MINERALOGY AND COOLING HISTORY OF FRO90054 COMPARED TO OTHER UREILITES; J. Chikami, T. Mikouchi, M. Miyamoto and H. Takeda, Mineralogical Institute, Graduate School of Science, University of Tokyo, Hongo, Tokyo 113, JAPAN

FRO90054 is a carbon-poor ureilite with mineralogy similar to some lodranites. Calculated cooling rate of the FRO90054 ureilite using Mg/Fe zoning profile of olivine rim by solving the diffusion equation is within the range of other ureilites also determined in this study. This result would support the classification on the basis of oxygen isotope data. Seven ureilites (Fa: 3-25) show similar cooling rate (0.5-6°C/h) and we could not find the relationship between the Fa component of olivine and cooling rate in ureilites. We identified a mineral in interstices of mafic silicates containing high Ni and P contents as schreibersite which is common in reduced lodranites and acapulcoites.

Introduction: Ureilites are one class of achondrites which are composed mainly of olivine and pyroxene with several carbon polymorphs and metal. They have chondritic characters such as oxygen isotope anomaly [1] and high noble gas content [2], while they exhibit achondritic petrofabric texture. Inspite of many works on ureilites, their origin is still controversial.

FRO90054, which is a lightly-shocked ureilite specimen in the EUROMET collections, is said to be an unusual ureilite, because FRO90054 plots well outside the field of C and N isotope data exhibited by other ureilites [3,4]. The bulk carbon content (0.24 wt%) is the lowest among known ureilites.

Olivines of ureilites show reduction rims because of a sudden drop of pressure and temperature presumably caused by possible destruction of the ureilite parent body [5]. Quantitative estimates of the cooling rate during reduction are important to understand cooling history of ureilites. Because the nearly absence of carbon might change the reduction condition of olivine rim, we compared chemical zoning profile of olivines and pyroxenes in FRO90054 to other ureilites by paying attention to metal in interstice and reduction rim of olivine.

Result: Unlike other common ureilites, FRO90054 contains large crystals of a coexisting augite-low-Ca pyroxene pair. The paired pyroxene of augite ($Wo_{33.8}En_{57.8}Fs_{8.4}$) and low-Ca pyroxene ($Wo_{4.9}En_{83.4}Fs_{11.7}$) in FRO90054 gave an equilibration temperature (1200-1250°C), according to the pyroxene geothermometer of Lindsley [6]. We found that some metals in the matrix contain Ni and high P content (Ni: 2.6 wt%, P: 13.8 wt%) whose chemical composition is nearly consistent with that of schreibersite found in some lodranites [7]. The core composition of olivines is fairly uniform (Fa_{11}). Olivine crystals are zoned and show Mg and Mn enrichment at a rim (~20μm) from the edge adjacent to the grain boundary. According to a diagram to estimate the cooling rate from the initial temperature using diffusion calculation [8], the cooling rate of 1.8-4 °C /hour gives a best fit for the observed zoning profiles of olivine reduction rims in FRO90054.

We confirmed that the Hammadah al Hamra 126 ureilite contained a coexisting augite-low-Ca pyroxene pair. The chemical composition of augite is $Wo_{25.5}En_{67.4}Fs_{7.1}$ and that of pigeonite is $Wo_{11.0}En_{72.6}Fs_{16.4}$. Equilibration temperature of 1200°C -1300°C was deduced from the pyroxene geothermometer [6]. The core composition of olivines is fairly uniform (Fa_{20}) and olivine crystals were very well reduced at a rim among studied ureilites. According to a similar method for FRO90054 olivine, we estimated the cooling rate of 0.1-0.7 °C /hour for Hammadah al Hamra 126. Olivines of Hammadah al Hamra 126 shows Mg enrichment at a rim (~70-100μm) and are more reduced than those of other ureilites. Thus, cooling rate for Hammadah al Hamra 126 is slower than other ureilites.

We performed similar analysis for olivine and pyroxene in the LEW88774, Y791538 and ALH82106 ureilites. Table 1 shows the cooling rates and equilibration temperature for a pyroxene pair in each ureilite (LEW88774, augite-low-Ca pyroxene lamellae; Y791538, orthopyroxene-pigeonite; ALH82106, augite-low-Ca pyroxene lamellae) [6,9,10].

Discussion: The mineral assemblage of FRO90054 has been reported to be similar to those of augite-bearing lodranites [4]. We found that FRO90054 contains schreibersite, which is a common mineral in

lodranites and acapulcoites [7], in interstices of mafic silicates. Although the mineralogy of FRO90054 is similar to those of primitive achondrites, oxygen isotope data of FRO90054 confirmed its affinity to ureilite [11]. The estimated cooling rate of FRO90054 also shows that it is within the range of ureilites although FRO90054 was said to be an unusual ureilite [3,4].
The cooling rates of 8 individual ureilites show similar values (Table 1). These cooling rates are consistent with those estimated by a TEM study of Ca-rich pyroxenes in the Y790981 (3°C/hour) and Y74130 (20°C/hour) ureilites using an experimental calibration curve of augite exsolution lamella wave length *versus* cooling rate [12,13], although the employed methods are different.

With regard to shock grade, FRO90054 is classified as lightly-shock, the ALH82106, Y791538, ALH77257 and PCA82506 ureilites as low-shock, Y790981 as medium shock [3,14]. We could not find a relationship between the shock grade of ureilites and cooling rate.

Clayton *et al.* [1] suggested a relationship between oxygen isotope data and the iron content of olivine cores in ureilites and classified them into three groups. According to Clayton's grouping, the Fa (3-25) components of olivine cores in ureilites we studied range from Group 1 to Group 3. We could find no relationship between the Fa component of olivine and cooling rate. It is interesting to note that similar cooling rates of 7 ureilites imply that they may be produced by a destruction of not a few parent bodies, but one parent body, although it might be thought that ureilites, which belong to different oxygen isotope groups, came from different ureilite parent bodies.

Conclusion: We identified a mineral in interstices of FRO90054 mafic silicates as schreibersite. The cooling rate of FRO90054 is consistent with those of other ureilites. We found that olivine reduction rims in ureilites show similar cooling rates although the Fa components of olivine are variable in ureilites.

We thank EUROMET for the meteorites samples and Ms.Yugami for analysis of shreibersite.

References:

[1] Clayton R.N. and Mayeda T.K. (1988) *GCA, 52,* 1313. [2] Begemann F. and Otto U. (1983) *GCA, 47,* 975. [3] Grady M.M. and Pilliger C.T. (1993) *LPSC, XXIV,* 551. [4] Baba T. et al. (1992) *Meteoritics, 28,* 319. [5] Berkley J.L. et al. (1980) *GCA, 44,* 1579. [6] Lindsley D.H. (1983) *American Mineral, 68,* 477. [7] Takeda H. et al. (1994) *Meteoritics, 29,* 830. [8] Miyamoto M. (1985) *Proc. LPSC, 16,* D116. [9] Miyamoto M. and Takeda H. (1994) *JGR, 99,* 5669. [10] Chikami J. et al. (1995) *Antarct. Meteorites, XX,* 43. 11] Clayton R.N. et al. (1995) *GCA,* in press [12] Mori H. and Takeda H. (1983) *Meteoritics, 18,* 358. [13]Grove T.L. (1982) *American Mineral, 67,* 251. [14] Goodrich C.A. (1992) *Meteoritics, 27,* 327.

Table 1. Cooling rates of ureilites

	Fa (core)	Cooling rate (°C/hour)	Equilibration Temperature(°C)	Shock grade	Ref.
ALH82106	3	1.8	1200	low	[10]
Y791538	8	0.4	1200	low	
FRO90054	11	1.8-4	1200-1250	lightly	
ALH77257	14	4-6	1250	low	[8]
Y790981	20	2-3	1250	medium	[8]
PCA82506	20	2.5-3	1250	low	[8]
Hammadah al Hamra 126	20	0.1-0.7	1200-1300		
LEW88774	25	0.5	1160		[10]