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Mineralogy and petrology of chondrule in Ouallen (Tanezrouft) meteorite

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ABSTRACT

A chondritic meteorite is found at the Sahara desert about 135 km WSW of Ouallen, Algeria in 1936. It contains various kinds of chondrules, up to 0.2-2 mm in diameter. Constituent minerals of chondrules are olivine, Ca-poor pyroxene, and those of matrix are olivine, Ca-poor pyroxene, Ca-rich pyroxene, troilite, chromite and kamacite. Glass fills the interstices of olivines and pyroxenes in chondrules. The average chemical compositions of olivine, Ca-poor pyroxene and Ca-rich pyroxene are $Fa_{25.8}$, $Wo_{1.8}$ $En_{79.9}$ $Fs_{18.3}$ and $Wo_{34.7}$ $En_{52.7}$ $Fs_{12.6}$. The average Fe/(Fe+Mg) rations of olivine, Ca-poor and Ca-rich pyroxenes in the barred chondrule are similar to those of the host rock in Ouallen chondrite. There is a wide range of Fe/(Fe+Mg) rations of olivine, Ca-poor and Ca-rich pyroxenes. The boundary between chondrules and matrix is distinct. Based on the texture and olivine composition, the Ouallen chondritic meteorite belongs to L3 chondrite after Van Schmus and Wood's classification (1967).

KEY WORDS

Barred olivine,Chondrite,Chondrule,L3, Meteorite,Ouallen,Radiating chondrule,Tanezrouft

Introduction

13 fragments were found in the Sahara desert at 24° 10′N., 0°5′E., about 135 km WSW of Ouallen,Algeria. The Tanezrouft meteorite is synonym as the Ouallen meteorite. We bought the Tanezrouft meteorite as LL3 type chondrite from Hori mineralogy. Mason (1963) reported on the basis of olivine composition (Fa_{20}) that the Ouallen meteorite is type H. However, the chemical composition os olivine is determined by an X-ray diffraction pattern. Olivine composition (Fa_{25}) analyzed by EPMA in the present study indicates L type chondrite. Mason (1963) reported as one of chondrites, and did not descibe in detail. If the Ouallen meteorite is type H, the Tanezrouft meteorite is not synonym of the Ouallen meteorite. Therefore, in the present study, I give chemical composition and description on the occurence of minerals and a barred olivine chondrule in the Ouallen chondrite. On the

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basis of these data, we classify the Ouallen chondrite according Van Schmus and Wood's classification (1967). In addition to this classification, the radiating barred olivine chondrule with a rare texture is described.

Petrography

The Ouallen chondrite contains various kinds of millimeter-sized chondrules such as barred olivine chondrule, radiating pyroxene chondrule, cryptocrystalline chondrule, porphyritic olivine chondrule and porphyritic pyroxene. Other chondrites have textures intermediate between these types. The porphyritic type is predominant, followed by the barred type. The boundaries between chodrules and the matrix are distinct. Constituent minerals comprise olivine, Ca-poor pyroxene, Ca-rich pyroxene, Fe-Ni metal, troilite, chromite and glass.

Fig. 1 shows the radiating barred olivine chondrule. Parallel olivine crystals forms as laths. Glass fills the interstices of theses olivines. Pyroxene crystal was observed surround olivine. The widths of laths of olivine surround pyroxene become thinner than those in glass, as shown in Fig. 1d and 1e. Ca-poor pyroxene forms as euhedral crystal in Fig. 1d. The observation suggests that pyroxenes crystallized by reaction of olivine and glass in the late stage crystallization of chondrule melts.

Mineralogical data and classification

Chemical compositions of olivine, Ca-poor pyroxene, Ca-rich pyroxene and glasses were determined with a JEOL 8060 superprobe, using standard procedure at Niigata University. The analyses of the olivine, Ca-poor pyroxene and Ca-rich pyroxene are given in Table 1 together with their structural formulae, calculated on the basis of 4 oxygen atoms for olivine and 6 oxygen atoms for pyroxene. Olivine is the abundant mineral, and usually shows subhedral from in matrix or elongated crystals in olivine porphyritic or barred olivine chondrules. The average composition is $Fa_{25.8}$. It is close to the average composition of olivine of the equilibrated L chondrites (Van Schmus, 1969) (Fig. 2a). Ca-poor pyroxene forms as subhedral crystals, and euhedral crystals in the barred olivine chondrule and fibrous crystals in radiating chondrules. The average molar composition is

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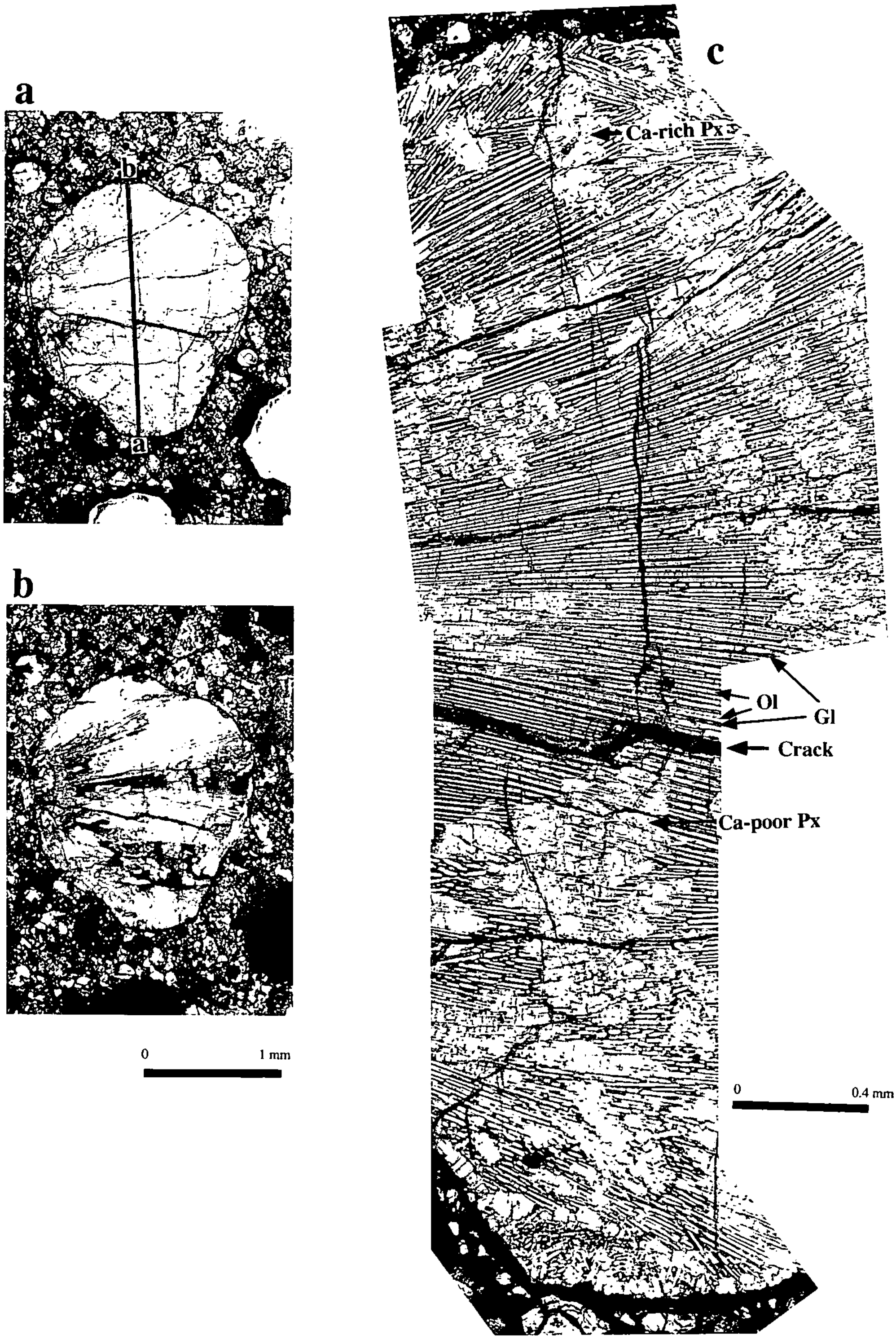
Figure 1 Photomicrographs showing barred olivine chondrule in the Ouallen meteorite. ⇨

a. Close nicol. b. Open nicol. c.High magnification(x2.5) along a line a-b in photograp b.

d. High magnefication(x10). Ca-poor pyroxene grows by reacting olivine and glass.

e. Back-scattered electron image of olivine laths with filling Ca-poor pyroxene and glass. Olivine appears light grey, Ca-poor pyroxene is medium grey, and glass indicates dark grey. Abbreviations: Gl, glass. Ol, olivine. Px, pyroxene.


a
b
a
b
0
1 mm
c
Ca-rich Px
Ol
Gl
Crack
Ca-poor Px
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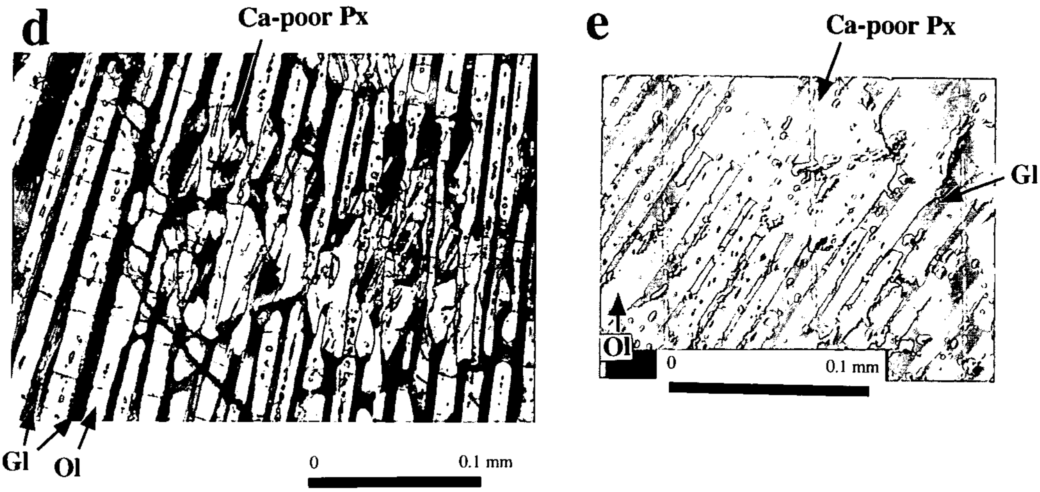

Table 1. The chemical compositions of olivine, Ca-rich and Ca-poor pyroxenes.

	Chondrule			Host rock		
Mineral	Ol	Ca-rich Px	Ca-poor Px	Ol	Ca-rich Px	Ca-poor Px
No of anal.	138	23	213	370	42	371
SiO_2	38.92	54.19	56.24	38.58	54.36	55.73
TiO_2	0.04	0	0.01	0	0.44	0.01
Al_2O_3	0	1.16	0.58	0.01	1.21	0.54
Cr_2O_3	0.20	0.31	0.14	0.09	0.32	0.46
FeO	23.77	8.34	12.23	23.14	7.89	12.22
MnO	0.54	0.19	0.40	0.40	0.04	0.43
MgO	38.26	18.01	30.03	38.28	18.53	29.86
CaO	0.09	18.32	0.46	0.04	17.01	0.91
Na_2O	0	0.19	0.14	0	0.73	0.19
K_2O	0	0	tr.	0	0.01	tr.
Total	101.82	100.71	100.23	101.14	100.54	100.35
	O=4	O=6	O=6	O=4	O=6	O=6
Si	1.000	1.975	1.989	1.002	1.976	1.976
Al^{IV}	0	0.025	0.011	0	0.024	0.022
Al^{VI}		0.025	0.013		0.027	
Cr	0.004	0.009	0.004	0.002	0.009	0.013
Ti	0.001	0	0	0	0.012	0
Mg	1.466	0.979	1.583	1.481	1.004	1.578
Fe	0.511	0.254	0.362	0.502	0.240	0.362
Mn	0.012	0.006	0.012	0.009	0.001	0.013
Ca	0.002	0.716	0.017	0.001	0.662	0.035
Na	0	0.013	0.010	0	0.051	0.013
K	0	0	0	0	0	0
Total	2.996	4.002	4.001	2.997	4.006	4.012
Fe/(Fe+Mg)	0.258	0.206	0.181	0.253	0.193	0.187
Wo		36.7	0.9		24.7	1.8
En		50.2	80.7		52.7	79.9
Fs		13.0	18.5		12.6	18.3

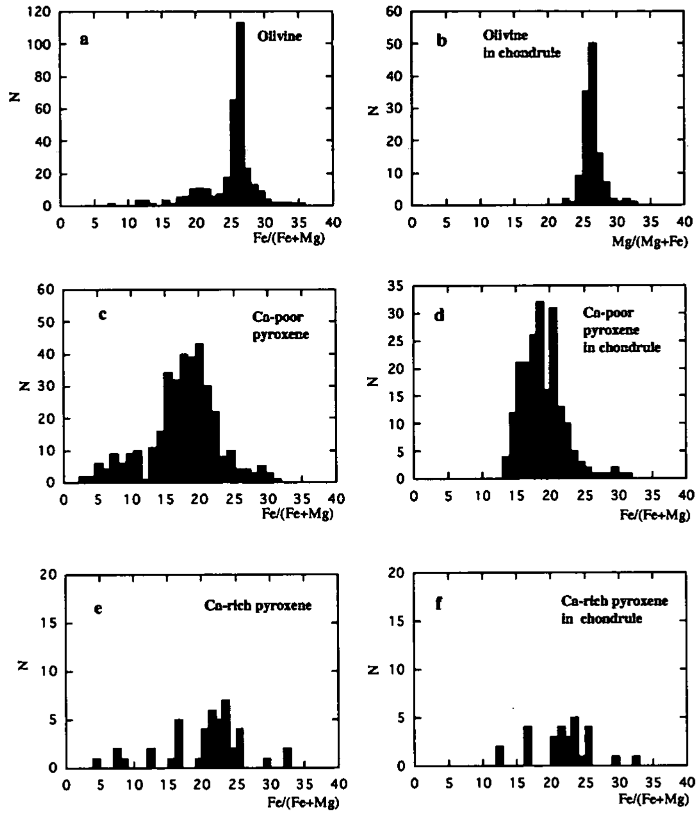

Figure 2 Comparison of Fe/(Fe+Mg) rations of olivines, Ca-poor and Ca-rich pyroxenes for the Ouallen host and the barred olivine chondrule.

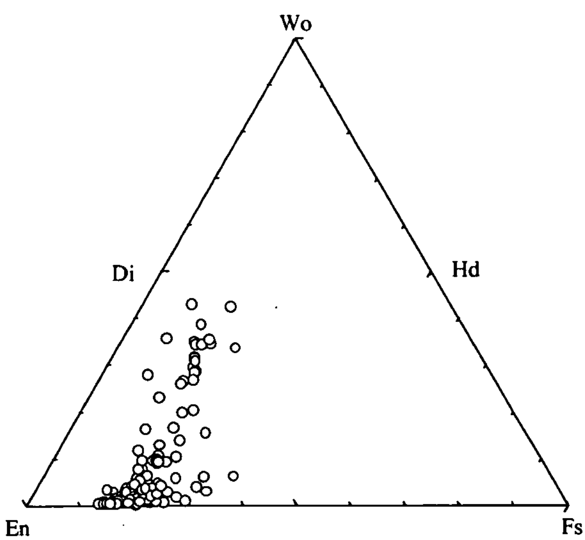

Figure 3. Plots of pyroxenes in the barred olivine chondrule.

$Wo_{1.8}$ $En_{79.9}$ $Fs_{18.3}$. Ca-poor pyroxene has composition similar to that in the equilibrated H chondrites (Van Schmus, 1969) (Fig. 2c). Small amounts of Ca-rich pyroxene are observed as subhedral crystals in the devitrified glass or minute crystals on the rim of Ca-poor pyroxene. Ca-rich pyroxene with average of $Wo_{34.7}$ $En_{52.7}$ $Fs_{12.5}$ has intermediate composition between the equilibrium H and L chondrites (Fig. 2e). There is a wide range of Fe/(Fe+Mg) ratios of olivine, Ca-poor and Ca-rich pyroxenes. When plotted in the Ca-Mg-Fe diagram (Fig. 3), they fall in the Mg rich side of diagram. These pyroxenes have a wide range of compositions from enstatite to diopside. Based on the compositional and petrographic analyses, I classify the Ouallen chondritic meteorite as L3. It is necessary to investigate the Ouallen meteorite reported by Mason (1963).

Fig. 4 shows a profile of 512 analyses along the line a-b in Fig. 1a. There are small cracks in the olivine barred chondrule. Iron oxides fill the interstices of these cracks. Though Fe/(Fe+Mg) rations of olivine, Ca-poor pyroxene and glass increase near the cracks and at the marginal part, those of olivine at the most part are uniform. Compared to olivine, Ca-poor pyroxene has a wide range of Fe/(Fe+Mg) ratio. Fe/(Fe+Mg) ratios of olivine and Ca-poor pyroxene in the barred olivine condrule are slightly higher than those in the Ouallen host.

Discussion

The bulk compositions and CIPW norms of a chondrule and seven glasses in the chondrule are given in Table 2. The bulk composition of the condrule is calcurated by using average of 512 point analyses on the line a-b in Fig. 1a. Its composition is similar to

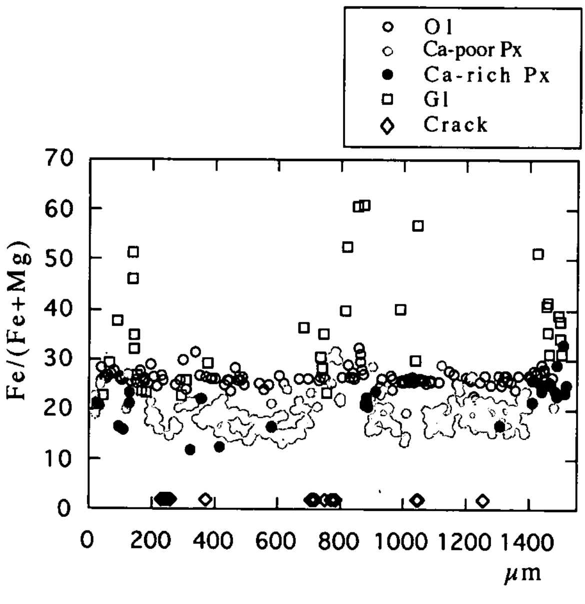

Figure 4 Fe/(Fe+Mg) ratio line profiles in olivine, Ca-poor pyroxene, Ca-rich pyroxene and glass across a barred olivine chondrule along its rims and small cracks.

Table 2. The chemical compositions of barred olivine chondrule and glasses.

	chondrule	G1-15	G1-46	G1-102	G1-160	G1-247	G1-274	G1-485
SiO_2	49.41	64.80	58.53	63.06	64.91	60.09	63.07	66.93
TiO_2	0.07	0.22	0.21	0.42	0.42	0.41	0.26	0.36
Al_2O_3	2.49	16.96	14.99	20.08	21.23	19.69	18.70	18.82
Cr_2O_3	0.43	0.50	1.10	0.08	0.13	0.20	1.55	0
FeO	16.56	2.56	4.68	2.73	1.64	5.12	2.93	1.06
MnO	0.38	0.01	0.06	0.08	0	0.12	0.01	0
Nio	0.04	0	0	0	0	0.08	0.06	0.01
MgO	28.11	4.86	3.07	4.38	2.54	7.25	1.48	1.08
CaO	1.90	1.81	3.29	1.37	2.16	1.28	2.47	2.29
Na_2O	1.02	8.31	8.46	7.21	8.44	7.49	9.43	9.17
K_2O	0.03	0.73	0.63	0.05	0.05	0.06	0.49	0.13
Total	100.44	100.76	95.02	99.46	101.52	101.79	100.45	99.85
Qz		1.2		9.5	6.1			6.3
C				5.7	3.3	4.9		
Or	0.2	4.3	3.9	0.3	0.3	0.4	2.9	0.8
Ab	8.6	69.8	69.7	61.3	70.4	62.3	78.7	77.7
An	2.1	6.8	1.1	6.8	10.6	6.2	7.2	9.8
Ne			3.1				0.4	
Wo	3.0	0.9	6.7				2.1	0.7
En	2.0	0.6	3.3				1.0	0.4
Fs	0.9	0.2	3.2				1.0	0.2
En	30.3	11.4		11.0	6.2	14.6		2.3
Fs	13.3	3.7		4.4	2.2	7.21		1.2
Fo	26.3		3.3			2.2	1.9	
Fa	12.7		3.5			1.2	2.1	
Cm	0.6	0.7	1.7	0.1	0.2	0.3	2.3	
II	0.1	0.4	0.4	0.8	0.8	0.8	0.5	0.7

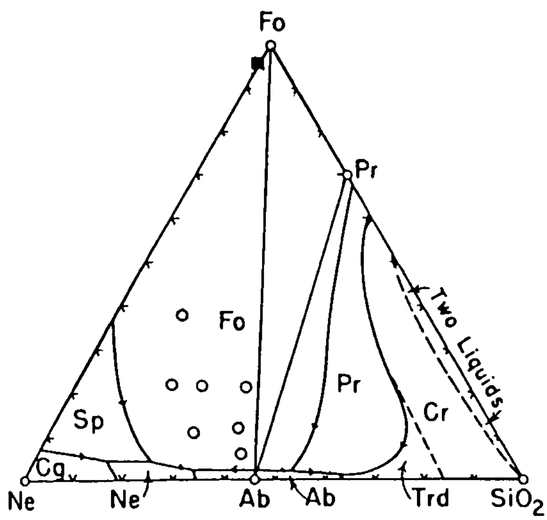

Figure 5. Liquidus diagram of the system Ne-Fo-SiO_2 after Schairer and Yoder (1971). Abbreviations: Ab, albite. Cg, Carnegieite. Cr, cristobalite. Fa, fayalite. Fo, forsterite. Ne, nepherine. Pr, protoenstatite. Sp,spinel. Trd, trigimite.

the the bulk composition barred olivine chondule (B22) and radiating chondrule (A22) in Yamato-74191(L3) reported by Kimura and Yagi(1980). The bulk composition of the chondrule in the present study is not rare.

The compositions of glasses are rich in SiO_2, Al_2O_3 and Na_2O. The compositions of glasses vary widely. G1-15,G1-102,G1-160 and G1-485 are quartz normative. Though G1-46,G1-247 and G1-274 have high SiO_2 contents, they are olivine normative. These glasses are plotted in the olivine primary field in Ne-Fo-SiO_2 diagram (Fig. 5) after Schairer and Yoder (1961). Based on absence of pyroxene in olivine porphyritic chondrules and the glasses enreched in SiO_2 far beyond the reaction line of enstatite+SiO_2+liquid, Kimura and Yagi (1980) concluded that chondrules have not crystallized at equilibrium. The compositions of glasses in the present study are also similar to those in barred olivine chondule and radiating chondrule in Yamato-74191(L3) reported by Kimura and Yagi(1980).

In general, when a molten droplet is cooled rapidly, it may quench to a glass; the same droplet cooled at an intermediate rate may nucleate and grow crystals; an initially molten droplet cooled very slowly will crystallize in its entirety (Wasson, 1985). Wood (1963) suggested that barred and radiating chondrules might have formed under rapid cooling. However, Kimura and Yagi(1980) suggested that rapid cooling from the liquidus temperatures is not needed to form even barred and radiating chondrules. The nucleation temperatures of barred chondrules were lower than those of olivine porphyritic chondrules. Tsuchiyama et al. (1980) reported that the cooling rate for producing barred olivine is from 120 to 50℃/min. Blander et al. (1976), Lofgren and Lanier (1990) and Lofgren (1996) reported on the basis of the texture of chondrite synthsized in the experiments that the barred olivine texture forms from the CH-1 composition at cooling rates of 500 to 2500℃/h. The upper temperature limit of melting for barred olivine chondrule cannot excees 1630℃ for more than tens of minutes. The temperature below 1630℃ indicates subliquidus temperature.

Consequently, in the Ouallen chondrite, olivine nucleates in the subliquidus region, and in succession olivine reacts with a residual liquid, olivine is surrounded by Ca-poor pyroxene. However, this reaction does not take place perfectly. Soon after, chondrules cooled rapidly with formation of glasses.

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