Lithophile element characteristics of acapulcoite-lodranite.

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Introduction:

Primitive achondrites are important meteorites to understand the early differentiation on asteroid bodies. Chemical compositions of primitive achondrites were affected by various degrees of partial melting [1], and changed from their precursor materials. Incompatible lithophile element abundances are sensitive to silicate partial melting. Among lithophile elements, Na, Al, and K are classified as plagiophile elements. These elements are particularly sensitive to the partial melting of silicates including plagioclase. In this study, we aim to characterize lithophile elements abundances in acapulcoite-lodranite clan meteorites to clarify the differentiation processes on their parent body(ies).

Samples and methods:

A total of 10 meteorites (two brachinites (EET 99402/07 pair) and eight acapulcoite-lodranite clan meteorites (acapulcoite: Dho 125, Dho 290, MET 01195/01198/01244 pair and NWA 725; lodranite: three portions of GRA 95209 and NWA 2235) have been analyzed in this study. Several chips weighing 200-300 mg of each meteorite were ground into powder for instrumental neutron activation analysis (INAA). As most of these achondrites had various sizes and amounts of metal grains, it was difficult to homogenize all the meteorite samples into powder. Therefore, for samples other than brachinites EET 99402/07 and acapulcoite Dho 290, magnetic separation was carried out by using a hand magnet. INAA was performed for the nonmagnetic portion of these samples. For EET 99402/07 and Dho 290, completely homogenized samples were analyzed as bulk samples.

Results and Discussion:

Lithophile element compositions of brachinite samples EET 99402/07 are mostly consistent with each other and literature values [2]. However our EET 99407 is depleted in plagiophile elements and slightly enriched in Ca and Sc. Such differences may be attributed to the heterogeneous distribution of pyroxene and plagioclase in EET 99407.

Lithophile element compositions of acapulcoites Dho 125, Dho 290, and NWA 725 are compared with literature data. Our data are not consistent with literature values [3]. Such a difference is distinct for rare earth elements (REEs). Our results show no Eu anomalies in three acapulcoites, while the samples analyzed by Patzer et al [3] have positive Eu anomalies. However, it should be noted that the compositional trend among these meteorites seems to be the same as noted in literature [3]. NWA 725 is less depleted in plagiophile elements, whereas Dho 125 and Dho 290 are more depleted.

No chemical compositional data have been reported for paired acapulcoites MET 01195/01198/01244. Although chemical compositions of these meteorites are similar to each other, an apparent difference could be confirmed. Potassium abundance of MET 01195 is significantly higher than those of the others. Chromium values of three MET meteorites are largely scattered, which can be explained by the heterogeneous distribution of chromite.

Lodranites GRA 95209 and NWA 2235 show distinct chemical compositions from those of typical lodranites. For GRA 95209, three samples were taken from different positions. GRA 95209 is less depleted in plagiophile elements and light REEs relative to those of typical lodranites. Our data of plagiophile elements and REEs for GRA samples are consistent with those of literature values [3]. It is highly probable that GRA 95209 is a transitional meteorite between acapulcoite and lodranite, as mentioned by Patzer et al. [3] and Floss [4]. No literature data have been reported for NWA 2235. This meteorite shows severe depletion in Na, Al, and Ca. However, K is less depleted. NWA 2235 shows light REE enrichment and negative Eu anomaly. Weathering may explain the enrichment in K and LREEs, considering that these elements are sensitive to the hot desert weathering [5]. However, NWA 2235 shows no enrichment in Sr and Ba (Sr = <27 ppm, Ba = <17 ppm) compared with other acapulcoite-lodranite (Sr = 0.5-203 ppm, Ba = 0.1-100 ppm). Therefore, there should be other reasons for the enrichment of K and LREEs in NWA 2235. Petrological observation of NWA 2235 showed that this meteorite has some Ca-phosphate but no plagioclase [6]. Our compositional data of NWA 2235 are consistent with such a petrological observation.

In a plot of CI-normalized Na/Sc (denoted as $(Na/Sc)_{CI}$) vs. $(Sm/Sc)_{CI}$ (Fig. 1), a classification scheme of acapulcoite-lodranite by Patzer et al. [3] is shown. Compositions of acapulcoites are nearly chondritic and scatter in a narrow range. On the other hand, lodranites are dispersed in relatively broad area. This indicates that most acapulcoites have little experienced silicate partial melting processes while lodranites have suffered various degrees of such processes. Literature value of anomalous meteorite LEW 86220 [3] has anomalously high Na/Sc and Sm/Sc ratios compared with any acapulcoite-lodranite meteorites. The linear correlation between LEW 86220 and acapulcoite-lodranite indicates that migration and intrusion of silicate melts occurred on acapulcoite-lodranite parent body [3]. Brachinite compositions show no compositional trend and have very wide range, overlapping with those of lodranites.

As shown in Fig. 1, our EET 99407 falls within the range of brachinites. Acapulcoite-lodranite clan meteorites analyzed in this study are plotted within the range of acapulcoites, except for NWA 2235. Most meteorites analyzed in this study are plotted within the range of primitive acapulcoites. The compositional range of primitive acapulcoites is consistent with those of chondrites. NWA 2235 is plotted out of the ranges of both acapulcoites and lodranites, and also distinct from another unusual acapulcoite-lodranite meteorite LEW 86220. Apparently, NWA 2235 is not on the trend of acapulcoite-lodranite and LEW 86220. This fact suggests that the petrogenesis of NWA 2235 is different from that of LEW 86220. There must have been another mechanism producing such meteorite like NWA 2235 in acapulcoite-lodranite parent body(ies).

As already described, three plagiophile element (Na, Al and K) abundances are deviated from CI chondrite- and Mg-normalized values in the primitive achondrites analyzed in this study. Figure 2 shows the deviation of these elements from CI and Mg-normalized values for individual meteorites as well as three meteorite groups against CI- and Mg-normalized Se values (expressed as $Se_{(Mg,CI)}$). The deviation shown here is expressed as $\{1\text{-}Al_{(Mg,CI)} + 1\text{-}Na_{(Mg,CI)} + 1\text{-}K_{(Mg,CI)}\}$. Some of our data are not consistent with the range of literature values. Nevertheless, our data and literature data show the same compositional trend. On this figure, three acapulcoites subgroups are clearly separable. In addition, a compositional trend from acapulcoites to lodranites can be seen. From these observations, it is suggested that both Fe-Ni-S eutectic partial melting and silicate partial melting occurred simultaneously on acapulcoite-lodranite parent body. Fe-Ni-S eutectic partial melting and silicate partial melting could be triggered by impact heating, leading the differentiation processes on acapulcoite-lodranite parent body [6, 7].

References:

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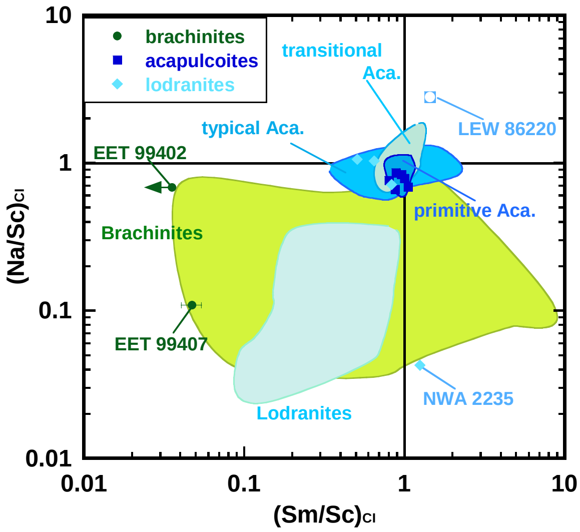

Fig. 1 CI-normalized Na/Sc vs. Sm/Sc ratio. CI values are from [8].

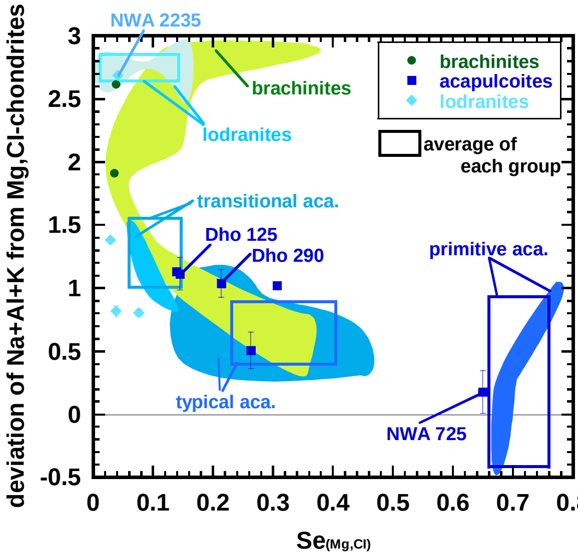

Fig. 2 Mg, CI-normalized deviation of Na+Al+K vs. Se. Literature values are showed as meshed range and box ranges showed the average of each subgroup with standard deviation (1σ).