Surface regolith mixing and space weathering of small solar system bodies

Sho Sasaki[1]; Takahiro Hiroi[2]

[1] RISE, NAOJ; [2] Dept. Geological Sci., Brown Univ.

The surface of airless solid silicate bodies shows darkening of overall reflectance, spectral reddening, and attenuation of absorption bands in time. Space weathering is considered to be responsible for these changes of optical properties. The space weathering should be microscopically the 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. Nanophase iron particles have been confirmed in lunar soils as well as meteorite sample. Experimental studies also confirmed the formation of nanophase ion particles on the surface should control the space weathering.

Although there are many S-type objects but few Q-type (ordinary chondrite-like) objects among the observed main belt asteroids, number of Q-type bodies increases among smaller near-Earth asteroids. Spectral slopes of near-Earth asteroids suggest that the transition from Q-type objects to S-type objects occurs around the size range 0.1 to 5km. It is advocated that the presence of regolith on larger bodies should enhance the space weathering. Smaller asteroids would not have weathered surface because regolith is scarce due to smaller gravity. Impact ejecta should have escaped and not accumulated back on the asteroid.

In 2005, the Japanese asteroid explorer Hayabusa observed a small (-550m) S-type asteroid (25143) Itokawa. The rocky small asteroid has weathered surface although it is lack of regolith; weathering there should have proceeded in a timescale of 10Ma. Itokawa is heterogeneous in both albedo and color, where the albedo difference is as high as 30% and brighter regions appear as patched areas. Color and spectral studies show that these variations can be explained by the space weathering process on LL (probably LL6) chondrite.

High resolution (cm) image on a darker boulder-rich terrain of Itokawa shows various size of dark boulders without fine regolith. Some large boulders have brighter scratches on the surface. This feature can be explained by impacts of small meteoroid particles if the rock surface is composed of a very thin weathered layer. Pulse laser irradiation simulating the space weathering shows that ordinary chondrite pieces without particulate surface can be weathered. It is probably because the chondrite surface has microscopic porosity.

Larger airless silicate bodies such as larger asteroids, the Moon and the Mercury are covered with regolith. The surface mixing probably caused by impacts would have weakened the weathering on the particulate surface. This mixing effect should be prevailing on larger bodies covered with regolith. The older view that the presence of regolith would strengthen the weathering should be corrected. 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.

Mariner 10 observations show that Mercury also has more impact craters associated with bright ejecta and rays than the Moon. This might imply that the weathering rate on Mercury is significantly slower than that on the Moon, although dust flux and solar wind flux causing the weathering should be one order of magnitude of greater on Mercury than on the Moon.

There is a possibility that the difference of weathering rate would be explained simply by compositional difference. If iron content on Mercury surface is significant low, we cannot expect high weathering degree. The other possibility for attenuating space weathering on Mercury would be deeper mixing depth. 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.