THE CHEMICAL COMPOSITION OF MATRIX, CHONDRULES AND BULK OF THE CM CHONDRITE JBILET WINSELWAN.

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Introduction: Carbonaceous chondrites have roughly similar fractions of matrix and chondrules. The composition of these two components is complementary (e.g. [1,2,3]). Mg-rich, Fe-poor chondrules and Si-rich, Fe-rich matrix produce a chondritic bulk meteorite composition. CM-meteorites with mostly forsteritic chondrules are particularly useful examples. We have analyzed chondrules, matrix and bulk samples of the recently found CM2 meteorite Jbilet Winselwan (JW) [4] to strengthen the arguments for complementarity and in order for better understanding of the processes involved in chondrule formation. According to [5], JW consists of approximately 50:50, chondrules and matrix, which are for the main part free of significant aqueous alteration.

Analytical procedures: We analysed 5 JW thin sections, 3 on loans from the Natural Histroy Museum in London and 2 from a private collector. Bulk chondrule compositions were determined according to procedures described by [6,7], using a Jeol JXA-8900RL electron microprobe. Matrix measurements were performed with a defocussed beam widend to 15 µm. For better comparison we analysed also matrix of the CM chondrite Murchison. To verify the reported Ti values, we measured well known standards with low Ti contents. The agreement was better than 10% in all cases. Major and trace elements of bulk samples were determined with ICP-MS and ICP-AES at the Université de Bretangne Occidentale.

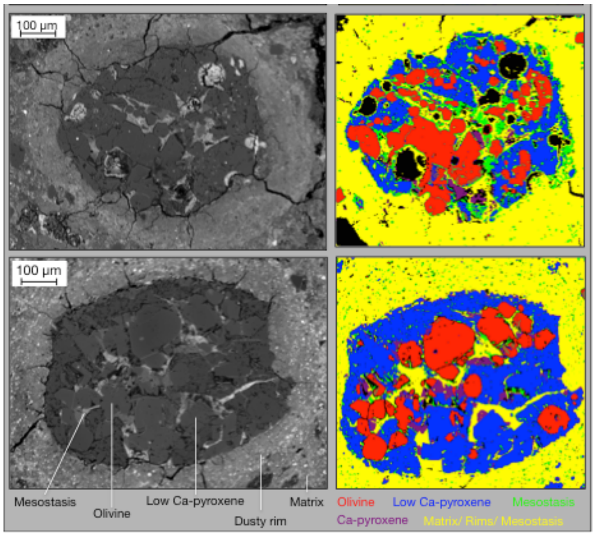

Fig. 1: Two typical chondrules in JW, dominated by olivine and low Ca-pyroxene.

Results: The bulk chemistry is typical of CM chondrites with some enhancement of elements sensitive to terrestrial weathering, like Sr, Ba, U and variable Ca [e.g. 8]. All of the 51 studied chondrules are porphyritic, mainly POP (~80 %), they are generally small (< 500 µm) and are often surrounded by a fine grained rim. Typical chondrules (Fig. 1) have olivine grains concentrated in the center and low-Ca pyroxene minerals at the rim. This zoned structure is typical of chondrules in carbonaceous chondrites [7]. Both, olivine and low Ca-pyroxene grains are unzoned and the transition from forsteritic olivine to FeO-rich matrix is within a few micrometers. Matrix contains numerous fragments. Matrix analyses of JW and Murchison are similar and comparable to literature data of matrix of other CM chondrites [9], except for variations in Al/Ti. Chondrules are compositionally variable, and very low in Fe and high in Si. Table 1 indicates average Si/Mg and Ti/Al wt%-ratios of all components.

	Si/Mg	Ti/Al
Chondrules	0.90 ±0.15	0.14 ±0.11
Matrix	1.36 ±0.16	0.03 ±0.01
Bulk	1.18	0.049
Calc. chd/mtx ratio	39/61	37/63

Table 1: Average Si/Mg and Ti/Al wt%-ratios in chondrules, matrix and bulk JW and calculated chondrule/matrix ratios.

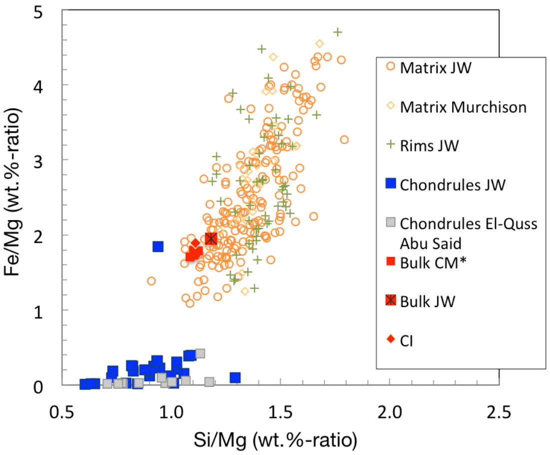

Fig. 2: Fe/Mg vs Si/Mg in chondrules, matrix and bulk of JW and in Murchison matrix.

In Fig. 2 we have plotted Fe/Mg and Si/Mg ratios of 25 bulk chondrules, 170 matrix and 50 rim analyses from JW as well as 30 matrix analyses from Murchison. The Fig. demonstrates the chemical complementarity of chondrules and matrix. For comparison, we have added chondrule data from the CM meteorite El-Quss Abu Said [2]. Al vs. Ti contents are shown in Fig. 3. They reveal likewise a complementary distribution between chondrules and matrix. The bulk meteorite is in both cases CI chondritic. Figs. 2 and 3 also show that accretionary matrix rims surrounding chondrules are compositionally similar to interchondrule matrix (see also [10,11]), except for a slight enhancement of Al/Ti in chondrule rims (Fig. 3).

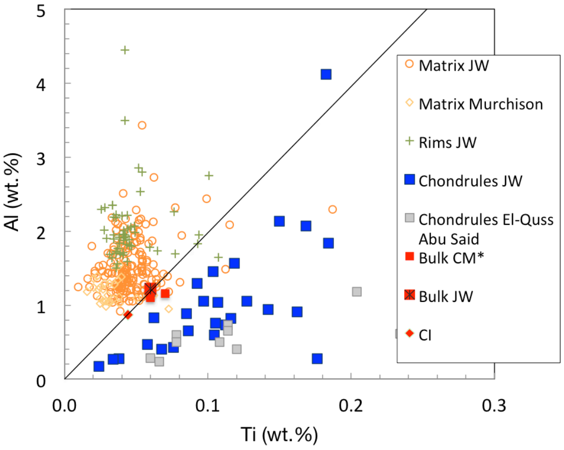

Fig. 3: Al vs. Ti in chondrules, matrix and bulk of JW and in Murchison matrix.

Discussion: The remarkable fractionation of the two refractory lithophile elements Al and Ti between chondrules and matrix was noticed earlier in Renazzo [1] and in Mokoia [3]. In all cases is Ti higher in chondrules and lower in matrix compared to Al. The formal condensation temperatures of Al and Ti at 10^{-4} bar are 1653 K and 1582 K, respectively [12]. Chondrules would have to preferentially accrete lower temperature condensates. There is, however, some evidence that Ti condenses ahead of Al. Fine-grained spinel-rich inclusions (FGI) of the Allende meteorite have high Al but low Ti [13]. It is generally assumed that FGI are condensates from a gas, depleted in superrefactory elements such as Zr and Hf and some REE. The low Ti contents in FGI suggest that Ti belongs to the group of superrefractory elements. The low Al/Ti ratio in chondrules is thus best explained by preferential accretetion of an early condensed Ti-rich phase, perhaps perovskite. At lower temperatures, when matrix minerals form, the early removed Ti-rich phases are missing and matrix forms with high Al/Ti.

The remarkable observation is that the Al/Ti matrix-chondrule fractionation does not occur in all meteorites from a single parent body. Thus Al/Ti is fractionated in Mokoia but not in Allende [3,14]. These differences probably reflect slightly different conditions during condensation of the parental gas and the absence of mixing of chondrules even at the scale of the bulk parent planet. A similar observation was made earlier by [15]. These authors noted that the Ca/Al is high in chondrules of the CV-chondrite Y-86751 but low in chondrules of Allende. Both meteorites belong to the same group and have the same bulk composition but are distinguished by differenecs in the formation conditions of high temperature minerals.

Conclusions: The new data on JW confirm the chondrule and matrix complementarity seen in many carbonaceous chondrites. As Mg, Si, Al and Ti are not srongly affected by secondary processes on the parent body [2,3,15] the observed complementarities must have been established before chondrule formation in the protoplanetary disk. In JW, Ti- as well as Mg-rich phases (perovskite and forsterite, respectively) were preferentially incorporated into chondrules (or chondrule precursor) and were lacking when matrix formed at lower temperatures. Thus, chondrules and matrix formed in a single chemical reservoir. The strong but variable chondrule-matrix fractionation of Al-Ti in meteorites from a single parent body indicates that small differences of conditions of chondrule formation were preserved on a very local scale.

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