

**A NEW ISOTOPE TRACER FOR THE EARLY SOLAR SYSTEM PROCESSES: STABLE CHLORINE ISOTOPES AND DISTRIBUTION OF CL-BEARING PHASES IN CHONDRITES.** N. Nakamura<sup>1</sup>, T. Fujitani<sup>1,2</sup> and M. Kimura<sup>3</sup>. <sup>1</sup>Graduate School of Science and Technology, Kobe University, Nada, Kobe 657-8105, Japan (noboru@kobe-u.ac.jp), <sup>2</sup>Marine Technical College, Ashiya 659-0026, Japan (fujitani@mail.mtc.ac.jp), <sup>3</sup>Faculty of Science, Ibaraki University, Mito 310-8512, Japan (makotoki@mx.ibaraki.ac.jp).

**Introduction:** In order to explore variations and their significance for the early solar system processes, we have established a precise analytical technique of stable chlorine isotopes for chondritic samples and reported preliminary results for 24 bulk chondrites (and one chondrule sample) [1,2]. For the further investigation into the observed Cl-isotopic variations, we present here more detailed discussion on the Cl isotopic composition and distribution of Cl-bearing phases in chondrites.

**Samples and Analyses:** We analyzed 12 bulk O-chondrites (Brownfield H3.7; Tahara H5; Allegan H5; Pultusk H5; Y-74191, L3.6; Hedjaz L3.6; Fukutomi L5; Homestead L5; Parnallee LL3.6; ALH 77304 LL3.7; Soko-Banja LL4; Dhurmsala LL6), 6 bulk samples and one chondrule from C-chondrites ([Orgueil CI]; Murchison CM2; Boriskino CM2; Allende CV3; Ningqiang CV3; Kobe CK4; Maralinga CK4) and 3 bulk E-chondrites (Abee EH4; Indarch EH4; Hvittis EL6). for Cl isotopes by TIMS (precision: ~0.2‰) and for Cl concentration by N-TIMS ID (precision: 1-2%) [1,3]. Due to too small size of sample available for us, Orgueil (CI) was analyzed only for Cl concentration. In addition to the 15 O-chondrites reported by Kimura and Ikeda (1997) [4], 3 chondrites, Y-74191, Murchison and Indarch, were examined for the distribution of Cl-bearing phases in this work.

**Distribution of Cl-bearing phases:** According to [4], main host phases in UOC are feldsparoids such as scapolites and sodalite which are fine-grained (~10µm in size). With increasing metamorphic grade, they are replaced with Cl-bearing phosphates such as Cl-apatites and become coarser (>100µm in size), which result heterogeneous distribution of Cl in EOC.

For Y-74191 L3.7, Cl is distributed abundantly as Cl-apatites (~100µm in size) associated with metal-troilite in matrix and within chondrules and chondrule-surfaces, and occasionally as Cl-bearing groundmass in chondrules (~10µm in size). Distribution of Cl-carriers in Murchison (CM) is quite different from that of O-chondrites; Cl is relatively homogeneous in total area including serpentine + tochilinite and matrix (Cl=0-0.3%). The highest Cl concentration (0-1.0%) was found in the

areas including PCP. More detailed analyses are required to characterize Cl-carriers.

For Indarch EH4, Cl-bearing phases were found in several areas enriched in Fe and Ni, indicating that they were formed from weathering of Cl-bearing phases such as djerfisherite and lawrencite. Because of much different Cl isotopic composition of the bulk meteorite from seawater (see below), possible terrestrial origin of Cl-bearing phases [5] may not be reasonable.

**Distributions of Cl concentrations:** As shown in Fig. 1, the Cl concentrations in O-chondrites range from 44 (Allegan, H5) to 270ppm (Parnallee LL3.6). It appears that the Cl concentration decreases, in general, from low metamorphic grade to higher grade in the same group. However, the large variations of Cl in type 5 chondrites, particularly the highest Cl concentration of Fukutomi L5 and a limited data point of type 6 chondrite may need further careful examinations to confirm if this trend is real or not.

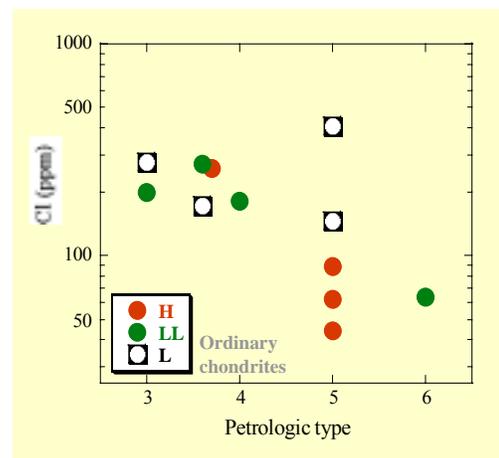


Fig. 1 Plot of Cl concentration vs. petrologic type for ordinary chondrites.

Heterogeneous distribution of Cl concentration (up to 10-20%) for <~0.3g-size samples are also observed for Allende and Murchison. Nevertheless, these variations are still limited compared to EOC. In Fig. 2, Cl concentration is the order of Cl>CM>CV~CK, which is well consistent with the abundance features of volatile elements generally

recognized for sub-groups of C-chondrites.

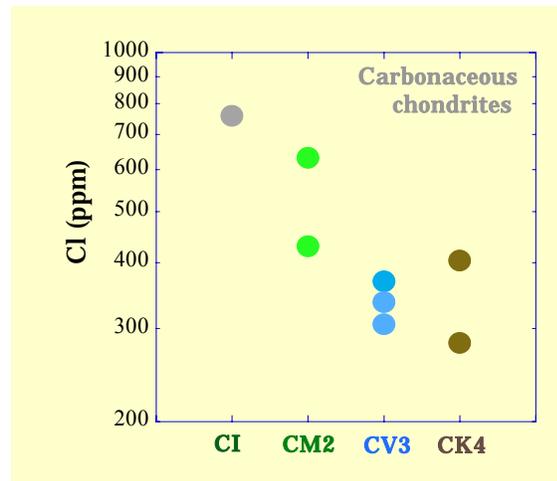


Fig. 2 Plot of Cl concentration vs. sub-groups of carbonaceous chondrites.

**Characteristic isotopic compositions of Cl for chondritic groups:** The isotopic composition of Cl is defined by  $\delta^{37}\text{Cl}_{\text{SMOC}} [\text{‰}] \equiv \{ \frac{[^{37}\text{Cl}/^{35}\text{Cl}]_{\text{Sample}}}{[^{37}\text{Cl}/^{35}\text{Cl}]_{\text{SMOC}}} - 1 \} \times 1000$  (SMOC: Standard Mean Ocean Chloride). As shown in Fig. 3, among 12 O-chondrites analyzed, Allegan (H5) indicates the highest  $\delta^{37}\text{Cl}$  (5.0‰) together with the lowest Cl. On the other hand, Y-74191 (L3.7) shows the lowest  $\delta^{37}\text{Cl}$  (-4.6‰) and the highest Cl. The other O-chondrites display about an array between these two chondrites, crossing the seawater just in the middle. E-chondrites indicate a smaller isotopic variation (possibly due to limited sample number) but are plotted in a distinctly different region from but show a similar trend to O-chondrites: Hvittis, EL6 indicates the highest  $\delta^{37}\text{Cl}$  and Indarch EH4 the lowest  $\delta^{37}\text{Cl}$ . These negative correlations between Cl vs.  $\delta^{37}\text{Cl}$  are characteristic for O- and E-chondrites, suggesting that Cl-isotopic fractionations occurred commonly for both groups. Both groups include different petrologic types related to the thermal metamorphism. We tentatively call this negative correlation as “metamorphic trend”.

A linear fractionation trend also exists for C-chondrites in Fig. 3. Kobe (CK4) indicate the lowest  $\delta^{37}\text{Cl}$  together with the lowest Cl and Boriskino (CM) the highest  $\delta^{37}\text{Cl}$  and Cl. Allende (CV) indicates the middle and heterogeneous  $\delta^{37}\text{Cl}$  among bulk (A and B) and chondrule samples: +2.3, 0.9 and 1.8‰, respectively. The highest  $\delta^{37}\text{Cl}$  of ~5.5‰ is anticipated for Orgueil from the correlation. The order of  $\delta^{37}\text{Cl}$  and Cl is: (CI)  $\geq$  CM  $\geq$  CV  $\geq$  CK. This order is parallel with

degrees of aqueous alteration of C-chondrites, which may be accidental. We prefer the idea that C-chondrites were produced by mixing of two different Cl-reservoirs (end-members).

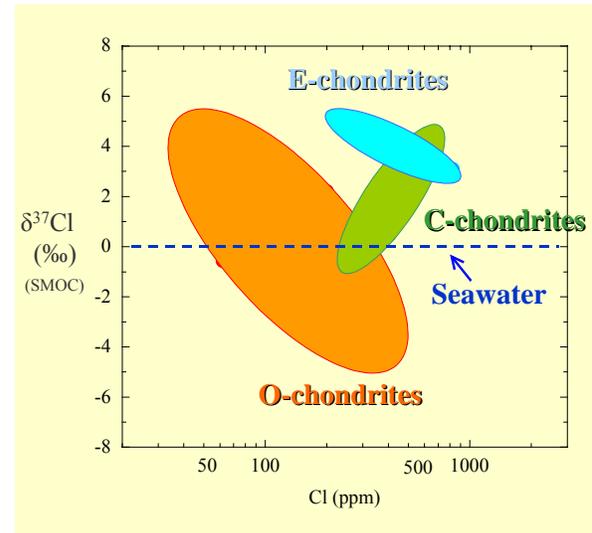


Fig. 3 Correlation between Cl isotopic composition and concentration for different groups of chondrites.

We strongly suggest that the Cl isotopic characteristics (metamorphic and mixing trends) observed for each chondrite-group are indigenous features which had been established during the course of nebular and/or meteorite parent-body processes. It is remarkable that bulk chondrites show a relatively limited range within a group but display significantly large variations in Cl isotopic composition (up to 10‰) for whole groups, which is much larger than those previously reported [6]. We suggest that several characteristic Cl reservoirs with even larger ranges of isotopic composition existed in the early solar system materials.

**References:** [1] Fujitani T. and Nakamura N. (2006) *30th Sympos. Antarct. Meteor.* 11-12. [2] Fujitani T. and Nakamura N. (2006) *Meteoritics & Planet. Sci.* 41, A59. [3] Fujitani T. and Nakamura N. (2006) *Geostandard Geoanal. Res.* 30, 113-118. [4] Kimura M and Ikeda Y. (1997) *Meteoritics & Planet. Sci.* 32, A72. [5] Buchwald V.F and Clarke R.S.J. (1989) *American Mineral.* 74, 656-667. [6] Bridges J. C. et al. (2004) *Meteoritics & Planet. Sci.* 39, 657-666.