STABLE ISOTOPE CONTRIBUTION TO CONSTRAINT THE UREILITE FORMATION.

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Introduction: Ureilites are ultramafic achondrite mainly composed of olivine and pigeonite. They are highly fractionated igneous achondrite but have also some primitive characteristic [1]. They are usually considered to be derived from a single parent body (UPB). The chemical composition and texture of ureilites indicate that they could be mantle residues after ~15-30% basaltic melt extraction during ureilite parent body (UPB) mantle melting [2]. Such high degrees of partial melting would not preserve primitive characteristic such as the O heterogeneity which is one particularity of these achondrites. An alternative explanation for the ureilite formation without intensive partial melting is smelting process [3]. This hypothesis suggested formation of ureilites by low degrees of partial melting without any homogenization of the UPB. In this study, we report new oxygen, zinc and iron stable isotopic composition and also ^{26}Al-^{26}Mg systematic for seven monomict ureilites Yamato (Y) 790981, Y 791538, Y 981750, Y 981810, Asuka (A) 881931, Allan Hills (ALH) A81101 and ALH 84136 to constraint the ureilite formation.

Result and discussion: The range of ^{17}O value in our five ureilites vary between -0.493 ± 0.001Ÿ to -1.887 ± 0.023Ÿ, which is consistent with the data previously obtained for other ureilites [4]. These values indicate poor homogenization and are inconsistent with high degrees of partial melting on the UPB. On the other hand, smelting process could occur with a low degree of partial melting where extraction of melt is too fast to erase the initial ê^{17}O signature [5-6].

Zn isotope analysis of the five ureilites yielded heterogeneous ^{66}Zn values ranging from +0.61 ± 0.01Ÿ to +1.06 ± 0.02Ÿ. This heavy isotope enrichment may reflect volatilization processes. In our study, we evaluated the possibility that ^{66}Zn signature could be produced by smelting process during ureilites genesis. To evaluate the effects of such a volatilization process, we modeled the Zn isotope fractionation in ureilites on the basis of the Rayleigh distillation equation, according to [7] when Zn isotope fractionation was explored during the smelting process in the metallurgic industry. In our model, a CI type chondrite initial composition was considered for the UPB precursor. Based on this assumption, we show that the observed ^{66}Zn variability in our ureilites match the data obtained using the smelting process model.

^{57}Fe values in ureilites are homogeneous within the standard error and give a non-chondritic average value of +0.10 ± 0.03Ÿ. This result shows enrichment in heavy isotopes. These ^{57}Fe signatures reflect an efficient extraction of S-rich metallic melt produced during initial metal-silicate segregation [8]. Smelting process requests that the UPB started to melt and the melt hence produced rapidly extracted in order to explain the enrichment in Fe heavy isotope observed.

No isochron has been observed with the $^{26}Mg*$ and $^{27}Al/^{24}Mg$ data analyzed in our five ureilites. If all these samples crystallized at the same time, the $^{26}Mg*$ data suggest our samples could come from different parent bodies. However, our data set could also reflect different crystallization ages from a single parent body. Considering the smelting process for ureilites formation, the second hypothesis could be considered. Indeed, smelting is a local process and could start at various times, depths and locations everywhere on the UPB. Assuming all the ureilites originated from a single parent body, a model age can be determined. This model age reflects the time when the ureilite common source differentiated from a chondritic reservoir. Using the average $^{26}Mg*$ and $^{27}Al/^{24}Mg$ value of non-CAI-bearing chondrite for the UPB precursor, this differentiation can be modelled at 1.09 ± 0.75 Ma after the CAI formation.

Conclusion: Results from several isotopic system (Al-Mg, O, Fe and Zn) indicates that smelting process can explain the UPB differentiation. This single UPB underwent two major steps: a limited melting step (in order to preserve ^{17}O heterogeneity), producing local metal-silicate segregation (^{57}Fe); and a smelting step forming the ureilites enriched in heavy isotopes of Zn. On the basis of this hypothesis and considering a chondritic composition of UPB precursor, we can obtain a model ^{26}Al-^{26}Mg age that suggests a very early differentiation for the UPB.

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