SIGNIFICANT ROLE FOR REGOLITH SOILS TO PRODUCE CARBON-BEARING GASES TO THE INTERIOR ON THE MOON AND ASTEROIDS COMPARED WITH EARTH-TYPE PLANETS. Y. Miura[1, 2]. [1]Yamaguchi University, Yamaguchi, 753-0074, Japan, dfb30@yamaguchi-u.ac.jp ; [2]NASA-JPL (Caltech), Los Angeles, USA.

Introduction: Formation processes of carbon-bearing (secondary) *atmosphere* on the Earth-type planets (Mercury, Venus, Earth and Mars) are mainly discussed isotopic gas compositions and impact-ejectors to produce gaseous atmosphere, though there is few consideration of *in-situ target-rock* [1, 2, and 3]. However, the target rocks are assumed to be based on the Earth-types of *crystalline* target-rocks [1, 4]. Recently on any shock wave condition, carbon-bearing gases are remained as various *carbon-bearing solids* on the Moon, Asteroids and Earth including artificial experiments [5-7], which can be applied to different target rocks of *porous* and *glassy* regolith soils. The main purpose of the paper is to elucidate new proposed model of carbon-bearing light-gases process (in air or solids) from impacts on porous rocks of volcanic and regolith soils of the Moon and Asteroids by comparing with the Earth-type planets.

Three topographic features on the surfaces: Three types of surface topography are obtained on the Moon and Earth-type planets as follows [1, 4, 5 and 7]:
1) *Cratered surface*: Main cratered surface is found on the Moon (and Asteroids) without atmosphere.
2) *Volcanic surface*: Main volcanic surface with long history is obtained at Venus, Earth and Mars with atmosphere.
3) *Both active volcanic and crater surface*: Active surface with volcanic and cratered features is found at present Earth with thick atmosphere.

From the above comparison, the surface topology is largely related with secondary atmosphere situation.

Target rocks to control light-gases: Hard crystalline target rocks of the planets produce evaporated light-gases (CO_2 and H_2O) to form atmosphere by continuous multiple impacts [3, 5 and 7]. This is confirmed by laboratory impacts on the hard target rocks to produce many fine particles with gas, liquid and solid states (*cf.* Fig. 1). On the other hand, regolith soils (called as “agglutinates” [1, 7]) with many voids, glasses and crystalline grains formed by multiple impact-mixing processes are observed on airless Moon and Asteroids [1, 5 and 8]. Void-rich target is indirectly checked by high-speed impact on crossed fiber texture with many voids (*cf.* Fig.1) [9].

Pit-type craters on the Apollo surface: Among larger craters on the airless Moon, many *smaller* impact craters (defined as “pit-type *depression* crater”) are considered to be significant roles of (*cf.* Fig.2) a) *light-gases* of projectiles (meteorites etc.) are transported into deeper *interiors* due to voids-rich mixed soils without much water or oxygen (not evaporated outwards so much finally) which are consistent with the analytical data of carbon-rich regolith soils and breccias [1, 10], and b) complicated *materials changes* between crystal and glass which produce multiple state-changes by impact energy. This process can be confirmed by uplift-gases from the interior and hole (depression)-structure at voids-bearing target rocks (on the Moon and Mars by recent space-explorations [11]; Fig.2).

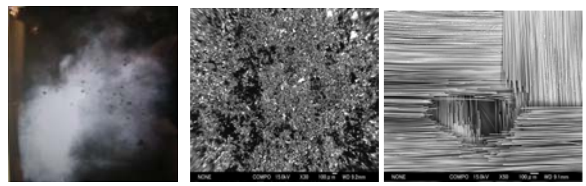

Fig. 1. Differences of impacted textures as fine light-ejectors (left), and fine mixed grains (middle) on hard rocks, and hole in fiber texture (shocked carbon in right FE-SEM [10]).

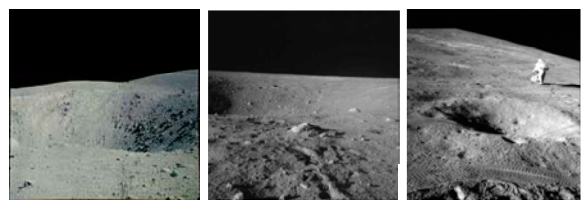

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Fig. 2. The pit-type lunar craters near landing-sites of the three Apollo 12, 15 and 16 missions. Regolith soils play roles of filters to pass light-gases into the interior [11].

Formation and maintenance of atmospheres: After the first original atmosphere of hot hydrogen and helium from the solar gases are escaped into space [1], then continuous surface impacts on *hard targets* of crystalline rocks by planetesimal or meteoroids produce light-gases evaporated to form *secondary atmosphere* [1-4, 12] (Table 1). However, when meteoroids projectiles are collided to the voids-rich regolith soils, light-gases are transported to deeper interior which are resulted in poor evaporated-gases uplifted than crystalline hard-rocks to form *secondary* atmosphere as shown in Table 1 [12, 13]. The voids-rich targets of lunar regolith soils play similar role of “reservoir” of *light-gases* (CO_2 and H_2O) during multiple impacts from projectiles of meteoroids to lunar interior.

Changes of carbon amounts on lunar soils: In order to analyze carbon-bearing phases formed by impact process, the reported data of the Apollo lunar

Table 1. Target textured surfaces for light-gas reservoirs .

Target materials	Gas reservoirs (air or solid) .
1) Hard crystalline rock	Atmosphere (Evaporation of light-gases). Earth planet.
2) Regolith porous soils	Interior fixing (Penetration of gases to solid).The Moon .

Table 2. Cycle of carbon-bearing gases on Earth-type planets.

Carbon-bearing cycles	Earth-type planets & the Moon .
1) Transportation by impacts on hard rocks and atmosphere:	Earth, Mars & Venus
2) *Impacts on regolith soils and little stable atmosphere:*	The moon, Asteroids & Mercury.

regolith soils are checked as shown in Fig. 3 which suggests irregular changes at the Apollo 15 drilled stem fines [14] and four Apollo-landing surface soils [15], whereas reported bulk carbon amounts are mixed with the solar winds, extra-lunar projectiles and impacted carbon-bearing micro-grains which should be analyzed in details more in future lunar explorations.

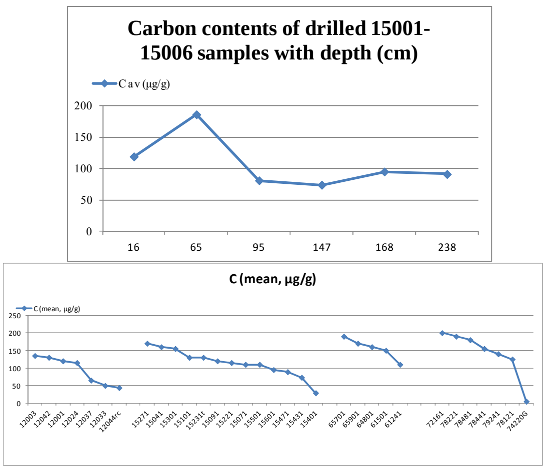

Fig. 3. Considerable changes of carbon amounts of Apollo 15001-15006 drilled stem s (above), and those of four Apollo-landing sites (12, 15, 16 and 17) as surface soils of the 32 Apollo lunar samples [14-17] (below).

Application to carbon-bearing gases cycles: The present proposed model can be applied to carbon-bearing cycles on the Moon, Asteroids and Earth-type planets as follows (Table 2):

1) *Light-gases* (*CO_2* and H_2O etc.) are transported by impacts on *crystalline rocks* mainly to form *in-situ* evaporated *atmosphere* (on Earth, Mars and Venus), or on *voids-rich regolith soils* to form craters to be also reserved as *carbon-bearing* light-gases phases at *the interior* on the Moon and Asteroids (probably Mercury).

2) Reserved gases in the *interiors* are evaporated relatively by main *tidal* (*i.e.* gravitational) forces (on the Moon, Asteroids and Mercury), main gravitational *volcanic* activity around the equators (Mars and Venus), and both *complicated* volcanic activity (Earth). Hot and cold CO_2 problems (Venus and Mars, respectively) [18]are analyzed more in the next space-explorations.

Summary: The results are summarized as follows:
1) Cratered surface of three-type surfaces on the Moon and Earth-type planets shows voids-rich regolith soils as significant roles of light-gasses transportation in the interior on the Moon and Asteroids without major evaporated atmosphere. 2) Shock-wave experiments on voids-rich carbon fiber texture are confirmed to regolith-type impacts to show penetrated features to deeper place, compared with ejected fine grains formed at the hard crystalline target rocks. 3) Continuous impacts on regolith soils are observed at various craters (esp. pit-type) on the Apollo landing sites. 4) Regolith-type surface produce air-less Moon mainly to reserve light-gasses to the interior, especially on the Moon. 5) Significant carbon amounts are obtained at lunar surface and drilled samples on the reported Apollo documents.
6) Transportation of light-gases on target materials during the impacts produces different carbon-cycles on the Moon and Earth-type planets finally .

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