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EPMA を用いたアポロ衝撃溶融岩片の全岩組成の推定
Estimation of bulk major element composition for Centimeter-Sized Impact Melt Clasts in Lunar Rocks using EPMA

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Most of lunar surface rocks are brecciated and mixed with various types of rock fragments and impact melt clasts during multiple impact events. We are testing the Late Stage Heavy Bombardment on the Moon surface [1-3] using Apollo 16 centimeter-sized impact melt clasts in ancient regolith breccias. Bulk composition is a key to understand original (pre-impact) lithologies where the clasts come from [4, 5]. Large-sized impact melt rocks (>5 cm) have been classified into 4 major group (Group 1 to 4) according to Sm and Sc compositions [6]. We compiled major element compositions of the previously classified impact melt rocks [6] and found that we can classify major impact melt groups even when we use major element compositions. However, our samples, centimeter-sized impact melt clasts, are highly restricted on their masses and makes us difficult to obtain bulk composition using conventional techniques (e.g. INAA and XRF). Defocused beam analyses (DBA) with EPMA is used to estimate the bulk compositions for limited mass samples using petrological sections, however, nobody tested accuracy of DBA techniques using certified geochemical standard.

We use a thin section of BCR-2 (fine-grained basalt supplied from USGS) and tested accuracy of DBA method using an EPMA (CAMECA SX-100) at NASA Johnson Space Center. We measured 12 elements (Na, Mg, Si, Al, P, K, Ca, Ti, Fe, Mn, Cr, and Ni) at >250 points with 20 micrometer beam diameter. We corrected density effect following the Warren (1997) method [7]. Averaged SiO_2 and FeO have larger difference from USGS values (+4.4 wt.% for SiO_2, -4.68 Wt.% for FeO) relative to other elements (up to +/- 2.4 wt.%). Although there are major changes in SiO_2 and FeO values after correct the density effect (difference from USGS values are up to -4.1 Wt.% for SiO_2 and up to +4.6 Wt.% for FeO), we suggest the DBA compositions can useable for the fine-grained materials to estimate the bulk major element composition for Apollo 16 impact melt clasts.

We estimated the bulk composition by averaged DBA method for two impact melt clasts in an Apollo 16 ancient regolith breccia 61135 which have optically different 5 regions (Clast1 R1, R2, and R3; and Clast 2 R1 and R2) to reveal the original lithology of the impact melt clasts. Five regions from the two impact melt clasts can be divided into three chemical groups of high-K, low-K and intermediate compositions. Clast 1 R3 has high K (K_2O=0.72 wt.%) and P (P_2O_5=0.35 wt.%), and low Al (Al_2O_3=20.7 wt.%) and Ca (CaO=12.0 wt.%). On the other hand, Clast 1 R1 and R2 have low K (K_2O=0.31-0.27 wt.%) and P (P_2O_5=0.08-0.07 wt.%) with high Al (Al_2O_3=26.1-25.2 wt.%) and Ca (CaO=14.5-14.0 wt.%). Clast 2, in both dark and bright regions, has an intermediate composition between high-K and low-K melts (e.g. K_2O=˜0.46, P_2O_5=˜0.16 wt.%, Al_2O_3=˜22.9 wt.%, CaO=˜12.8 wt.%). The bulk Mg# of the 5 regions are similar (Mg#=80-78).

If the melts in the two clasts are related, there are two possible origins: (1) A single impact event hit a complex lithological target and incompletely mixed the melts, to produce high-K, intermediate-K, and low-K melt fractions. (2) An impact produced either a high- or low-K melt. A second impact produced a melt at the other end of the K spectrum. The melts in Clast 1 represent those two end member melts. If the second impact melt digested older fragments of the first impact melt, then that may have produced the intermediate compositions of Clast 2. Alternatively, the melts are not related and require three or more impact events.

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