LUNAR SAMPLE RETURN MISSIONS USING A TELE-ROBOTIC LANDER H. Downes[1,2,3], I.A. Crawford[1,2], Alexander L[1,2]. [1]Department of Earth and Planetary Sciences, Birkbeck University of London, Malet Street, London WC1E 7HX, United Kingdom; [2]Centre for Planetary Sciences at UCL-Birkbeck; [3]Department of Earth Sciences, Natural History Museum, Cromwell Road, London SW7 5BD, UK

Introduction: The Deep Space Gateway has the potential to engage in acquisition of samples from sites on the lunar surface, and to return them to Earth. Specifically, operation of tele-robotic landers and rovers from the DSG enables more complicated surface operations than can be achieved with purely automated vehicles. Such tele-robotic landers could be developed which can examine different parts of the lunar surface, collect specific targeted samples, and return these samples to the DSG for preliminary examination before return to Earth for analysis. This will pave the way for similar tele-robotic rovers to operate on the surface of Mars in future missions, but will also enable lunar scientists to obtain samples of specific rock-types from previously unsampled parts of the lunar surface, including the lunar farside. This presentation will discuss several possible areas of lunar science in which scientific questions have been posed which could be answered by such targeted sampling.

Farside lunar basalts: Basaltic volcanism on the Moon is mainly found on the nearside and only limited amounts occurred on the lunar farside. All Apollo and Luna returned samples are from the nearside regions. Thus there are many unanswered questions regarding the ages and compositions of basaltic volcanic activity on the farside. There are suggestions that farside volcanism continued to 2.5 Ga [1], which have implications for the heat flow of the lunar interior. Sample return from any of the regions of farside basaltic volcanism would provide many more constraints on models of lunar volcanic activity, as both age and composition could be determined with very high precision on such samples in terrestrial laboratories.

Young lava flow regions: Most lunar lava flows erupted in a narrow time window between 3.9 and 3.1 Ga. Evidence from crater counting suggests that some volcanic activity continued until 2.5 Ga, and even perhaps 1 Ga [2], but the age determined for the youngest sampled lava is only 2.9 Ga. Recently it has been suggested that basaltic activity may have continued until 100 Ma in some regions [3]. Geochronological dating of samples returned from specific regions of the lunar surface in which young volcanic rocks may be present is the only way to determine whether any of these suggestions of young volcanism are correct. If confirmed, these young ages would require significant modification of our models of the lunar interior and its heat production, and would greatly increase our understanding of the processes which caused the volcanic activity.

Silica-rich volcanic units: Silicic volcanism is extremely rare on the Moon, but there is evidence for occurences in isolated regions such as at Compton-Belkovich on the farside and at the Gruithuisen Domes on the nearside [4, 5]. The origin of silicic magma on a planetary body dominated by basaltic magmatism is as yet unresolved. Geochemical analyses of samples from any of the regions in which the products of silicic volcanism have been found would be of immense value in understanding the formation of such magmas, and hence extend our understanding of magmatic processes on the Moon.

Olivine-rich regions: Unlike on the Earth, where samples of mantle and lower crustal material are often brought to the surface as xenoliths in volcanic eruptions, we currently have no samples of the lunar mantle or lower crust. Nevertheless, several localities on the lunar surface have been found to be rich in the mineral olivine, which is thought to be a dominant component of both the lunar mantle and lunar lower crust [6]. Sample return from these sites would allow us to investigate these hitherto uninvestigated regions of the Moon's interior, and would provide new constraints on models of the origin of lunar basalts and the nature of the lunar crust.

Palaeoregolith deposits: Lunar regolith deposits have been exposed to billions of years of Solar System history, and can provide a record of the solar wind (via ion implantation) and the passage of the Solar System through the Galaxy (via retention of cosmogenic nuclei from Galactic Cosmic Rays (GCRs)) [7,8,9]. Apollo regolith samples were collected from the surface of the Moon, where the regolith has been gardened by meteorite impacts over geological time, resulting in time-averaged records of Solar System evolution. In order to obtain undisturbed records of the ancient cosmic environment, we require samples that have been exposed to the space environment at known times and for known durations [10]. Such records should be retained by regolith deposits which have been covered by younger lava flows. These "palaeoregolith" deposits would contain a record of the solar wind and GCRs which impinged on them while the deposits were at the surface. The record would be terminated when the lava flow buried the deposit. Returned samples of the strata underlying and overlying the palaeoregolith deposit would be amenable to standard radiometric dating, thus providing a precise age and duration of exposure to the intervening regolith. Samples of the palaeoregolith would be analysed to determine their exposure to GCRs and solar wind, using mass spectromentry in terrestrial laboratories.

Mission requirements: All of the sample return missions described above would require similar elements, including (1) precision landing of a spacecraft at locations where specific rock-types are known to outcrop (located via high-resolution cameras); (2) ability of the craft to roam around the lunar surface to locate the precise position for sample collection (via telerobotics by astronauts operating from the DSG); (3) sample collection via boom arms or drilling. The latter would be specifically required for the palaeoregolith deposits which, by definition, are situated beneath the surface of the Moon; (4) extraction of samples or drill-core; (5) examination of samples by camera from the DSG; (6) transfer samples to a return vehicle; (7) return samples to DSG for further examination by astronauts; (8) return samples to Earth for curation and analysis.

Some of these elements are currently undertaken either by Mars Rovers or by submarine Remotely Operated Vehicles (ROVs) operating in scientific missions beneath Earth's oceans. Other elements (precision landing system; extra-terrestrial drilling technologies) are currently being invested in by ESA. Real-time telerobotic operations from the DSG on the lunar surface would provide a wealth of experience which could be transferred to similar operations on other planets, specifically Mars, if future missions included orbiting manned spacecraft.

There is a significant requirement for DSG crew interaction in this project. The astronauts would need to be in contact with the rover whenever the rover was active on the lunar surface. Rover-lander activity could only take place during the lunar day, and when the DSG was in direct communication with the lander.

Facilities for storage of samples in an inert atmosphere (or in vacuum) on the DSG would also be required, to keep the rock samples as pristine as possible before shipment to Earth.

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