Carbon and Rare-Earth-Elements of the Moon and Meteorites.

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Introduction:

Carbon and rare-earth elements (REE) are remained in impact breccias on the Moon [1-4]. The main melting process to produce elemental concentration of "Moon-type (or asteroids-type) deposits" is considered to be" impact process" with state changes [2-4]. The main purpose of the paper is to elucidate the Moon-type (or asteroids-type) elemental concentration on carbon and the REE, which will be one of main target for next lunar space exploration [3, 4].

Carbon in meteorite:

Formation condition of E-meteorite is relatively vacuum (with less oxygen) and collisions processes on Fe-rich larger asteroids bodies, whereas H, L, and LL-meteorites shows relatively intermediate condition of vacuum and collisions at different Fe contents of smaller bodies (Fig.1).

The C (carbonaceous)-stony meteorite is formed from relatively crust-rich bodies (less SiO_2 and MgO) with collisions to generate CO_2 gas and Oxygen gas to form water with solar wind hydrogen, where Ca contents are increased to form minor carbonates with fluid condition (Fig.1).

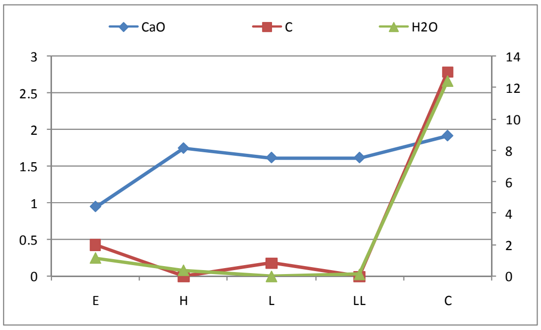

Fig.1. Chemical (bulk) diagrams of CaO-C-H_2O in five major chemical groups of meteorite. The carbonaceous meteorite has clear increases of carbon, water and CaO.

Carbon and REE in the Moon and asteroids:

Carbon element is one of 30 elements which are enriched in carbonaceous meteorites than terrestrial crustal rocks.

The Apollo samples contain more carbon in breccias samples, which indicates as follows:

1) Carbon sources which are three sites in terrestrial breccias (i.e. meteorites, atmosphere and target rocks), are only two sites of projectile meteorite and target rocks.

2) On airless Moon it should be contributed from the solar winds components with gaseous elements around the Sun originated the asteroids and planetary materials, which are difficult to identified only carbon isotopes due to unknown sources of carbon for previous collected samples.

The REE elements are used to be contained in carbon and calcium in several terrestrial minerals. However, Figure 2 shows enriched REE in terrestrial crust rock and less REE in carbonaceous meteorite from the elemental abundances based on Si.

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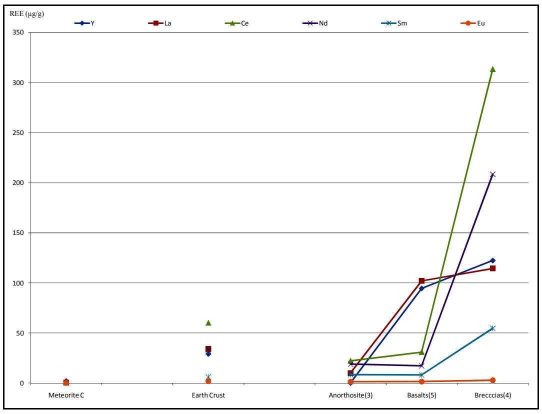

Fig. 2. Average contents of carbon and the REE-Y, La, Ce Nd, Sm and Eu in the Apollo samples of the highland anorthosite, basalts and impact breccias [1-4].

The impact breccias of the Apollo lunar rocks are only valuable samples to discuss the sampling sites and thin-section textures in wide area. Figure 3 shows Y and Ce of the REE elements are separated clearly in carbonaceous meteorites and terrestrial crust.

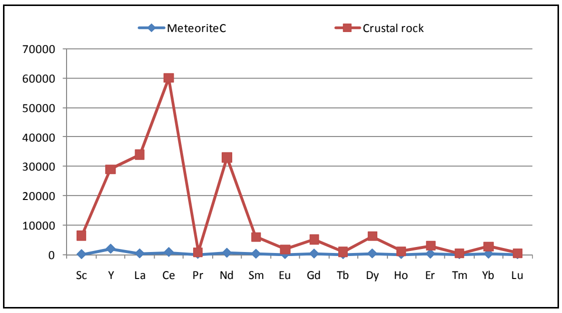

Fig.3. Elemental abundances of the REE on carbonaceous meteorite (Y-rich) and terrestrial crust (Ce-rich). Content in Y-axis shows ppm (by weight).

Figure 2 shows that carbon and REE (Y, Ce and Nd etc.) contents are increased largely at the lunar polymict breccias among the highland troctolite, volcanic basalt, regolith soils and impact breccias as follows (Table 1).

1) All contents of carbon and the REE are largely deficient in the highland rocks with Ce-rich peak. This data indicate that crystallized minerals do not include the REE due to localized melting and crystallization at silent lunar crust than terrestrial crust rocks during the crustal developments.

2) Volcanic basalts shows lower REE contents, though the REE contents of Y and Ce elements are higher contents.

3) Regolith soils show higher contents of carbon and the REE (especially Y element). This suggests that regolith soils are mainly originated from basaltic rocks (at the Apollo sampling sites of the near side with major Mare basalts) or carbonaceous meteorites.

4) Polymict breccias show the highest contents of these REE elements, especially Ce and Nd. This indicates that Ce content is considered to be significant indicator of impact melting mixing, though high Nd content has contribution for magnetic properties around the impact craters due to its high magnetic properties, as new interpretation based on the REE content on the lunar impact breccias. However, there are some Y-rich breccias in the Apollo basaltic landing samples as one of the target rocks by meteoroids.

Table 1. Anomalous data of lunar REE and carbon

1) *Carbon and the REE:*
The highest contents in the polymict breccias

2) *Y and Ce contents of the REE:*
Clear increase in polymict breccias

Enrichment of the REE on the Moon:

The present result of REE-rich lunar breccias on the Moon by comparison with the terrestrial REE-bearing rocks as follows:

1) The REE at primordial Moon and Earth are continuously transported to the surfaces mainly from meteoritic impacts. This is mainly because carbonaceous meteorites and lunar highland rocks have exceedingly lower REE contents, than the impact breccias on the Moon and terrestrial Sudbury breccias.

2) When we discuss the planetary materials with time and location factors, the main source of the REE is originated from meteoritic materials at the first transportation as shown in the Apollo lunar breccias. However, on active Earth with continuous followed melting processes, the REE-rich rocks can be found at terrestrial crusts as Earth-interior origin than meteorites.

3) The REE-rich rocks are considered to be found at all impact melting breccias on the Moon, Mars, Earth, Venus and Mercury. However, terrestrial REE-rich rocks are finally difficult to discuss the main REE sources due to complicated melting processes on active Earth as many stored localities.

4) The present results of the REE-rich rocks indicate next new REE resources on extraterrestrial rocks especially in impact breccias.

Summary:

The present results can be summarized as follows:

1) There are clear increases of carbon and water in the carbonaceous stony meteorite, together with Ca content in bulk composition.

2) The carbonaceous stony meteorite is formed from relatively crust-rich bodies to generate CO_2 gas and water with increase of Ca contents, which is obtained also in the Tagish carbonaceous meteorite.

3) The lunar Apollo breccias contain the highest amounts of the REE (esp. Ce) deposits with carbon, which will be strong material indicator of impact melting signature in impact craters.

4) The REE deposits can be explained as planetary materials with significant time and location factors to be melted. The Main source of the REE is considered to be originated from meteoritic materials at first transportation as shown in the lunar breccias.

5) On the other hand, on active Earth with continuous complicated melting processes of volcano, meteoritic impact and earthquake, the REE-rich rock can be found finally on terrestrial crusts concentrated, as Earth-interior origin (with multiple steps for the REE concentration).

References:

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