FORMATION OF MOON-TYPE ROCKS BY MULTIPLE IMPACTS WITH POROUS, CRYSTALS AND GLASSY SOILS.

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Introduction: Previous planetary and lunar surfaces are considered to be formed by primitive crystalline rocks and minerals (called as “Earth-type rocks) with homogenous feldspar-rich layers related with magma ocean process [1, 2]. Many anomalous data of lunar rocks can be explained by heterogeneous regolith soils with many voids, glassy and crystalline grains on airless Moon or Asteroids (called as “Moon-type rocks” in this paper). The main purpose of the paper is to elucidate lunar surface formation by multiple impacts on regolith soils with agglutinate glasses on airless Moon and Asteroids, by comparison with homogeneous Earth-type rocks with crystalline minerals, together with carbon-bearing products on impacted materials.

Impact rocks on crystalline target rocks: Crystalline target rocks on the Earth-type rocks of air-planet are obtained at the oldest crystalline rocks of anorthosite, gneiss and granite on the major continents, though impacted heterogeneous targets on airless primordial Earth are considered to be similar to those on present airless Moon. Impact products on large and hard crystalline targets of the Earth-type rocks are impact breccias (pseudotachylite), melt glasses (suevite) and shatter-cone textures with impact minerals of shocked quartz, labradorite-feldspar, zircon and carbonate [3-5].

The Apollo lunar rocks show heterogeneous impacts rocks of breccias, glasses and impact rocks on the anorthosite (*i.e.* FAN) and evolved norite and troctolite (*i.e.* Mg-suite) [1, 2, 6]. However, shattercone and shocked quartz of silica-rich silicate rocks could not be obtained clearly on the Apollo lunar rocks, which indicates that continuous rock-crystallization from mafic (olivine and pyroxene of peridotites or basalts) to felsic minerals (Ca- to Na, K-feldspars of large granites or rhyolites) up to silica quartz cannot be developed probably due to interruption by multiple impacts (*cf.* Table 1) .

Table 1. Main impacted products by two-type target rocks.

Target rocks	Impacted rocks and minerals
1) Hard crystalline rocks. *(On air-planets)*	Breccias. Shatter-cone. Shocked Quartz grains. Plagioclase glass.
2) Regolith porous soils *(Airless Moon etc.)*	Breccias. Agglutinates. Glasses. Regolith-type voids mixture [7] .

Impacts on lunar regolith soils with mixed glass and voids: In order to explain main differences in Earth- and Moon-type rocks, characteristic target rocks of regolith soils should be analyzed in details. Regolith soils on the Moon are considered to be formed by impact debris of the primordial lunar rocks, though there are following problems without crystalline magmatic rocks formed by magma-ocean model (Fig. 1):

1) Proposed pristine Apollo lunar rocks (FAN or Mg-suite) separated by magma-ocean process reveal plagioclase-rich rocks with *significant Fe, Ni and Co* contents of extra-lunar compositions (Fig. 2) [8-11].

2) Different target rocks on the oldest lunar rocks can be explained on the Apollo samples (67216 FAN or 16110 Mg-suite rocks etc.) [12] as *heterogeneous aggregation* of primordial Moon.

3) Compared with younger basalts (15555, 12051), relatively older lunar rocks and breccias (15418, 14321 and 14303) show *higher porosities* (ca. 2 to 9 times) and lower density by impacts [12] (Fig.1).

4) Figure1 suggests that older surface rocks of the airless Moon (and some Asteroids) reveal heterogeneous target materials with *regolith-type mixtures* of voids, crystals and glasses formed by multiple impacts (called as “*agglutinates*” [6-7] rather than crystalline rocks separated by magmatic-ocean.

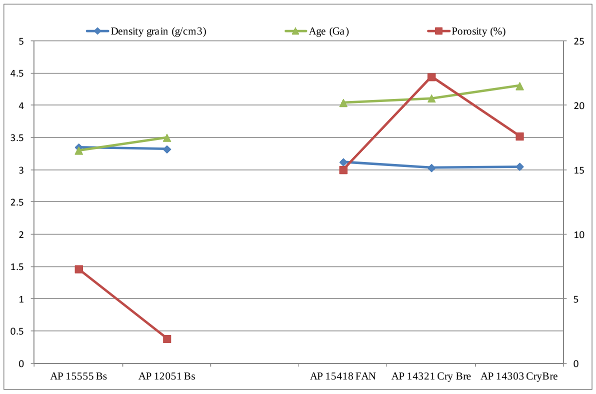

Fig. 1. Characteristic data of density, porosity and age compared with the pristine Apollo lunar samples of Mare basalt (15555 and 12051) and highland anorthosite (15418) and breccias (14321 and 14303) by reported data [1, 2, 6, 7, 12]. The diagram suggests that primordial lunar rocks reveal heterogeneous target materials with mixtures of voids, glasses and crystals formed by multiple impacts.

Characteristic Moon-type minerals: The Apollo lunar rocks show characteristic Moon-type minerals different with the Earth-type minerals with slow magmatic evolution as follows [13-16]:

1) Number of minerals analyzed on the Moon is less than a few % than that of terrestrial minerals [1, 6], which suggests that primordial lunar basement rocks have little alteration by any hydrothermal activity.

2) Major crustal minerals of plagioclase shows a) higher amounts of foreign Mg and Fe from mafic minerals [6, 8, 14], b) a few vacant sites in Ca-rich plagioclase composition (without major cation elements) with carbon ele-

ment [15, 16], and c) few lunar plagioclase has micro-lamellar textures during formation with slow-cooling [14] .

3) Impact breccias contain significant amounts of carbon, chlorine and rare-earth elements (REE) which indicates formation condition of significant impact indicator of impact process [13, 15, 16, and 17]

Impact signatures by carbon and Fe-Ni-Co contents: Significant amounts of iron-meteoritic components (Fe, Ni, Co) and carbon element can be applied to dynamic impact mixing process on the lunar samples [1-12] in details as follows (Fig. 2):

1) Five pristine lunar samples of two anorthosites (FAN-types) and three Mg-suite-types show interesting suggestion to lunar dynamic processes.

2) The oldest FAN breccias (67016) have *higher* data of Fe, Ni, Co and C contents than younger crystalline FAN sample (67075) [10, 11, 18], which indicates first *pristine* FAN sample shows *dynamic impact* process to form the surface (Fig. 2).

3) The oldest Mg-suite-type samples (76535 and 15455) [18] with *less* values of the above four contents show the *highest value of Ni* contents of the 14321 breccias, which indicates dynamic *mixing* process at shallow interior on *later stage* (Fig.2).

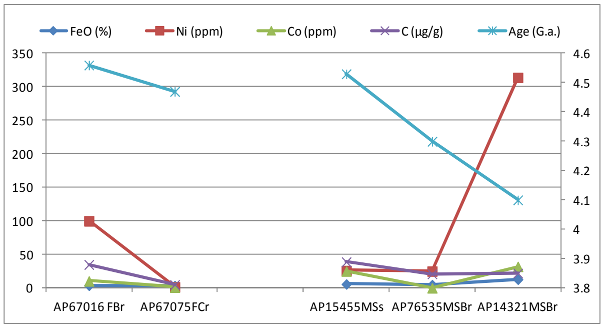

Fig. 2. Five data of FeO, Ni, Co and C contents and age of two highland (FAN) and three evolved (Mg-suite) Apollo lunar samples [1, 18] to show dynamic impacts.

Formation of crystalline blocks by impacts: The similar crystalline rocks with the Earth-type magmatic melting process might be formed from mixtures of glassy agglutinates in the regolith soils to be crystallized during heating relatively at higher temperature with slow cooling near *central peak site* of larger impact crater [9-11]. The detailed study will be discussed in other submitted abstract paper of the LPSC-2012 meeting [11].

Summary: The results in this study are summarized as follows:

1) Moon-type rocks with regolith soils are formed by multiple impacts on heterogeneous surface, which are confirmed by two combined reported data of a) density, porosity and age compared with the pristine Apollo lunar samples of Mare basalt and highland breccias, and b) FeO, Ni, Co and C contents and age of the two highland evolved rocks.

2) The diagram of density, porosity and age suggests that primordial lunar rocks of the highland anorthosite and breccias reveal mixed target materials of voids, glasses and crystals formed by multiple impacts.

3) Five data of FeO, Ni, Co and C contents and age indicate first FAN sample with dynamic impact step, whereas Mg-suite-type with less values of the above four contents show the highest value of Ni contents on the sample of later stage by dynamic mixing process.

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