Rare Earth and Trace Elements Abundances of Refractory Inclusions in Ningqiang Meteorites. A. Yamakawa[1], H. Hiyagon[1], Y. Lin[2] and M. Kimura[3], [1]Department of Earth & Planetary Science, Graduate School of Science, The University of Tokyo, Tokyo 113-0033, Japan. y-akane@eps.s.u-tokyo.ac.jp. [2]Institute of Geology and Geophysics, Chinese Academy of Science, P.O.Box 9825, Beijing 100029, China. [3]Faculty of Ibaraki University, Mito 310, Japan.

Introduction: The relationship between bulk chemical compositions and rare earth element (REE) abundance patterns remains poorly constrained for refractory inclusions (Ca-Al-rich inclusions, CAIs) and amoeboid olivine aggregates (AOAs). Lin and Kimura [1] observed bulk chemical compositions of refractory inclusions and AOAs in Ningqiang carbonaceous chondrite, and suggested that they vary along the condensation trajectory on the anorthite-gehlenite-forsterite plane in the order: hibonite-bearing Type As, hibonite-free Type As, spinel-pyroxene inclusions, and AOAs from high to low temperatures. As a part of the systematic study of the Ningqiang meteorite, we analyzed abundances and distribution of REEs and other trace elements in the Ningqiang CAIs and AOAs, and investigate the correlation between the bulk chemical composition and REE abundance for better understanding of the formation processes of CAIs.

Techniques: Samples were measured using a CAMECA ims-6f ion microprobe at the University of Tokyo. We used an energy filtering method for determining REE abundances.

REE analyses were performed using a $^{16}O^-$ primary beam at -12.5keV with a ~1nA beam intensity. Positive secondary ions from the sample were accelerated at 10keV and analyzed at a low mass resolution of ~300. A 60V energy offset with an energy window of 30eV was applied to eliminate complex molecular interferences to the peaks of REEs [2].

Sample: We analyzed so far ten inclusions: a hibonite-bearing fluffy Type A (FTA) (NQJ3-3-4), two hibonite-bearing compact Type A (CTA) (NQJ3-3-1.4), a hibonite-free CTA (NQJ3-5-9), three hibonite-free FTA (NQW1-1, NQW1-16 and NQL2-3-3) and a spinel-pyroxene-rich inclusion (NQW1-5). Most inclusions consist of melilite and spinel as major phases, anorthite, diopside and perovskite as minor phases, and nephelite and hedenbergite as altered phases.

Results and Discussions: Almost all inclusions we analyzed show flat REE patterns with Eu, and sometimes Yb, anomalies. Most perovskite and some fassaite show negative Eu anomaly, while melilite shows positive Eu anomaly.

Since Eu and Yb are more volatile than the other REEs (under relatively oxidizing conditions), Eu and Yb would condense only partially at a certain temperature while other REEs have condensed almost completely. If condensation stopped at this temperature (possibly due to separation of the inclusion from the gas), negative Eu and Yb anomalies would be produced. The remaining gas would become enriched in Eu and Yb. If an inclusion with relatively flat REE pattern acquires excess Eu and Yb from the remaining gas at lower temperatures, positive Eu and Yb anomalies would be produced.

Only NQW1-16 show a Group II pattern, in which heavy REE (Gd to Er and Lu) are depleted relative to light REE (La to Sm). It may form from the gas left behind after an ultra-refractory component was removed from the gas [3]. The bulk chemical composition of this inclusion is in the middle of the condensation trajectory, and hence, there seems to be no correlation between the REE pattern (flat vs Group II) and bulk composition. Although it has been reported that fine-grained inclusions tend to show Group II REE pattern[4], we observed so far only one Group II inclusion in Ningqiang meteorite. The reason for this is not clear at present, but may be due to limited number of analyses.

An interesting observation is that some inclusions with compositions of lower temperature condensates (NQW1-16, NQW1-5, NQW3-1) show positive anomalies in Ce, Yb and Eu. Celium may become as volatite as Eu and Yb under an oxidizing condition, because it exists in the form of CeO_2 as well as CeO in the gas phase. Hence, positive anomalies of Ce, Yb and Eu may be interpreted as enrichment of the most volatile REEs. This also implies that these inclusions fromed in a relatively oxidizing condition.

At present, we have not yet observed clear correlation between REE patterns and bulk chemical composition or texture of the refractory inclusions in Ningqiang meteorite, probably due to limited number of analyses. We will carry out more analyses to better understanding condensation conditions as well as later alteration processes (e.g. melting) of CAIs.

References: [1] Lin Y. and Kimura M. (2003) *Geochim. Cosmochim. Acta 67,* 2251-2267. [2] Fahey A. (1988) *PhD Thesis, Washington University.* [3] Boynton W. V. (1983) *Rare Earth Element Geochemistry. Developments in Geochemistry, 2ed.* 63-114. [4] Tanaka T. and Masuda A. (1973) *Icarus* 19, 523-530.

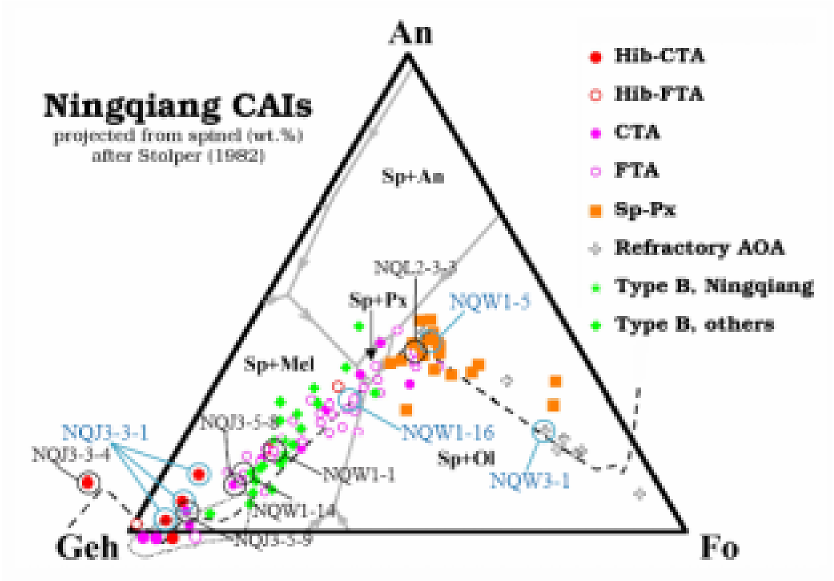

Figure 1: Bulk chemical compositions of the Ningqiang CAIs projected from spinel onto anorthite-gehlenite-forsterite ternary plane [1].

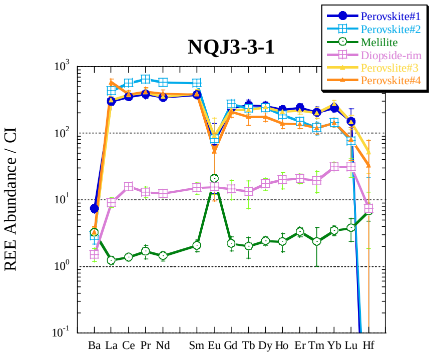

Figure 2: REE patterns of different phases in a hibonite-bearing CTA, NQJ3-3-1.4.

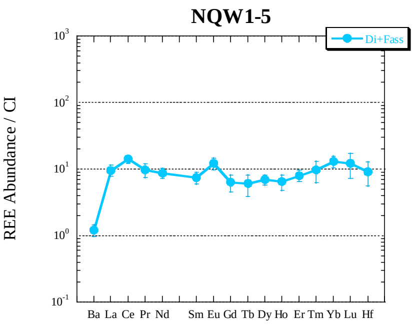

Figure 4: REE pattern of a spinel-pyroxene rich inclusion, NQW1-5.

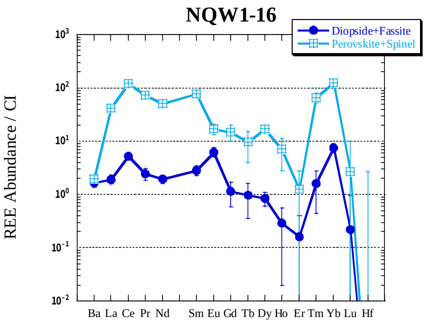

Figure 3: REE patterns of two analysis spots in a hibonite-free FTA, NQW1-16.

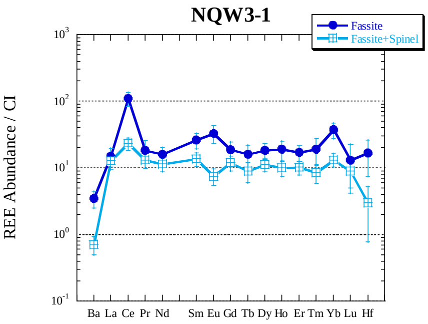

Figure 5: REE patterns of two analysis spots in a AOA, NQW3-1.