GEOLOGY, GEOCHEMISTRY AND GEOPHYSICS OF THE MOON: PRIORITY SCIENTIFIC TASKS, RESEARCH METHODS AND SCIENTIFIC EQUIPMENT. E. N. Slyuta[1], [1]Vernadsky Institute of Geochemistry and Analytical Chemistry, Moscow, Kosygina Str. 19, Russia, slyuta@mail.ru.

Introduction: Studying the Moon as a geological object also determines the main research methods for solving priority scientific problems of the geochemistry, geology and geophysics of the Moon and the exploration of lunar resources. Obviously, all scientific tasks are interrelated to one degree or another. However, each of the tasks also requires a certain research method and, accordingly, a scientific tool, without which it cannot be solved in principle. Geologists and geophysicists are well aware that a violation of the methodology of geological or geophysical surveys, as a rule, leads to big mistakes in the received scientific information, as well as to economic and financial losses. The Moon is no exception. Thus, the scientific research program of the Moon should ensure the solution of priority scientific problems with maximum scientific effectiveness at optimal and reasonable costs. Obviously, we must get away from one-time unique and therefore expensive missions. It really should be a long-term, interrelated and well-designed program..

Priority Research Objectives: The priority scientific tasks of the study of the Moon in the international scientific community over the past 20 years are well developed, agreed upon, and many of them are ranked on a 10-point scale [for ex., 1]. The Table lists the priority scientific tasks that have the highest priority score from eight to 10. Over time, new tasks are added, for example, the task of studying frozen volatiles in the Polar Regions, or the task of studying gases not only of the solar, but also of the earth's wind implanted in the minerals of lunar soil [2].

Research Methods: Geological methods include a complex of morphological and structural-geological studies of the lunar surface in places of regolith sampling and drilling holes with precise cartographic coordinate reference (geological survey) and reference to a specific geological situation.

Geochemical research methods include a study of the chemical and mineral composition of lunar soil, the chemical and isotopic composition of volatile components in lunar regolith, the absolute and exposure age of minerals, rocks and layers (isotope geochemistry).

Geophysical research methods include a study of the internal structure of the Moon, the physical characteristics of the lunar crust, mantle and core, thermophysical, electromagnetic and physico-mechanical properties of lunar rocks. Geophysical research methods are also auxiliary in the exploration of lunar resources (geophysical survey).

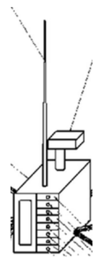
ID	PRIORITY SCIENTIFIC TASKS	Rating
mG1	Origin and dynamic history of the Earth - Moon system	**10**
mG2	The study of the terrestrial wind gases implanted in the lunar soil (composition of the Earth's primary atmosphere, time of the Earth's magnetosphere formation, time of the appearance of biogenic oxygen on the Earth, time of synchronization of the Moon's rotation)	**10**
mG3	The degree of differentiation and the internal structure of the Moon	**10**
mG4	The formation history of the early crust on the Moon	**10**
mG5	The structure of the lunar crust and upper mantle and the origin of the mascons	**9**
mG6	Global dichotomy and regional heterogeneity of the composition of the crust and mantle	**9**
mG7	History of lunar magmatism and volcanism	**9**
mG8	Lunar geological chronology (timeline scale)	**9**
mG9	Moon's internal heat flux	**9**
mG10	The origin of the ancient magnetic field of the Moon (magnetic anomalies)	**9**
mG11	Implanted, weakly bound and frozen volatiles in lunar soil (lunar resources)	**10**
mG12	Substance of asteroids, comets and the young Earth in lunar soil	**9**
mG13	Changes in the activity and composition of the solar wind and galactic cosmic rays in lunar regolith over a period of more than 4 billion years	**8**

Lunar Basic Network: A number of priority scientific problems with ID of mG1, mG3, mG5, mG9, mG10 (Table 1) can only be solved with a network of scientific stations with a certain set of scientific instruments located on the lunar surface (Table 2). The Vernadsky Institute has developed the concept of autonomous automatic scientific research stations (ARS) of the container type, which can be delivered to the surface of the Moon using any automatic landing spacecraft, moon rovers, and in the future with manned expeditions. The minimum number of such stations on the

Moon is three, and the optimum is 8-10. The life of each station is at least 10 years. ARS mass - 50-60 kg. A network of such stations on the Moon can be formed gradually over 15-20 years. With the help of international scientific cooperation, this may be done faster.

Table 2. Scientific Equipment of ARS

1. Seismometer
2. Logging thermal probe (down to 3 m)
3. Gravimeter
4. Magnetometer
5. Plasma and Dust Detectors
6. TV-camera (spectrometer)
7. Laser corner reflector.
8. Beacon.
9. RITEG.



Drilling Rig LB-15: To solve many of the priority tasks with ID of mG1, mG2, mG4, mG6-8, mG12, mG13 (Table 1), the key method is sampling lunar soil and delivery to the Earth and study of samples in laboratory conditions. In this case, the method and location of sampling lunar soil is extremely important. To solve most of the scientific problems noted, delivery of a stratified regolith column down to underlying rocks, including the oldest regolith layers, is required. The Vernadsky Institute is developing the concept of a new generation of drilling rig LB-15 (Fig. 1), which will allow drilling and sampling to a depth of 1.5 to 6 meters, depending on the number of drill rods, and in the future down to 10-15 meters.

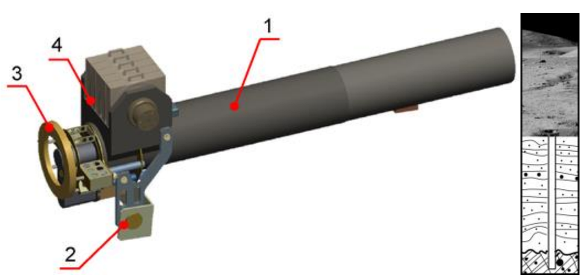


Fig. 1. Project appearance of drilling rig LB-15: 1 – automatic drilling rig; 2 – frame with drive for deployment; 3 – pressing mechanism; 4 – sample containers.

Lunokhod "Robot-Geologist": Solving the priorities scientific problems with ID of mG1, mG4, mG6-8 (Table 1) requires thematic geological and geophysical surveys of regional structures with soil sampling on the surface every 2 km and shallow (3-6 m) drilling of several (at least 5) wells along a route of about 500 km in length. An example is a route through the volcanic province of Rumker Mons and the adjacent plain. This is a unique geological structure, near which there are basalts of all ages - from the Lower Imbrian to the Copernican system. To carry out regional geological and geophysical surveys on the Moon, the Vernadsky Institute developed the concept of the heavy lunokhod Robot-Geologist [3]. The scientific equipment of the lunar rover consists of three main complexes - navigation complex, geochemical exploration, and geophysical exploration. A draft design of the lunar rover under the leadership of Roscosmos is being developed at the Central Research and Design Institute for Robotics and Technical Cybernetics.

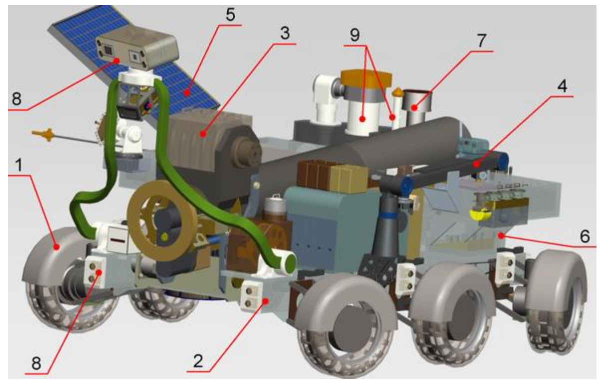


Fig. 2. The design of the lunar rover "Robot-Geologist." 1- system of movement; 2 - supporting structure; 3 - drilling rig LB-15; 4 - manipulator; 5 - power supply system; 6 - thermal control system; 7 - navigation complex; 8 - system of technical vision; 9 - control and communication systems.

Lunokhod "Explorer": For the study and exploration of weakly bound and frozen volatiles in the Polar Regions (mG11, Table 1), under the scientific guidance of the Vernadsky Institute, the concept of a geological prospecting lunar rover "Explorer" has been developed, which will allow studying volatiles in lunar soil down to 2-3 m in situ without sampling of lunar soil [4]. This is a middle type of lunokhod weighing about 300 kg with scientific equipment weighing about 60 kg. The length of the route is about 50 km. A draft design of the lunokhod under the leadership of Roscosmos is being developed at the Lavochkin Association.

This rover has a lightweight screw drilling rig [4]. The soil in the form of sludge is fed by a screw under a sealed bell. As a result of mechanical and thermal effects on the soil, weakly bound and frozen volatiles are sublimated under a bell, from where they are delivered through a pipe to a mass spectrometer to study the chemical and isotopic composition. A prototype of a reusable screw drilling rig is being developed at the Vernadsky Institute.

References: [1] Shearer, C. et al. (2007) CAPTEM. http://www.lpi.usra.edu/captem/. [2] Terada K. et al. (2017) Nature Astronomy. 1, #0026, 1-5. [3] Vasiliev A. et al. (2017) 28th Daaam Int. Symp. Vienna, Austria. 0780-0786. [4] Slyuta. E. (2017) Mining of Mineral Deposits, 11(4), 117-125. DOI: 10.15407/mining11.04.117