THE KAGUYA (SELENE) MISSION AND ITS LUNAR SCIENCE.

M. Kato, Y. Takizawa, S. Sasaki, and SELENE Project Team, Japan Aerospace Exploration Agency (3-1-1 Yoshinodai, Sagamihara, Kanagawa 229-8510, Japan. E-mail: kato@planeta.sci.isas.jaxa.jp)

Introduction: Japanese lunar orbiter Kaguya (SELENE) has been successfully launched from Tanagashima Space Center TKSC on September 14, 2007. On October 4 the Kaguya has been inserted into large elliptical orbit circulating the Moon. After lowering the apolune altitudes the Kaguya has reached the nominal observation orbit with 100 km circular and polar on October 19. On the way to nominal orbit two subsatellites Okina (Rstar) and Ouna (Vstar) have been released into the elliptical orbits of 100 km perilune, and 2400 km and 800 km apolune, respectively. After the checkout of bus system, the extension of four sounder antennas with 15 m length and the 12 m mast for magnetometer, and deployment of plasma imager nominal observation term for ten months has been started on December 20. On October 31, 2008 the nominal observation had been completed through successful operation of deep lunar eclipse and orbital control. Since November 1, 2008 the mission is extended using saved fuel.

Science Targets: All instruments have highest-level quality in their specification which expects to get highly useful data for lunar science [1, 2]. Second level of science can be achieved by integrating data obtained complementarily by plural instruments in a same category of useful characteristics.

Lunar chemical constituents: Lunar chemical constituent is a first priority target in studying origin of the Moon and chemical distribution of the inner area of primordial solar system. Two categories of data, elemental abundance of lunar surface by XRS and GRS, and mineral composition by MI and SP define the rock types and their distribution on the lunar surface. Information of subsurface constituents in lunar crust can be acquired by investigating central peaks of craters formed by rebound of impact shock in the formation of crater, which is observed larger than about 40 km in diameter on the Moon. Large basins such as South Pole Atkins in diameter of 2500 km are scooped to 12 km depth and expose interior materials of lower crust or extrude upper mantle of the Moon. These remote-sensing data reveal about 15 % volume of chemical constituent of the Moon.

Gravity field measurement deduces knowledge on polar moment of inertia of the Moon, to estimate the size of lunar core. Gravity data by Lunar Prospector estimates the iron core radius of 220 to 450 km [3]. Science results of Kaguya mission can not definitely estimate the whole abundance of the Moon, because the mission has never had any instruments of in-situ measurement of lunar interior. However, it is possible to improve intensively the knowledge on chemical constituent of the Moon by assuming mantle material constituent by Apollo seismological investigation.

Lunar interior structure: As mentioned in previous subsection, size of lunar core allows being estimated using polar moment of inertia deducing from gravity field measurement. Shallow interior and subsurface structures can be investigated directly by LRS. Sounding by 5 MHz radio wave reveals subsurface layer structure such as density and/or material discontinuity up to about 5 km depth. Gravimetric data by RSAT and VRAD, and topographic ones by LALT will be used to estimate thickness of crust of whole Moon. Crust in basin area and mares in nearside is thin, and highland in farside is overlaid on thick crust. Kaguya mission definitely improve certainty of crustal thickness.

Dichotomy of nearside and farside: The dichotomy in the Moon is recognized in topography and rock distribution between nearside and farside. Large mares are occupied 60 % of lunar nearside. Large altitude difference more than 16 km is formed in farside. The dichotomy is investigated by geological study of material distribution and crustal thickness.

Differentiation in magma ocean: If the origin of the Moon is formation of “magma ocean”, many evidences must be retained on the lunar surface. Rock distribution must be identified as an evidence of differentiation of magma ocean. Formation of South Pole Atkins basin and large mares by extruded magma in nearside are main geological events after occurrence of magma ocean 4.6 billion years ago. Therefore, geological recovery or reburying of the basin and mares is necessary to reproduce magma ocean age. Detailed investigation on geology by Kaguya makes clear the origin of magma ocean. Magma ocean model has great advantage in giant impact origin for lunar formation. Short duration of accretion to the Moon after the giant impact allows heating up the surface of the Moon enough to realize magma ocean.

Origin of lunar magnetic field: Apollo rock sample contains magnetic minerals assuming magnetization in weak but definite magnetic field. In early time the Moon may have definite magnetic field such in the Earth. LMAG team of Kaguya mission is searching weak magnetic remnant less than 10^{-5} Tesla collaborating with Electron Spectrum Analyzers of PACE.

Origin and Evolution of the Moon: Ultimate targets in lunar science are “Origin and Evolution of the Moon”. Second level of science targets as mentioned in previous section may direct to the final target. Kaguya mission is expected to get new insight in lunar science. In-situ observation using lander system must be executed to study structure and material distribution of the lunar interior.

New Data of Observation by Kaguya: Kaguya data have already improved previously reported ones up to Clementine and Lunar Prospector missions. Multi-band Imager provides new and detail information of lunar crust by reflectance image of central peaks of craters. Spectral Profiler definitely measures mineral composition of characteristic feature of lunar surface such as central peaks of craters[4]. High resolution images of Terrain Camera show volcanic activity of lunar farside to younger age by crater counting to smaller size of craters of 100 m in diameter [5]. Direct measurements of gravitational field of farside are carrying out using RSAT onboard subsatellite Okina. It reveals gravity anomaly of farside basins is very different from nearside ones which shows simple positive anomaly. In Apollo basin coaxial distribution of positive and negative anomalies are definitely observed by reflecting the difference of subsurface structure and material [6]. Lunar Altimeter LALT makes high resolution topography map of STM359 model [7, 8]by measuring altitudes by every 1.6 km interval including polar regions, where Clementine mission never measured directly and photograph were used to estimate the topography of polar area higher than 75 degrees in ULCN2005.This map indicates highest point of southern rim of Dirichlet-Jackson basin and lowest bottom of Antoniadi crater in South Pole Aitkens basin. The difference of altitudes attains 19.8 km in lunar farside. Center of figure of the Moon is offset to be 1.93 km to the Earth side from center of gravity. Rader sounder LRS are successfully sounding the lunar surface and subsurface. Especially in mare regions of nearside subsurface discontinuity are identified to be permeability boundary of geological strata [9]. Rader echoes in farside are much contributed by reflection from rough surface such as craters of highland. So subsurface echo can be identified after applying information of surface topography. The result of LRS observation also makes possible to compare with Apollo ALSE results for subsurface of Mare Serenitatis. Apollo sounder indicated deep discontinuity of 3 to4 km depth. On the other hand Kaguya LRS identified the shallow discontinuity at 500 m depth. Reanalysis of Apollo data by using the same method is necessary to settle this controversy. Gamma-ray spectrometer GRS identifies global distribution of radioactive elements, U, Th, and K [10]. Uranium distribution must be higher reliable than previous estimation, where energy of gamma ray from uranium is limited by detector energy range. Plasma analyzer PACE can analyze mass and energy of solar wind [11]. Electron and proton are detected in the wake of the Moon. PACE also observes the reflected protons from lunar surface. Magnetometer LMAG identifies magnetic anomaly in northwest part of South Pole Aitkin basin by reducing electromagnetic noise employing twelve meter mast. Several anomalies reported by 30 km altitude observation of Lunar Prospector are identified by Kaguya LMAG of 100km altitude.

Table1. Kaguya Science Instruments and Experiments

Elemental distribution measurements
X-ray Spectrometer (XRS) Gamma-ray Spectrometer (GRS)
Mineralogical distribution measurements
Multi-band Imager (MI) Spectral Profiler (SP)
Topography of lunar surface and subsurface
Terrain Camera (TC) Lunar Radar Sounder (LRS) Laser Altimeter (LALT)
Precise gravity field measurements
Differential VLBI Radio Source (VRAD) Relay Satellite Transponder (RSAT)
Plasma environment study
Lunar Magnetometer (LMAG) Charged Particle Spectrometer (CPS) Plasma energy Angle and Composition Experiment (PACE) Radio Science (RS) Upper-atmosphere Plasma Imager (UPI)
Public outreach
High Definition TV Camera (HDTV)

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