Tafassasset: A Metal-Rich Primitive Achondrite with Affinities to Brachinites. C. E. Nehru[1,2], M. K. Weisberg[2,3], J. S. Boesenberg[3], M. Kilgore[4]. [1]Dept. Geology, Brooklyn College, Brooklyn, NY 11210, [2]Dept. Physical Sciences, Kingsborough College of the City University of New York, 2001 Oriental Blvd., Brooklyn, NY 11235, [3]Dept. Earth and Planetary Sciences, American Museum Natural History, NY, NY 10024, [4]Southwest Meteorite Lab., PO Box 95, Payson, AZ 85547

Introduction: Tafassasset (Tafa) is a recent find (26 stones recovered between 2000-2001) from the Tenere desert (Niger) [1]. Tafa is an unusual metal-rich meteorite with an achondritic texture. Its classification is contentious and is the main focus of this work. Bourot-Denise et al. [1] suggested it was a metamorphosed CR chondrite based on O-isotopes that plot near the CRs, high metal abundance (10%) like the CRs and textural regions that they interpreted to be relict metal-rich chondrules texturally similar to those in the CR chondrites. However, a different sample of Tafa was classified as a primitive achondrite with a recrystallized texture [2]. Zipfel et al. [3] reported that both samples of Tafa (one in Paris and the other in Freiberg) are paired and are bulk compositionally similar to the primitive achondrites (brachinites and lodranites). Our continuing interest in the primitive CR chondrites and primitive achondrites led us to study this intriguing sample. If Tafa is a recrystallized CR, it is important as the first highly equilibrated sample from the CR parent body(ies) and may provide important clues to thermal processes on chondritic asteroids. If it is related to the brachinites, it is important in being the first metal-rich brachinite and may provide clues to deciphering the petrogenesis of this poorly understood primitve achondrite group. The thin section that we studied showed remarkable similarity to Brachina, albeit metal–rich. The goal of this study is to determine the relationship of Tafa to the brachinites and understand its origin.

Results: *Texture.* Tafa is texturally very similar to Brachina, but is metal-rich. Metal abundances are very low in brachina and the other brachinites. Tafa is generally fine grained (0.04 mm) with some coarser grains (up to 0.3 mm). It has an equigranular seriate texture. Olivine is by far the dominant phase and varies from subhedral to anhedral in form, similar to Brachina [4]. The texture is well equilibrated with abundant 120° angle triple junctions between olivine gains. Pyroxene and plagioclase generally occupy interstitial areas and thus, appear to be later than olivine in the crystallization sequence. Chromite occurs as inclusions in the major minerals, as well as in interstitial areas. Metal and sulfides appear to be interstitial and seem to have crystallized late.

Modal Abundances. A metal-free, recalculated mode of Tafa is very similar to Brachina (Table 1). Both Tafa and Brachina are olivine-rich with lesser amounts of pyroxene and feldspar. Fe-Sulfides constitute about 2.0 of Tafa and 3.2 of Brachina. A major modal difference between Tafa and Brachina is the high metal abundance (about 8.0 vol. %) in Tafa and only trace metal in Brachina. Also, Tafa has 4 vol.% low-Ca pyroxene and Brachina has trace amounts.

Table 1. Modal abundances and mineral compositions for Tafa and Brachinia.

Mode (vol.%) (metal/Sulfide-free)		**Tafa**		**Brachina from [4]**
Olivine		77.9		83.1
Low-Ca Pyx		4.1		trace
Ca-Pyx		8.8		5.7
Plagioclase		7.7		10.2
Chromite		1.5		0.5
Phosphate		trace		0.5
Total		100		100
Metal (vol. %)		8.0		trace
Sulfide		2.2		3.2
Mineral Comp. (mol.%)				
Olivine	Fa	29.3		30.2
Low-Ca Pyx	Fs	24.3		25.6
	Wo	2.0		4.0
Ca-Pyx	Fs	12.4		12.9
	Wo	39.4		38.7
Plagioclase	An	26-44		22
Anorthoclase (glass?)	An	23-25		8.6
	Or	6-13		11.2

Mineral Compositions. Silicates in Tafa are very similar in composition to those in Brachina (Table 1). Anorthoclase glass is present in both meteorites with compositions of An_{23-25}, Or_{6-13} in Tafa, and $An_{8.6}$, $Or_{11.2}$ in Brachina [4]. The FFM ratios of Tafa Chromites are similar to those of Chromites in other brachinites [4]. However the Cr/(Cr+Al) ratios are slightly lower than those of the other brachinites. Tafa metal compositions are variable with Ni concentrations up to about 31 wt. %. In Brachina metal is very low in volume, but has a higher Ni content (about 51%).

Pyroxene Thermometer. Coexisting low-Ca and Ca-rich pyroxene compositions yield an equilibration temperature of about 875°C, somewhat lower than those obtained for Brachina (about 1050°C) [4].

Oxygen Isotopes. The oxygen isotopic composition of Tafa [1] differs from the main group of brachinites

(MGB) [5]; however, it plots close to the LEW 88763 anomalous brachinite [6] on the 3-isotope diagram (Fig. 1). Both Tafa and LEW 88763 plot close to the CR chondrites [7], suggesting a possible relationship to the CR group. A relationship to the CR chondrites seems to be supported by the high metal abundance of Tafa and areas in Tafa that have been interpreted to be relict metal-rich (CR-like) chondrules [1]. However, Tafa, like the brachinites, has a bulk composition (Zn, Al/Mg, Mn/Mg) that differs from CR or any other chondrite group [3].

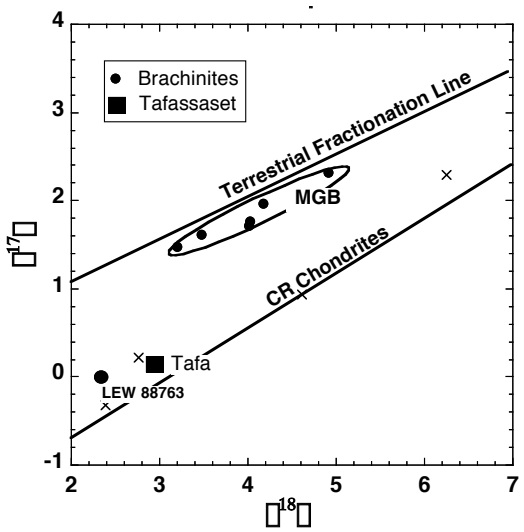

Figure 1. Oxygen 3-isotope diagram showing oxygen isotopic compositions of Tafa [1], Main Group Brachinites (MGB) [5], the LEW 88763 brachinite [6] and some CR chondrites (plotted as x) [7]. Also shown are the terrestrial fractionation line and the CR chondrite line.

Discussion and Conclusions: Zipfel et al [3] argued that the Tafa meteorite samples are fractionated from CI and/or other chondrite groups. Al/Mg and Mn/Mg ratios are similar to other primitive achondrites and suggest partial melting. Tafa's texture suggests partial or total melting followed by recrystallization and equilibration. We did not find any area that appeared to be a relict chondrule, like that described by Bourot-Denise et al. [1], in the section that we studied. This may be due to heterogeneity in the meteorite. The sample of Tafa that we studied has textural, modal and compositional similarities to Brachina, except for the relatively high abundance of metal. Therefore, Tafa's texture, modal and mineral compositions, as well as its Al/Mg and Mn/Mg [3] are consistent with a relationship to the brachinites. The oxygen isotope composition of Tafa plots near the CR chondrites on the 3-isotope diagram, but also very close to the LEW 88763 anomalous brachinite. However, the amount of metal present in Tafa is distinctly higher than in any of the brachinites. On balance, we conclude that Tafa is closely related to the brachinites and may be the first metal-rich brachinte.

The brachinites are primitive achondrites because their compositions are near-chondritic and their textures are not. They may be materials from an incompletely differentiated parent body or bodies. Their compositions suggest that they experienced small degrees of partial melting of a chondritic starting material, with some brachinites more fractionated than others [8]. The bulk composition of Tafa indicates that it too underwent some degree of partial melting [3]. However, Tafa did not experience loss of metal during melting. Its petrogenesis may have included low degrees of partial melting of a CR chondrite-like parent, followed by a long period of heating to metamorphic temperature resulting in its current recrystallized texture and equilibrated assemblage. Although density-driven metal-silicate fractionation may be expected, the brief period and low degree of melting may have prevented separation of metal. An alternative explanation is that metal was injected in at later time, possibly during an impact event, but this seems less likely.

We conclude that Tafa is a brachinite-like meteorite. Oxygen isotope compositions suggest two grouping of brachinites. One group is the main group brachintes (MGB) and the other may consist of Tafa and LEW 88763. Tafa and LEW 88763 may have evolved from a different chondritic starting material than the other brachinites, possibly a CR chondrite-like material. However, further work is needed to determine its relationship to the CR chondrites. The high abundance of metal and the identification of areas that may be relict chondrules [1] suggest that Tafa is closer to its chondritic starting material than any other primitive achondrite, and therefore, more primitive.

Olivine rich meteorites are of interest to planetary astronomers studying asteroids and attempting to match them to known meteorite groups [9]. Spectral reflectance studies have been used to infer that the silicate mineralogy at the surface of several asteroids is dominated by olivine (e.g., [10, 11]). Tafa and related primitive meteorites such as the brachinites, which are olivine rich, may well be the materials that planetary astronomers are looking for.

The brachinites are a diverse group of primitive achondrites and metal-rich Tafa adds to their diversity.

References: [1] Bourot-Denise M. et al. (2002) *LPS XXXIII*, Abstract # 1611. [2] Russell et al. (2002), *Meteoritics & Planet. Sci., 37,* #5092 [3] Zipfel J. et al. (2002) *Meteoritics & Planet. Sci., 37,* #5092. [4] Nehru C. E. et al. (1983) *Proc. Lunar Planet. Sci. Conf., JGR, 88,* B237-B244. [5] Clayton R. N. and Mayeda T. K. (1996) *GCA, 60,* 1999-2017. [6] Nehru C. E. et al. (1992) *Meteoritics, 27*, 267. [7] Weisberg et al. (1993) *GCA, 57*, 1567-1586. [8] Nehru et al. (1996) *LPS XXVII*, 943-944. [9] Prinz M. (1998) *Meteoritics & Planet. Sci., 33*, 3. [10] Cruikshank and Hartman (1984) *Science, 223,* 281-283. [11] Bell et al., (1988) *LPSC, XIX,* 57-58.