Multivariate analysis on major element compositions of Apollo 16 impact melt

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Impact melt rocks and clasts form Apollo 16 landing site record heavy bombardment history called the Late Stage Heavy Bombardment (LHB) supported by impact reset ages of the impact melt rocks clustering around 4.1–3.8 Ga [e.g. 1-3]. However, the age clustering might include a sampling bias; for example, some rocks could record the same impact event. Therefore, attempting to identify and characterize individual impact events is important to understand LHB. Bulk compositions is one of important factors to identify the impact event. Bulk chemical composition of impact melt thought to maintain almost average composition of pre-impact target material. Classification of Apollo 16 impact melt has established using trace element compositions using Sc and Sm [4]. Based on the method, impact melts are classified into major 4 groups, Group1 to 4. However, most of the impact melt especially small mass samples does not have such information. Therefore, we are developing new classification scheme using only major element compositions.

We have compiled 330 published data of major, minor, and trace element compositions of Apollo 16 impact melt rocks and clasts [e.g. 4-9]. We selected samples which have 9 major and minor element data (Si, Ti, Al, Fe, Mg, Ca, Na, K, and Cr) and have been already classified by conventional method using trace element information (95 total data). We conducted principal component analysis (PCA).

Our PCA results indicate a difference between mafic and felsic impact melt rocks, although sub-types of Group 2 melt are widely distributed. PC1 distinguishes between mafic and felsic impact melt; more specifically, felsic melt is distinct from mafic melt relatively rich in Fe and/or Mg and poor in Al, Na, and K (wt.%). These elemental compositions have good correlation with PC1 (correlation coefficients are -0.98 and 0.99 respectively for Fe+Mg and Al+Na+K). In addition, our work shows PC2 results correlating with the Mg/Fe weight ratio (correlation coefficient is -0.81; Fig. 2). When we plotted Al+Na+K (wt. %) and Fe/Mg (weight ratio) of Apollo16 impact melt rocks, the plot has similar trends when compared to the PCA-based trends, although the y axis (PC2 and Fe/Mg) is slightly different. Hence, this plot is also useful in the identification of impact melt types using only 5 major elements (Al, Na, K, Fe, and Mg).

Our PCA results indicates that Apollo 16 impact melt rocks can be statistically classified by using only 9 major elements, as well as trace element abundances. Moreover, our results indicate that impact melts can also be classified by using 5 elements by plotting Al+Na+K and Mg/Fe.

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