^{26}Al-^{26}Mg Systematic and ^{26}Mg* Anomaly in Ureilites.

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Introduction:

Short-lived radioactive isotopic systems such as ^{26}Al-^{26}Mg are powerful to study the chronology of the early solar system due to their high timeframe resolution during the lifetime of their parent elements. As such, they can be considered as the most efficient chronometers for the first few million years (Ma) of the solar system history. The now extinct radionuclide ^{26}Al, decayed to ^{26}Mg with a half-life of ~0.73 × 10^6 years [1]. This chronometer can thus date only the objects that formed during a period of ~5 Ma after the solar system formation.

Ureilites are the second largest group of differentiated meteorites (260 specimens) after the HED (Howardite-Eucrite-Diogenite) meteorite group. They are ultramafic achondrites mainly composed of olivine and low-Ca pyroxene (pigeonite). They are highly fractionated igneous rock but have also some minor primitive characteristic [2] suggesting a complex history for their formation. Ureilites have been defined as partial melting residues [3] or ultramafic igneous cumulates of a chondritic precursor [2]. Today, there is a consensus about the partial melting residues origin of ureilite. Chemical composition and texture argue that ureilites are mantle residues of ~15-30% partial melting of the Ureilite Parent Body (UPB) mantle after the extraction of basaltic magma [4, 5]

However, the UPB is still unknown. First, O isotope and high C-content (up to 5%) [6] suggest that this UPB could be carbonaceous chondrite but a recent study shows that some chemical and textural characteristics are particular and not found in the known C-rich chondrite types [7]. New investigations confirm that UPB is a single parent body for all ureilites that underwent heating and differentiation very early in the Solar System but disrupted by a major impact rapidly after its formation [8]. Fragments of this first asteroid re-accreted to form a daughter asteroid from which are issued ureilites. However, ureilites recorded the differentiation process of the primary UPB. Dating these rocks can thus give the formation age of ureilites before the disruption of the initial UPB. Some previous studies have dated ureilites with short-lived isotopic systems like ^{53}Mn-^{53}Cr and ^{182}Hf-^{182}W and suggested a differentiation of the UPB and formation of ureilites within 1 to 2 Ma after CAI formation [9, 10]. This implies these meteorites are old enough to be dated by the ^{26}Al-^{26}Mg isotopic system.

In this study, Al-Mg systematic has been investigated in five different monomict ureilites to date these type of achondrite: Yamato (Y-)790981, Y-791538, Y-981750, Y-981810, Asuka (A-)881931.

Analytical techniques:

All the preparation and chemical procedures were realized in clean laboratory at ULB. Around 200 mg of each sample were gently crushed in an agate mortar and sieved for obtaining a fraction between 64 to 150 µm. A fraction of ~50 mg was kept for bulk analyze. We proceeded to mineral separation on all samples. The metallic phase was separated with a hand magnet. The lighter metallic phase was obtained by density separation with heavy liquid (methylene iodide). Mg will be measured in this light fraction only. Magnetic separation using a Frantz magnetic separator was used on the silicate phase to obtain three different fractions: pure olivine (ol.) fraction; pure pyroxene (px.) fraction and a second pyroxene (px.2) fraction. All sample and mineral fractions were dissolved with an HNO_3/HF mixture (2:1) followed by a step in concentrated HNO_3 (+H_2O_2) to destroy the organic matter and a step in concentrated HCl. All samples and fractions were dissolved again in HNO_3 before the Mg separation procedure. An aliquot of each sample was taken without any purification for the ^{27}Al/^{24}Mg ratio measurements. For the whole rock data presented here, Mg was separated using cation-exchange resin (Bio Rad AG®50W-X12, 200–400 mesh). Elution and sample collect were performed with 1N HNO_3. The purification was repeated three times in order to insure a perfect separation of Mg and limited interferences with matrix.

Mg isotopes were measured on ULB MC-ICP-MS Nu-plasma. Samples were introduced in 0.05N HNO_3 using an Aridus desolvating nebulizer. Measurements were performed in medium resolution in order to avoid the possible isobaric interferences (^{12}C^{14}N) [1]. The instrumental mass bias was corrected by standard-bracketing with DSM-3 standard. Each measure cycle for standards and samples consisted of a cycle of three blocks of 20 integrations with a concentration of ~200 ppb, corresponding to ~7 volts on ^{24}Mg. Terrestrial standard BCR-2 was measured between each sample with a δ^{26}Mg* value of 0.006±0.011 to control the accuracy of the measurements.

Result and discussion:

The preliminary results obtained for δ^{26}Mg* on whole rock ureilites are showed in Fig. 1. Ureilites Y-791538 and Y-981750 and Y-981810 show a negative anomaly in δ^{26}Mg* that encompasses the terrestrial value and are respectively -0.031 (±0.030), -0.011 (±0.023) and -0.002 (±0.017). Y-790981 ureilite is fully comprised in the terrestrial domain with a value of 0.001 (±0.005) for δ^{26}Mg*. Finally, only A-881931 ureilite present an excess in δ^{26}Mg* (δ^{26}Mg* = 0.023 ±0.032) partially not resolvable from the terrestrial average. Error bars are relatively large and need to be reduced with further measurements. However, these preliminary results suggest that some ureilites have a deficit in ^{26}Mg*.

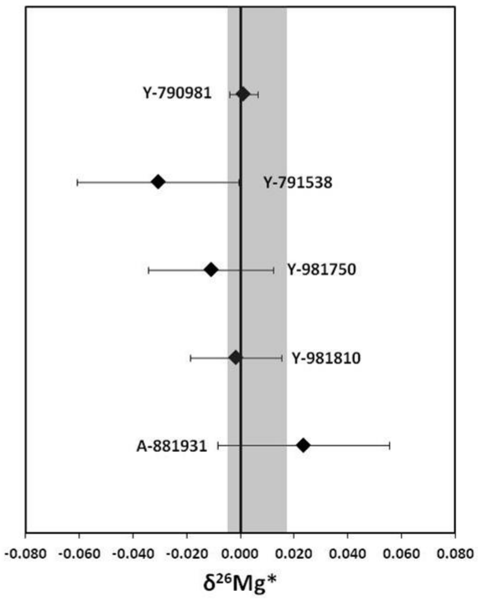

Figure 1: δ^{26}Mg* measurement in the different ureilites analyze. Grey zone corresponds to the terrestrial standard (BCR-2 range value). All sample comprised in this range do not have any δ^{26}Mg* anomaly. Errors shown in this diagram correspond to standard error ($s_e = s_d/\sqrt{n}$). The δ^{26}Mg* is reported relative to the DSM-3 standard.

All these five ureilites have also a sub-chondritic value for the ^{26}Al/^{24}Mg ratios (0.003 to 0.009). Baker et al. [11] observed a correlation between a deficit in δ^{26}Mg* in achondrite (pallasites, ureilites) with a low value of Al/Mg ratios. This observation can be explained by a silicate differentiation of the UPB very early in the solar system history with a lack of ^{26}Al in the ultramafic component of the parent body. This is also an evidence that this type of achondrite formed during the life of the ^{26}Al.

Conclusion:

Preliminary results on ureilites presented here indicate that four of the five ureilites analyzed have an anomaly in δ^{26}Mg*. Internal isochrons on these samples will be performed to date precisely these ureilites with ^{26}Al-^{26}Mg isotopic system. However, the resolvable ^{26}Mg* anomaly is associated with large errors. Further analyzes are required in order to validate our results.

References:

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