
Introduction: Carbonaceous chondrites (CC) have well defined bulk compositions. Refractory, moderately and highly volatile elements of CI-chondrites match uniquely with the less precise solar photospheric elemental abundances. Thus CI-abundances may be substituted for average solar system abundances. Other groups of CC deviate from CI: Elevated refractory elements in all CC, except CR and variable depletions of moderately and highly volatile elements [1]. Mg/Si and refractory element ratios are constant in bulk samples of CC, but fractionated in chondrule and matrix fractions, providing a unique opportunity to study the environment of chondrule formation.

Mg/Si ratios in CC: The Mg/Si (wt) ratio in CC is well defined at 0.902: 0.896±0.03 (22 samples) [4], 0.907±0.03 (18 samples) [5] and 0.903±0.02 (22 samples) [2]. There is a slight, barely resolvable increase of 2 % from CI to CV. Meteorites of the Renazzo group (CR) have CI-chondritic Si/Mg and Al/Mg ratios, the latter is unique among CC. The solar photospheric Mg/Si ratio is 1.0±0.2.

The two volumetrically important components in CR-chondrites are as in all CC fine grained matrix and coarse grained chondrules. Matrix in CR contains variable amounts of water. But there is no indication for reactions of the hydrous matrix with the anhydrous chondrules often rimmed by FeNi-metal. This reflects very low parent body temperatures and excludes elemental exchange between chondrules and matrix on the parent body. Chondrules in CR are dominated by MgO-rich olivine implying high Mg/Si ratios of 1.04 for average chondrules. Matrix has a complementary low ratio of 0.64 (see [6,7] for details). The fraction of matrix in Renazzo calculated from these data is 35.5% compared to about 36% determined from petrography [8] which is well within the uncertainties of the average Mg/Si ratios. The high Si content of the matrix of all CR-chondrites has been confirmed by recent studies [9,10]. Renazzo matrix is far away from CI-composition, it is fractionated.

An important additional observation is that the bulk Mg/Si-ratio of the Al Rais meteorite is almost identical to the Renazzo ratio, although the fraction of matrix in Al Rais is nearly twice as large as in Renazzo [8]. Matrix and chondrule compositions of Al Rais cannot be the same as of Renazzo, because a different mixture of the same components would produce a different bulk composition. The same matrix compositions of Renazzo and Al Rais would require a very different population of chondrules for both meteorites and vice versa. There are no uniform matrix and chondrule compositions in CR meteorites, although the trends are similar with high Mg, low Si in chondrules and low Mg high Si in matrix and bulk CI Mg/Si ratio. Matrix and chondrule formation are not independent. Forsteritic olivine was preferentially incorporated in chondrules. Later condensing Si-rich components ended up in matrix. This matrix-chondrule dichotomy is present in all carbonaceous chondrites although often less pronounced than in Renazzo, as shown by Hezel and Palme [6].

Fractionated refractory elements in chondrules and matrix: Although the level of refractory elements is variable in CC, ratios among refractory elements are generally constant, i.e. ratios of Al, Ca, Ti and REE. Chondrules and matrix may, however, have fractionated refractory element patterns, that are complementary.

Ca/Al: In Allende chondrules have on average lower than CI Ca/Al-ratios and matrix higher, whereas in the very similar CV-meteorite Y-86751 matrix is higher in Al than Ca and chondrules are lower, exactly opposite to Allende [11]. Small differences in the high temperature processing of chondrule precursor material was responsible for these fractionations.

Al/Ti: An even stronger signal comes from the ratio of the two refractory elements Al and Ti in Renazzo and probably other CR-chondrites. Klerner [7] reported a significant enrichment of Ti relative to Al in chondrules of Renazzo and correspondingly low Ti content of matrix, while bulk Renazzo has a CI-chondritic Al/Ti ratio. New data by [6] on chondrules and matrix in Renazzo have confirmed the Al-Ti fractionation in Renazzo, which is show in Fig.1. The chondrule data are from [6,7]. Also plotted are bulk CC data from [2,4,5]. The error bars of chondrules in Fig. 1 reflect the uncertainty of the extrapolation from 2D to 3D in calculating bulk chondrule compositions [12]. In a recent study of the matrix of the two very primitive CR chondrites QUE 99177 and MET 00426 Abreu and Brearley [10] showed that matrix compositions in these meteorites are comparable to Renazzo. Fifteen out of 16 matrix areas have higher than chondritic Al/Ti ratios, indicating that low Ti-matrix is a general characteristic of CR-chondrites.

Matrix analyses of Al Rais also gave an average Ti/Al ratio of 0.021 (average of 100 analyses), compared to
the CI-ratio of 0.053 [7]. McSween and Richardson (1977) [13] report a ratio of 0.031 for Al Rais matrix. There are indications that some CV-chondrites have high Ti/Al in chondrules and low Ti/Al in matrix. Efremovka, Leoville and Vigarano matrix analyses by [7] indicated Ti/Al ratios of 0.031, a similar value was found by [13] for Vigarano matrix. It appears that low Ti/Al in matrix is characteristic of many, if not all CR and CV chondrites. In a recent paper [14] reported chemical data on over 90 bulk chondrules from the CV3 chondrite Mokoia. A Ti vs Al plot shows that most chondrules have a higher than chondritic Ti/Al-ratio. The two matrix analyses indicating a complementary Ti deficit in Mokoia matrix are from [7,14].

**Discussion:** The complementary Mg/Si relationship of chondrules present in all carbonaceous chondrites requires preferred incorporation of forsteritic olivine in chondrules and incorporation of residual Si-rich material in matrix. Fractionated Ti and Al in chondrules and matrix is present in CR and some CV. It is presently unclear if this is a characteristic signature of all CV. This requires separation of chondrule precursor material at high temperatures, e.g. preferred accumulation of perovskite.

Chondritic Mg/Si in Allende is characteristic of mm-sized chunks of Allende. Thus complementarity was established in comparatively small nebular regions, involving only a few hundred chondrules or even less. It even appears that areas with the same bulk composition in Renazzo have different proportions of matrix and chondrules. Since matrix in Renazzo is fairly constant, the average chondrule compositions must be variable, reflecting chondrule matrix fractionation on a very local scale [7]. Models of chondrule formation requiring different formation regions, chondrule size sorting or chondrule formation by collisions of molten planetesimals can be excluded.