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Lunar Polar Regolith: Plans to Study *in situ* and Perspectives of Samples Return

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1. Introduction

At some regions on the lunar poles the temperature of the shallow subsurface was found to very small, much smaller than 100 K [1]. Surprisingly, some Extremely Cold Regions (ECRs) were discovered to lie not only inside but also outside the Permanent Shadow Regions (PSRs), which are never irradiated by the Sun. Such cold regions should trap the numerous kinds of volatiles provided their molecules would occur to be their. Indeed, the neutron mapping data have shown [2, 3] that many local ECRs have enhanced content of hydrogen in the regolith, and, in general, the polar areas of the Moon have higher content of hydrogen in comparison with the moderate latitudes. Hydrogen is thought to be the signature of water, one of the most intriguing volatiles in the Universe. However, if ECRs contain the water, they should also contain many other volatiles as well.

These expectations have been experimentally proven by direct measurements of composition of material of artificial impact in NASA's LCross mission [4]. The molecules of TBD were found in the regolith of the Cabeus crater, which is one of the coldest ECR on the Moon. The content of water in the regolith of Cabeus could was estimated to be about 5 wt% both by LCross direct measurements [4] and LRO orbital observations [2,3]. While another places at lunar poles could contain less content of volatiles, they would still be rather high in content in comparison with the well-studied regolith at the equatorial belt of the Moon.

Therefore, the recent studies of the polar Moon put forward two main questions to researches:

(1) What is the full list of volatiles, which are stored in the polar regolith?

(2) What is the origin of lunar polar volatiles?

Below the future space missions are presented, which goal is getting responses to these questions.

2. Testing lunar volatiles *in situ*

Two missions to study the polar Moon are now under development by Roscosmos. The first one is the lander of the "Luna-Glob" project scheduled at 2015 with "Soyuz" launcher. This lander with the total mass of TBD kg will deliver to the vicinity of the South pole the limited set of 30 kg science payload (the limitation is resulted from additional mass allocation for higher redundancy of new avionics and subsystems of the lander). Three instruments among them are dedicated to study the volatiles of polar regolith.

ADRON is the active neutron instrument, which pulsing neutron generator produce short pulses of 14 MeV neutrons to irradiate the shallow subsurface, and which neutron and gamma-ray detectors measure induced post-pulse emission of neutrons and gamma-rays. The data of ADRON allows to estimate the average content of hydrogen down to 60 cm of subsurface and to evaluate the content of the soil constituting elements. LIS is the IR spectrometer, which is able to measure the spectral features of IR emission, which are associated with water or hydroxyl molecules. The LIS will be installed on the spacecraft robotic arm, which will point the instrument toward different local spots at 2 meters proximity from the lander. Robotic arm will deliver the samples of the upper most layer of regolith to the third instrument LASMA, which uses the laser ablation technique to measure mass spectrum of atoms and molecules of a sample.

The following results are expected from the data of the measurements of these instruments: how much water is within 60 cm of the shallow subsurface, and which particular volatiles are deposited within the upper most layer of few cm.

The second lander of the project "Luna-Resource" is scheduled for launch in 2017, by the "Soyuz" launcher also. It will be based on the heritage of the lander "Luna-Glob", but will have more mass of 50 kg for science measurements. The smaller landing site in the vicinity of the South pole will be selected for this lander, and for this mission the available orbital data will be mostly used to find the most promising site with the highest content of water and volatiles. In addition to ADRON, LIS and LASMA, the payload will include the complex suite of analytical detectors with chromatographer and mass-spectrometer for detailed study of polar volatiles. It is important that the lander will have robotic drill to get the samples at different depths from the top down to 2 meters of subsurface. Therefore, the measurements onboard the "Luna-Resource" will allow to characterize the content of polar volatiles with high accuracy taken at different depths of the shallow subsurface.

3. The perspectives of lunar polar sample return mission

Provided the missions of "Luna-Glob" and "Luna-Resource" will be successful, the next step for polar Moon exploration should be the mission "Luna-Grunt" for *lunar polar sample return* (LPSR) in 2020. This mission will need to use the heavy "Proton" launcher. In the best case scenario, the TBD kg lander for LPSR will land close to the landing site the previous of "Luna-Resource" lander, which regolith have been already studied *in situ*. This knowledge will be used to develop tools and processes for sampling.

Analysis of lunar polar samples will allow to study the set of cosmogenic volatiles, which were delivered by comets into the inner part of the solar system. These samples imprint the chronology of the solar system, from the past time of the current lunar poles alignment till now. Moreover, the nearest space island, the Moon, could also store the substance of the interstellar origin, because some comets are known to be interstellar bodies arrived from another stars. Finally, the solar wind should also contribute to deposits of lunar polar volatiles, which are produced by chemical reactions with atoms of the regolith. Therefore, the history of solar activity is also recorded in volatiles at lunar poles.

There are three new technology elements of the planning LPSR mission, which differ it from the previous successful robotic lunar sample return mission of Soviet "Luna-24":

1) The set of 10 – 12 individual samples will be returned, which are taken from different spots and different depths of subsurface.

2) The process of sampling acquisition will keep the samples cold enough to preserve volatiles from evaporation.

3) Each sample will be hermetically encapsulated in cryogenic conditions to avoid evaporation of volatiles immediately after delivery from the subsurface.

The mission for LPSR is the challenging one, which will require huge efforts of space engineers and scientists to be successful. The mission is very much appropriate for international cooperation, when the world level centers of excellence shall work together for joint success. After samples of lunar polar regolith would be delivered to the Earth, they should be distributed to science institutes over the glob for studies. Or, even more preferable, the joint center could be created by cooperating Agencies for collaborative studies of lunar polar sample and for planning future steps of polar Moon exploration.

4. References

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