HOW DOES SPACE WEATHERING DEPEND ON THE SURFACE CONDITION OF AIRLESS BODIES (ASTEROIDS, THE MOON, AND MERCURY)?

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Introduction:
The surface of airless silicate bodies in the solar system show darkening of overall reflectance, spectral reddening, and attenuation of absorption bands in time. Space weathering is considered to be responsible for these optical signatures and to explain spectral mismatch between lunar soils and rocks, and between asteroids (S-type) and ordinary chondrites. It was proposed and believed that formation of nanophase metallic iron particles in soil coatings from the deposition of ferrous silicate vapor, which was formed by high velocity dust impacts as well as sputtering by solar wind [1]. Nanophase iron particles have been confirmed in lunar soils as well as meteorite sample [2-5]. Experimental studies also confirmed the formation of nanophase ion is responsible for the space weathering [6-10].

Itokawa has changed the view of space weathering on asteroids:
Spectral slopes of near-Earth asteroids suggest that the transition from Q-type (ordinary chondrite-like) objects to S-type objects occurs around the size range 0.1 to 5km [11]. Presence of regolith on larger bodies should enhance the space weathering. Smaller bodies would not have weathered surface because regolith is scarce due to smaller gravity.

Observation of 550m Itokawa by Hayabusa suggested that the rocky small asteroids should be weathered although they are lack of regolith and that weathering there should have proceeded in a timescale of 10^7 yr [12]. Itokawa is heterogeneous in both albedo and color [13-15]. The albedo difference is approximately 10-20% from 7km distance and as high as 30% on close-up images (Figure 1). Color and spectral studies show that these variations can be explained by the space weathering process on LL (probably LL6) chondrite composition [16-17].

High resolution (a few cm) image on a darker rough terrain of Itokawa shows various size of dark boulders without fine regolith (Figure 2). Some large boulders have brigher scratches and dots on the surface. This feature can be explained by impact of small meteoroid particles if a rock covered with a very thin weathered layer. Pulse laser irradiation simulating space weathering revealed, ordinary chondrite pieces without particulate surface can be weathered, probably because the surface has microscopic porosity [18]. Experimentally rocky surface is less likely to be weathered than particulate surface. However, surface mixing probably caused by impacts would have weakened the weathering on the particulate surface. This effect should be taken into account for larger bodies covered with regolith.

Space weathering on larger bodies and effect of mixing:
Both the Moon and the Mercury are covered with regolith. On the Moon, timescale for the space weathering is discussed from the age of rayed crater, where bright rays would be composed of excavated unweathered materials. The timescale for the weathering (disappearance of rays) would be as long as a few 100My to 1by [19].

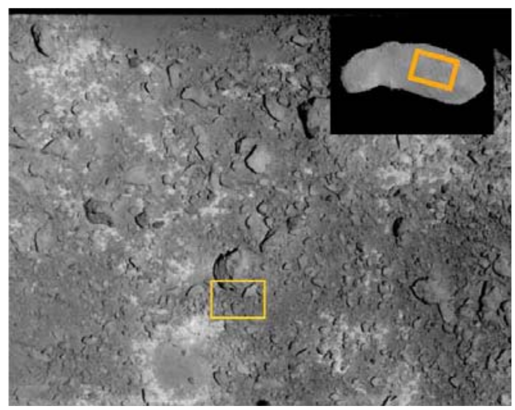

Figure 1 Albedo variation on Itokawa (JAXA). A rectangle in the inset is the position of this image. A rectangle in the lower figure denotes the position of Fig.2.

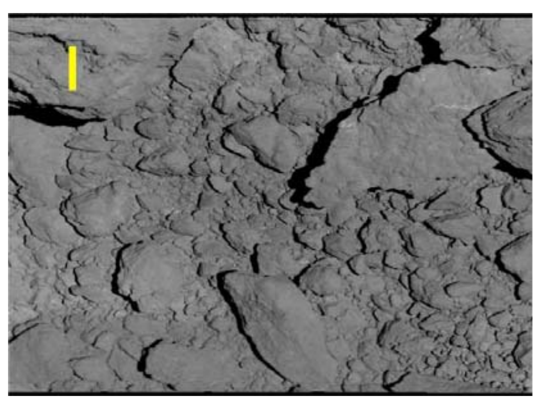

Figure 2 High resolution image of surface boulders of Itokawa (a scale in the image denoting 1m) obtained by Hayabusa (JAXA). Boulder surface looks dark with brighter spots. The surface is lack of fine regolith.

According to the observation by Mariner 10, Mercury also has more impact craters associated with bright ejecta and rays than the Moon (Figure 3). This might imply that the weathering rate on Mercury is slower than that on the Moon, although dust flux and solar wind flux causing the weathering should be one order of magnitude of larger on Mercury than on the Moon [20].

Size of nanophase iron particles should affect the space weathering [21]; reddening is mainly controlled by smaller nano-particles. On Mercury, the size of nanophase iron particles could increase by Ostwald ripening at high temperature of several 100 degree. Less weathering degree would be expected at lower latitude where the surface temperature in daytime is higher [22]. There would be another cause for the growth of nanophase iron particles. Laser irradiaiton experiments showed apparent growth of nanophase iron particles after repeating irradiation. Repeated heating by dust impacts as well as solar wind irradiation would have caused the growth of nanophase iron, which would saturate the weathering degree.

Of course, we cannot ignore the possibility that the difference of weathering rate would be explained simply by compositional effect (e.g., less Fe on Mercury). The other possibility for attenuating space weathering on Mercury would be deeper mixing depth (Figure 4). The surface mixing by impacts on Mercury is greater than that on the Moon, because of higher impact flux and velocity of incoming meteoroid bodies.

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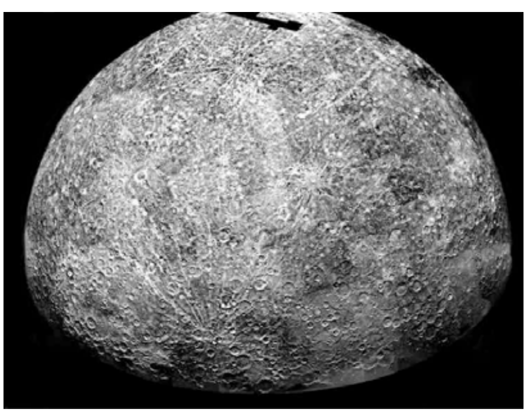

Figure 3 Mercury surface with rayed craters (NASA).

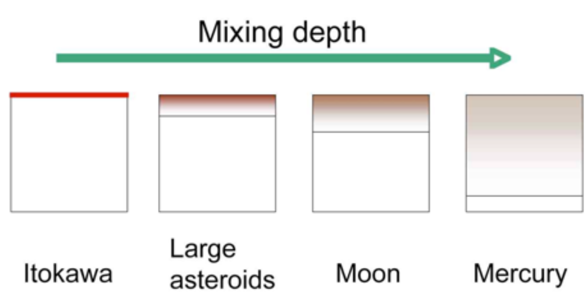

Figure 4 A model of surface mixing with various mixing depth. Space weathering degree would be lower with the larger mixing depth.