EXPLORATION OF CARBON-BEARING MATERIALS ON THE MOON. Y. Miura, Inst. Earth Sci., Graduate School of Sci. & Eng., Yamaguchi University, Yoshida 1677-1, Yamaguchi, 753-8512, Japan, yasmiura@yamaguchi-u.ac.jp

Introduction: All elements on the Moon as exploration are mainly discussed on the elements based on Apollo mission rocks. Carbon element which is inevitable for circulation sysyem on the active Earth and expected life activity on the Moon and Mars is considered to be explored. In order to explore carbon element on the Moon, suitable locations on the Moon are analyzed in this paper.

Carbon abundances in the Universe and the Solar System: Four elements of hydrogen (H), oxygen (O), carbon (C) and nitrogen (N) are inevitable for human and living resources for circulation system. From elemental abundances of elements C, H, O and N in Universe, the Sun, carbonaceous meteorites, and crustal rocks, sea water and human on Earth [1, 2], the followings are characteristic.

1) Element H is abundant in Universe and the Sun than in terrestrial materials of water and human.

2) Element O is much on the Earth as water, human and crustal rocks.

3) Elements C and N are the same behaviours that much concentration in human body than in any extra-terrestrial materials.

Meteorites of carbonaceous chondrites are main sources of elements C, N and O in the Solar System (except the human body), as listed in Fig.1. This suggests that three elements C, H and N are concentrated elements in the Solar System by impact growth process [2, 3] due to richer elements than the Sun and the Universe. As most abundant materials of the three elements are human body and sea-water of the Earth, then rock materials are main resources of elements O and C when we go out from the Earth which there are concentrated materials of the four elements of C, H, O and N (Figs.1 and 2).

The above consideration indicates that when we go to the Moon to explore lunar resources, main resources of three elements of H, C and N are mainly supplied from carbonaceous chondrites on impact-related rocks on the Moon (except H from the Sun), though element O is rich in lunar rocks as in the same as crustal rocks of the Earth.

Loc/ppm	H	O	C	N
Universe	750000	10000	5000	1000
Sun (S.S.)	750000	9000	3000	1000
C.Meteor.	24000	410000	15000	1400
Earth C R	1500	460000	1800	20
Earth S W.	107800	857000	28	0.5
Earth Hum	100000	610000	230000	26000

Fig.1. Elemental abundances of C, H, O and N in Universe and the Solar System of the Sun, carbonaceous meteorites, and Earth materials of crustal rocks, sea water and human body [1, 2].

Carbon abundances on the Moon: Carbon element is strongly richer in crustal rock of the Earth (ca. 25 times higher) than lunar rock in the Moon (cf. Fig.1). However,

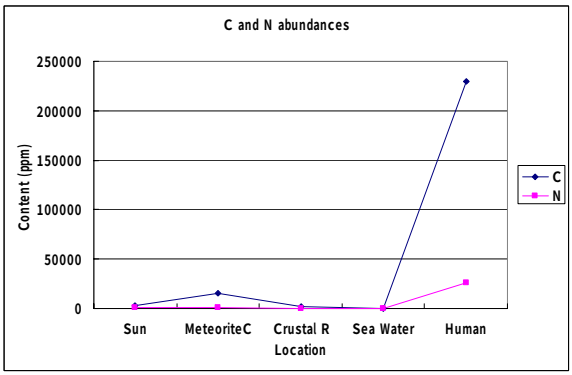

Fig.2. Elemental abundances of carbon and nitrogen in the Sun, carbonaceous chondrites, and terrestrial materials of crustal rocks, sea water and human body [1, 2].

In comparison, nitrogen element is rich in terrestrial atmosphere but very poor in crustal rock of the Earth due to much concentration to human body. Nitrogen on the Moon is rich in surface rocks formed by impacts (ca.3.5 times higher) than rocks in the Earth. Therefore, nitrogen is rich on the lunar rocks [1-3].

Extra-lunar origin of carbon element on the Moon: Extra-lunar origins of carbon can be found at fine breccias of regoliths on the Moon [4, 5]. In fact, Figure 3 shows that carbon and nitrogen are richer in fine regolith breccias than hard rocks of Apollo mission [4, 5], ca. 3.6 higher than hard rocks.

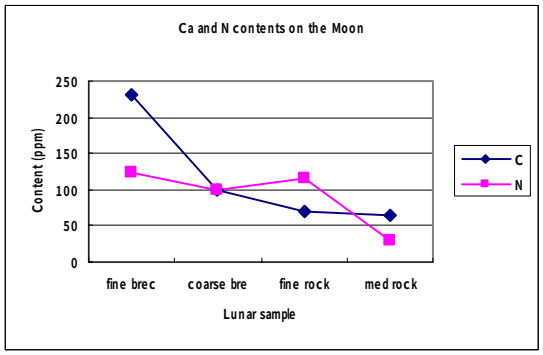

Fig.3. Carbon and nitrogen contents of Apollo lunar samples as fine and coarse regolith breccias, fine rock and medium rock [4, 5].

Impact carbon cycles of lunar system: Although there are no report on active carbon cycles on the

Moon, but impact-induced reaction on the Moon can be expected between lunar rock and fine liquid-vapor system. Due to no large liquid state of sea-water on the Moon, large cycle of carbon system as in Earth (to form limestone and coal etc.) [6-11] cannot be found, but very small cycle of carbon system on the Moon should be found. In fact, there are reports on Apollo lunar sample as carbon and carbide minerals as tiny fragments. Therefore, there is possible impact carbon cycle system on the Moon by two types of projectiles:
1) Extra-lunar impacts by comets to produce fluid carbon states on the Moon.
2) Normal heavy impact by carbonaceous and/or iron meteoroids to form carbides with silicon and iron on the Moon.
3) Carbon storing process on the Giant impact to form the primordial Moon.
Carbon transported from deeper places of the Moon will be future underground exploration on the Moon (Table 1).

Elements rich in meteoroids compared with the terrestrial crust: Apollo lunar samples indicate extra-lunar elements of Pt-group elements and so on from meteorites are found in breccias samples [4, 5]. From elemental abundances of carbonaceous meteorite and terrestrial crusts [1,2], carbon element (rich in carbonaceous chondrites) to form some minerals is higher abundance than terrestrial crust which can be applied to lunar surface. In fact, C is 5.8 times higher, than crust of Earth (Table 1).

Table 1.. Location to find carbon element on the Moon [2-11].

Location of exploration	Remarks
Impact sites near craters	Impact cyclic system
Underground of breccias	Impact mixing
Transportation process	Volcanic up-lift

Summary: The present paper is summarized as follows:
1) The Moon has small cycle of major C-H-O-N elements by projectile impacts of meteoroids or comets.
2) Extra-lunar supply of carbon on lunar regolith breccias by carbonaceous meteoroids and comets are considered to be during shock wave impact event.
3) Locations on the Moon to explore C elements are sites of regolith breccias and volcanic transportation of the Moon.
4) Numerous impact events on the Moon are considered to form local cyclic reaction of element C from primordial age of the Moon.

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