

POSSIBILITY OF H AND S DETECTION ON THE MOON BY SELENE MISSION. A. A. Berezhnoi^{1,2}, N. Hasebe¹, T. Hiramoto¹, T. Miyachi¹, N. Yamashita¹; ¹Advanced Research Institute for Science and Engineering, Waseda University, 55S-301 34-1 Okubo, Shinjuku, Tokyo 169-8555, Japan; ²Sternberg Astronomical Institute, Universitetskii pr., 13, Moscow, Russia

Introduction: The possible existence of water ice in permanently shadowed regions near the lunar poles has been postulated by Watson et al. [1]. The delivery rate of water into the cold lunar polar craters due to degassing from the lunar interiors, micrometeorite bombardment, solar wind, and comet impacts was investigated [2]. Some experiments have been made to search for the existence of water in the polar regions. Areas with ice-like radar echoes were detected during the Clementine-Deep Space Network bistatic experiment [3]. Another attempt to detect hydrogen-containing compounds near the lunar poles was made using Lunar Prospector neutron data [4]. The mass of water ice was estimated as 2×10^{14} g in the south polar region, and its mass fraction as about 1.5 % in the south polar caps [4]. The observable amount of lunar polar hydrogen can be explained by action of solar wind flux on the lunar surface [5]. However, a recent analysis of hydrogen content based on Lunar Prospector data supports the idea that a significant portion of the enhanced hydrogen near the poles is most likely in the form of water molecules [6].

The possibility of polar volatiles other than water ice has been considered by some investigators [7-9]. Sprague et al. [7] proposed that unusual radar properties of Hermean poles make a compelling case for the presence of elemental sulfur at the upper layers of polar regolith on Mercury.

Comet hypothesis for the origin of lunar polar volatiles has not been well studied. The fraction of cometary matter captured by lunar gravitation field is estimated by Berezhnoi and Klumov [10], which showed that volatile compounds in lunar temporary atmosphere finally accumulated completely in cold traps. Comet impacts deliver H_2O , CO_2 , SO_2 ices to cold traps.

The content of volatile elements at the poles of the Moon: The hydrogen content in equatorial lunar regions is 50 ppm. Analysis of low-orbit Lunar Prospector data shows that the hydrogen content in the polar crater Shoemaker-Faustini is 1700 ppm, and that in other polar craters the hydrogen content varies between 60-150 ppm [6].

In Apollo samples, the carbon abundance is 5200 ppm [11]. In cold traps the carbon abundance would be higher than that in equatorial regions due to the presence of CO_2 ice and complex organic compounds.

Sulfur-containing compounds can be used as important lunar resources. In Apollo returned samples, the sulfur abundance varies from 0.05 to 0.3 wt % [11].

The sulfur content at the poles of the Moon would be higher than that at the equatorial regions because sulfur is a volatile element. The sulfur on the Moon is thought to be delivered through asteroid and comet impacts, solar wind, and micrometeorite bombardment. Berezhnoi and Hasebe [12] estimated that about 3×10^{15} g of sulfur was delivered to cold traps during last 3×10^9 years. The latitudes of regions of sulfur thermal stability were estimated as 86-90N and 86-90S, which correspond to the area of sulfur polar caps of about 10^{15} cm² [13]. It is clear that the loss rate of sulfur is less than that of water due to lower partial pressure, higher atomic mass and longer photo destruction time, though the ratio between delivery and loss rates of sulfur at the lunar poles is still unknown. If we neglect the loss mechanisms of sulfur from cold traps, we can estimate the sulfur content as high as 3 g/cm² or 1 wt % in upper meter layer of the lunar regolith.

Gamma-ray spectroscopy onboard SELENE mission: The SELENE project is a Japanese lunar polar orbiter scheduled to be launched in 2005. This spacecraft will study the Moon during one year at a nominal altitude of 100 km. In SELENE, Ge detector with an excellent energy resolution (3 keV at 1.33 MeV) and spatial resolution of 130 km will be employed as a gamma-ray detector [14]. Let us estimate possibilities of H, S, and C detection at the poles of the Moon. Major gamma-ray lines emitted from sulfur through neutron capture and inelastic scattering reactions are 0.84, 2.23, 2.38, 3.22, and 5.42 MeV. The intensive line at 0.84 MeV lies only 3 keV away from strong Al line. Sulfur line at 2.23 MeV can be resolved near strong Si line at 2.235 MeV. Intensive line at 5.42 MeV is free from interference with surrounding lines of other elements. Ten hours of accumulation time collected by lunar polar mission carrying Ge gamma-ray detector, for instance, enable us to detect more than 0.5 wt % S in lunar soil [15]. SELENE gamma-ray spectrometer collects 5 and 80 hours/year*space-resolution at 60 degrees of latitude and at the poles, respectively [14]. The most intensive hydrogen line at 2.223 MeV can be identify by SELENE, for 40 hours of accumulation time it will be possible to detect 0.1 % water mass fraction or 0.01 wt % of hydrogen [16]. The most intensive carbon line at 4.438 MeV is impossible to detect because of interference by strong O line at the same energy. Another C lines at 1.262, 3.684, and 4.945 MeV are also very close to strong O lines.

We have made Monte Carlo calculation that simulates gamma-ray spectra expected for lunar polar regolith containing different H and S content. In these simulations a well-known GEANT4 code was used. The chemical composition of dry polar regolith is assumed as that of ferroanorthosite. Obtained thresholds of detectable H and S content are higher than those received by [15, 16]. At 80 hours of accumulation time is it possible to detect hydrogen if H content is higher than 0.03 wt % (see figure). At the same accumulation time sulfur cannot be detected if sulfur content is less than 0.5 wt %. Another calculations show that at 13 hours of accumulation time hydrogen is detected at 0.1 wt % and sulfur is detected at 2 wt %. But the mean hydrogen content at SELENE spatial resolution is lower than 0.1 wt % [6]. So the threshold of hydrogen content detectable by SELENE gamma-ray spectrometer is higher than that of Lunar Prospector neutron spectrometer.

Conclusions: SELENE gamma-ray spectrometer can confirm the Lunar Prospector results that hydrogen exists near the poles of the Moon only at high values of accumulation time. This instrument has the capability to detect sulfur polar caps if sulfur content is higher than 0.5 wt %. So the first detection of sulfur at the poles is possible because the estimated sulfur content at the lunar poles is about 1 wt % [12]. Future lunar polar orbiters should determine the composition

and spatial distribution of lunar polar volatiles.

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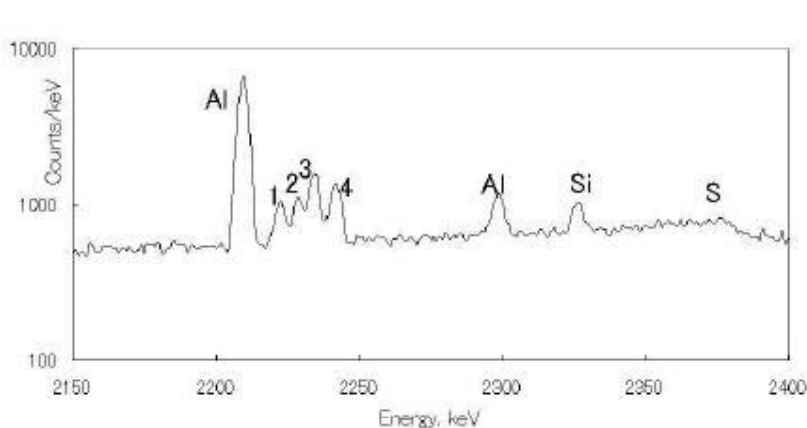


Figure. Expected energy spectrum from the lunar surface obtained by SELENE gamma-ray spectrometer. Number 1 – H line, 2 - S line and O single escape peak, 3 – Si line, 4 - Mg, Al, Si escape peaks. The S line at 2.3797 MeV cannot be seen. The accumulation time is equal to 80 hours. The hydrogen and sulfur contents are equal to 0.05 and 0.2 wt % respectively. Calculations were made without taking into account Compton scattering in the lunar regolith.