TAFASSASSET: AN EQUILIBRATED CR CHONDRITE.

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Introduction: 26 stones totaling around 110 kilos were found in 2000 and 2001 in the northern part of the Ténéré desert (Niger). The stones are only slightly weathered (W0/1) and the fusion crust is still visible. Large metal grains or veins protrude in places. Metal is abundant and on first examination the meteorite could easily be mistaken for a metal-rich metamorphosed ordinary chondrite. However the composition of the equilibrated mafic silicates contradicts this and so do the oxygen isotopes which fall in the CR range.

Table 1 lists the main characteristics of Tafassasset and compares them with those of Renazzo:

Tafassasset	**Renazzo (CR2)**
Fa 29.3; Fs 24.3	Fa 0.5-47; Fs 1-11
Metal: ≈10 vol%	Metal: 7.4 vol% [1]
Presence of large (mm) metal-bearing relict chondrules (Fig. 2a)	Abundant large (0.6-1mm) metal-bearing chondrules (Fig. 2b)
Large isolated rounded metal grains found in the inter-chondrule space	Large isolated metal grains present in the matrix
Interchondrule space consists mostly of subhedral olivine with interstitial plagioclase, chromite and phosphate and abundant small sulfides (Fig. 2a).	Fine-grained amorphous matrix is present between the chondrules. It is loaded with µm-sized sulfide grains
Metal grains often edged with feldspars, chromites and/or phosphates	Metal contains 0.1-1 wt% P and Cr
$\delta^{17}O = 0.18 \pm 0.08$ $\delta^{18}O = 2.94 \pm 0.2$	*(EET) $\delta^{17}O = 0.22$ [1] *(EET) $\delta^{18}O = 2.76$ [1]
$\Delta^{17}O = -1.35$ (Fig. 1)	*(EET87770) $\Delta^{17}O = -1.22$

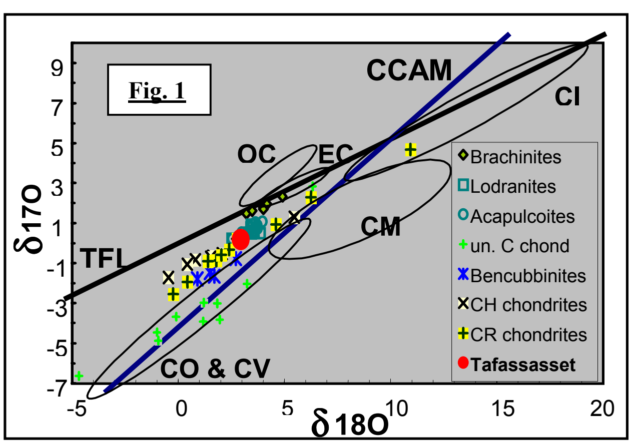

Figure 2: (a) A relict chondrule in Tafassasset; (b) a chondrule from Renazzo. There are large rounded metal grains (white) within the chondrules in both cases and smaller grains around its edges. The opaques in the surrounding "matrix" are almost exclusively sulfides (light grey). In the case of Tafassasset, the material in which the relict chondrule sits has recystallized. It consists mostly of olivine (medium light grey) with minor plagioclase (dark grey). The chondrule consists of olivine poikilitically enclosed in pyroxene (medium dark grey). Accessory plagioclase is sometimes present in relict chondrules, often close to metal grains, but none is visible on this picture.

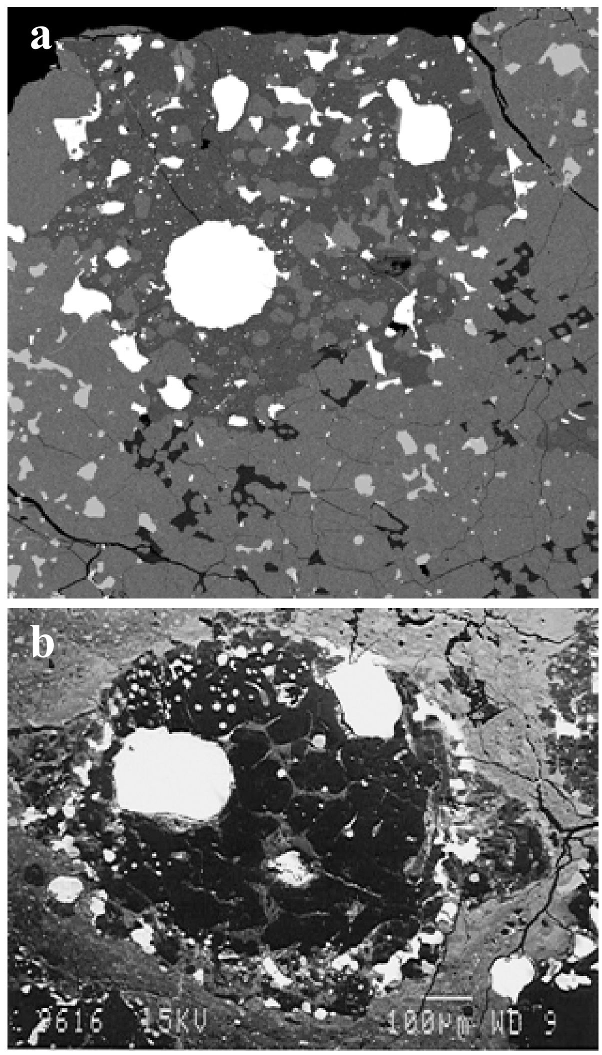

Table 2: Representative analyses of oxide and opaque minerals in Tafassasset. Plag[1] is the plagioclase in the interchondrule space, plag[2] is the plagioclase edging metal grains. Metal[3] is metal associated to troilite in the interchondrule space, metal[4] is beads enclosed within silicates. Pentlandite consists of small specks within the troilite.

oxides	SiO_2	Al_2O_3	TiO_2	FeO	Cr_2O_3	MnO	V_2O_5	MgO	CaO	Na2O	K_2O	P_2O_5	total
Olv (Fa 29.7)	37.79	0.00	0.04	25.90	0.03	0.49	0.00	35.10	0.03	0.04	0.00	0.00	99.43
Opx (Fs 24.6)	54.37	0.46	0.26	15.82	0.40	0.51	0.00	26.72	1.94	0.05	0.01	0.00	100.52
Plag[1] (An 46.4 Or 2.2)	56.98	**25.68**	0.00	0.71	0.00	0.00	0.00	0.04	**9.66**	**5.90**	**0.39**	0.18	99.54
Plag[2] (An 26.6 Or 5.2)	61.61	**22.61**	0.03	0.78	0.03	0.01	0.18	0.04	**5.64**	**8.02**	**0.93**	0.17	100.05
Chromite	0.00	8.37	2.83	28.61	55.43	0.35	0.88	3.56	0.00	0.00	0.02	0.02	100.08
Merrillite	0.14	0.09	0.01	0.65	0.03	0.08	0.29	3.34	46.15	2.36	0.08	46.75	99.96

Opaques	Fe	Ni	Co	Si	P	Cr	S	Cu	Total
kamacite	93.10	6.07	0.55	0.01	0.01	0.01	0.01	0.00	99.75
martensite	87.02	12.85	0.46	0.00	0.02	0.01	0.02	0.08	100.46
metal[3]	78.22	20.33	0.48	0.00	0.03	0.05	0.07	0.13	99.31
metal[4]	66.69	30.98	0.66	0.06	0.01	0.07	0.04	0.25	98.75
troilite	63.42	0.00	0.00	0.02	0.00	0.08	35.68	0.03	99.23
pentlandite	42.88	16.72	0.10	0.00	0.01	0.01	32.18	6.56	98.47

Table 3: A comparison of the main petrographic characteristics of chondrule relicts and interchondrule space.

Within chondrule relicts	In the interchondrule space
euhedral olivine poikilitically enclosed in orthopyroxene	large adjacent olivine in an almost continuous network
plagioclase (An24) only at the edge of the metal grains	localized plagioclase (An45) interstitial between olivines
chromite mostly subhedral and at the edge of metal grains	localized anhedral chromite interstitial between olivines
merrillite mostly subhedral and at the edge of metal grains	localized anhedral merrillite interstitial between olivines
opaques consists mainly of rounded metal grains	opaques consists mainly of small euhedral sulfide crystals
metal consists mainly of martensite and kamacite	
presence of tiny opaque droplets within the mafic silicates	

EMP data and the main petrographic particularities of Tafassasset are summarized in Tables 2 and 3, and Fig.2. A very striking feature is the presence of plagioclase feldspars, chromite and phosphate differing in texture (and even in composition for the feldspars) depending on their position inside or outside the relict chondrules, suggesting that these phases have two different origins.

Discussion: The petrographic similarities between Tafassasset and Renazzo (Tab. 1) are sufficiently striking to make the similarity in their oxygen isotopes unlikely to be due only to a coincidence and most of their differences can be explained in terms of thermal metamorphism and possibly shock. Analogies with ordinary chondrite metamorphism are however not straightforward because of the differences in chemistry of the starting material. A few hypotheses can still be made: (1) The intensity of the metamorphism was not sufficient to totally erase the chondrules, the compositional differences between the feldspars inside or outside chondrules and the original distribution of metal and sulfide. (2) The interchondrule space largely dominated by olivine and with interstitial feldspars, chromites and feldspars is the result of the metamorphic transformation of fine grained matrix, dark inclusions, and possibly some porphyritic olivine chondrules, most of the remaining chondrule relicts presumably being derived from porhyritic olivine-pyroxene chondrules. (3) The feldspars, phosphates and chromites in the interchondrule space were made mostly from the Ca, Na, Al, P and Cr originally present within the fine-grained matrix, whereas the feldspar found around the metal grains within chondrules relicts presumably derived from chondrule glass and the chromite and phosphate edging the metal grains from oxidation of Cr and P originally in solid solution within that metal as described in [2].

Conclusion: Tafassasset is a metamorphosed CR chondrite which provides us with a unique chance to understand the effects of metamorphism on highly unequilibrated objects with a bulk composition different from that of ordinary chondrites.

References: [1] Weisberg M. K. et al. (1993), *GCA 57*, 1567-1586. [2] Zanda B. et al. (1994), Science 265, 1846-1849.