MAFIC, CALCIUM AND CARBON CONTENTS OF THE LUNAR PLAGIOCLASES OF THE APOLLO SAMPLES AND LUNAR METEORITES. T. Tanosaki[1] and Y. Miura[2], [1]Ritsumeikan University, Kyoto, Japan. [2]Faculty of Science, Yamaguchi University, Yamaguchi, Japan (Contact address: Chuou 4-chome 1-2, Yamaguchi, 753-0074, Japan. yasmiura@yamaguchi-u.ac.jp)

Introduction: In order to discuss the compositional characteristics of the Apollo lunar plagioclases with compositional defect calculated in major elements [1-5], reported bulk data of mafic, CaO, and carbon contents are summarized to compare with calculated compositional defects of the lunar plagioclase-feldspars, together with comparative in-situ compositional checking by the lunar meteorites in this study, which are main purposes of the present paper .

Compositional variations of lunar plagioclases: The values of "An content (mol.%)" in plagioclase feldspar minerals based on the Earth (as enough Na, K and Ca exchanges during the slow-formation) are summarized in the Apollo lunar samples with clear collection sites as follows [1-5] (as shown Fig. 1):

1) Sixteen Mare basalts show wide values of 80-95An (mol.%) , 0-1.2MgO (wt.%), and 0.3-2.6 FeO (wt.%).
2) Fifteen Ferroan anorthosites show narrow values of 93-98An (mol.%), 0-0.1MgO (wt.%), and 0.1-0.2FeO (wt.%), except one norite 78235 as high values of 1.5 MgO (wt.%) and 1.2 FeO (wt.%) with 93 An (mol.%).
3) Twenty-five breccias show wider values of 76-98An (mol.%) , 0-0.37MgO and 0.1-0.48 FeO (wt.%).
4) Impact reaction to form breccias produce higher exchange of Ca and Na due to wider change of 22 An content (mol.%) in range values, compared with those of the basalts, where the wider range-values of the compositional mixings are triggered by extra-lunar materials (including solar air contribution) .
5) Lunar plagioclases with "limited Ca-rich region" suggest that there is little progressive evolution on the Moon based on "limited reaction" (mainly Ca-rich) than terrestrial feldspars with wide range-values of K, Na and Ca-end members.
6) Lunar basalts show higher mafic contents of FeO and MgO more than 1.0 wt.% in the half samples, which suggests weaker and limited igneous crystallization (maybe produced quickly after impacts by the extra-lunar objects on the Moon).
7) Lunar breccias show small mafic contents less than 0.5 (wt.%), which indicates that impacts produce light elemental exchange of Na and Ca, but not in the heavy mafic (Fe and Mg) contents within target rocks.

Reported calcium and carbon contents: There are few reported carbon (C) contents on Ca-rich plagioclases on the Apollo samples by in-situ data. However reported Apollo samples data with bulk carbon compositions are summarized as follows [1, 3, 5]:

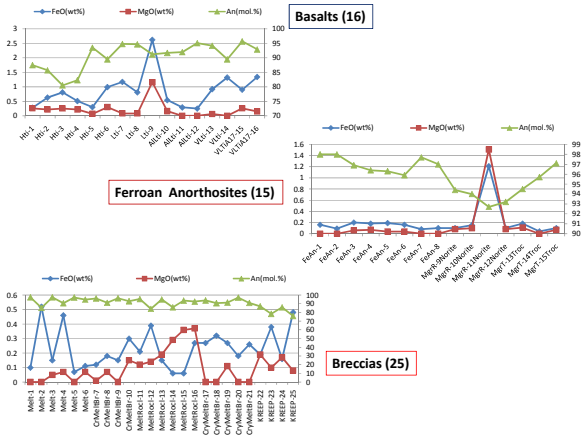

Fig. 1. Bulk compositions of FeO, MgO and An-contents of selected 56 Apollo lunar plagioclases (16 basalts, 15 anorthosites and 25 breccias) [1, 2]. This indicates that impact breccias show wide An-contents.

1) Four kinds the Apollo Mare basalts reveal lower carbon and calcium contents relatively.
2) Five regolith soils of the Apollo 11-17 samples reveal relatively high carbon and calcium contents.
3) Four kinds of breccias of the Apollo 14-17 reveal the highest carbon (385 μ g/g) and calcium (19.2 wt.%) contents among three types of the Apollo samples.
4) Impact reaction to form breccias produces higher calcium with carbon (esp. in Apollo 16 samples), which indicates that higher carbon contents are obtained during impact reaction transported by extra-lunar materials including the solar wind of the solar air.

In-situ FE-ASEM observations of the lunar meteorites: In-situ analyses (*i.e.* without any carbon contamination during sampling) of C (carbon), Fe and Ca elements of two lunar meteorites (including NWA-4483breccias) have been performed by the Field-Emission Analytical Electron Microscopy (FE-ASEM) with the ZAF calculation [3, 5] as follows:

1) The lunar meteorite breccias NWA-4483 include carbon and calcium elements as carbon-rich and calcium-rich grains as shown in Fig. 3.
2) Othergrains of the lunar meteorite show mainly carbon and calcium-bearing grains (see in Fig. 3).
3) Both in-situ analytical data of the lunar meteorites indicate that significant carbon elements are combined with calcium or iron elements in this study.

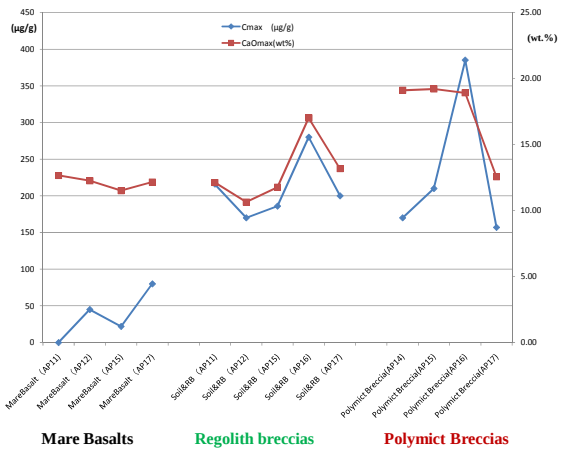

Fig. 2. Carbon-bearing Mare basaltic rocks, regolith soils and polymict breccias of the reported the 13 Apollo lunar rocks [1, 3, 5], where maximum contents of bulk carbon are used in the diagram. This indicates that impact breccias show high carbon contents during impact reaction.

Carbon contents of lunar meteorites

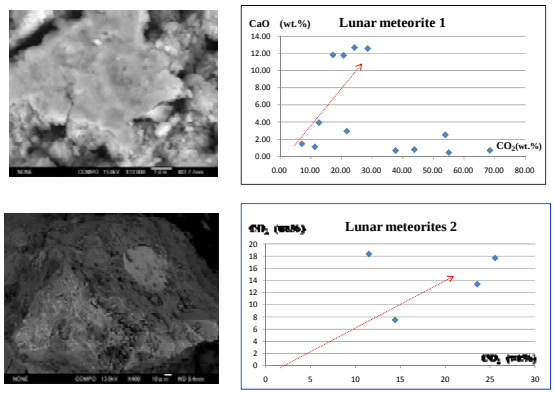

Fig. 3. Carbon-bearing lunar meteorites (NWA-4483) obtained by in-situ analyses of the Field-Emission Analytical Electron Microscopy (FE-ASEM) with the ZAF calculation [3]. Both analytical data indicate that significant carbon elements are combined with calcium or iron elements in this study.

Previous plagioclase An contents: Previous calculation of plagioclase composition with K-Na-Ca in complete igneous evolution (as in the Earth) has little consideration of compositional defects in the main elements of feldspar and carbon contents [1-4]. The appropriate calculation and consideration methods are expected to be developed in the following study [1-5].

Yoshiokaite with compositional defects by impact: The Yoshiokaite in the Apollo lunar sample is found at groundmass of regolith glass in the Apollo 14 regolith breccias 14076 sample as compositional defect of the lunar -related minerals (in other minerals) [6].

Summary: The present study are summarized as follows:

1) From data analyses of reported 56 lunar Apollo plagioclases in three types (basalts, regolith soils and breccias), the breccias samples show higher range-values of 22 An content (mol.%) in difference between lower and higher data, which suggests that Ca and Na in the plagioclases are changed largely during impact reaction. Lunar plagioclase compositions with "limited Ca-rich region" indicates that there are (a) localized Ca-rich plagioclases (due to less active Moon evolution), (b) relatively high Mg and Fe contents (rapidly mixed with mafic elements from lunar mantle rocks mainly by impact-related activity), and (c) calculated compositional defects of the Ca-rich plagioclases probably triggered by impact events with carbon-bearing mixing (transported by extra-lunar materials including solar air with the solar wind contribution).

2) Almost lunar basalts show higher mafic contents to suggest weak igneous crystallization after the impacts, compared with strong elemental change of Ca ele ments.

3) From data analyses of the reported 13 lunar Apollo groups in the three types, the breccias of the Apollo 14-17show the highest carbon and calcium contents , which indicates that higher carbon contents are obtained during impact reaction.

4) In-situ analyses of two lunar meteorites (including NWA-4483breccias) with the FE-ASEM show significant carbon elements combined with calcium or iron elements (also on the Moon).

5) The suitable calculation and consideration methods of plagioclase compositions should be proposed to understand formation processes clearly.

6) Compositional defect of the lunar plagioclases (by impact-related reaction) are supported by the The Yoshiokaite mineral in the Apollo14 regolith sample.

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References: [1] G. Heiken, D. Vaniman and B. French, *Lunar source book* (Cambridge Univ.Press) (1991), 468-474. [2] H.-R. Wenk and W. R. Wilde, *Contrib. Mineral. Petrol.*, 41 (1973) , 89-104. [3] Y. Miura, *LPSC(LPI) 41* (2010) 2462. *LEAG-2010* (2010) 3005. [4] Y. Miura, *LPSC XIX (LPI)* 19 (1988) 1401(794). [5] Y. Miura (2010): *Proc. Int. Symp. Sci. Utilz Moon* (SUM2010) (accepted for pub.). pp.8. [6] D. T. Vaniman and D. L. Bish, *Am. Mineral.*, 75 (1990) 676-686.