatable regarding the Apollo 16 landing site. Another rock of basaltic composition [12] was compared to the sample number 10084 of the Apollo 11 fines [13] and to the low-alkali sample Yellow-79135-30 of the Apollo 17 picritic glass beads [14], due to their common richness in Ti, and to the NAO-1 with encouraging results. The TJ-1 simulant was compared to the Apollo 14 soils [10] and to a high-K basalt (sample K60) [15], the latter is the nearest to the lunar soils regarding the major elements. Although the K60 is slightly better than the TJ-1 as lunar simulant, which is remarkable, more work of research is necessary to find better samples for significant improvements. The situation of the Martian simulants is not much different. An average of several geochemical analyses of Martian soils obtained by the Vikings, Pathfinder, Spirit, Opportunity, and Curiosity missions, was compared to the simulants JSC – Mars 1, MMS, JMSS-1 [16] and another Chilean sample, all of them of basaltic composition. There are differences and similarities in oxides among the various simulants and together with the JSC-Mars 1 the Chilean sample is only slightly better than the others.

Current search: We are now in the process of search for new samples that will be taken in different location of the Atacama's desert, Pre-Cordillera, and Cordillera regions of the Andes. The new samples will be analysed with XRF and ICP equipment and compared to the available simulants and to their planetary counterparts.

Conclusions: The various missions planned by the Chinese (CNSA), European (ESA), Indian (ISRO), Japanese (JAXA), and American (NASA) space agencies have brought up since long time the issue of the planetary analogues, particularly for the Moon and Mars. Several tests of mechanical mobility of the rovers, drilling, Raman spectroscopy, and ground penetrating radar have already been done in the desert of Atacama [17][18][19][20], which is considered one of the best Mars analogues on Earth for its mineralogical variety and dry environmental conditions [21]. Certainly, these tests were significant but further work is necessary to consolidate the importance of the desert of Atacama as the best place where to find lunar and Martian Simulants. As a further step of our project is a continued and thorough study of the available simulants currently used by the worldwide space agencies, it is important to better understand their strengths and their weaknesses that must be compared to the new simulants. A first analysis is presented here in order to show the potential of the desert of Atacama aimed at discovering lunar and Martian simulants with characteristics as much similar as possible to the soils already analysed by the Martian rovers and the Apollo missions. Once a better simulant than the existing ones is found, it is expected to develop a great synergy among engineering, mining, geology, astrobiology, and planetary science. This synergy will thus become a new basis for national and international collaborations in the application of the lunar and Martian simulants to a wide range of experiments also in laboratory of height.

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