COMPOSITIONAL TRENDS IN CHONDRULES FROM UNEQUILIBRATED ENSTATITE CHONDRITE, PARSA

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ABSTRACT. Multielemental analysis of chondrules from unequilibrated E3 chondrite Parsa show that the lithophile elements, both refractory and volatile, are enriched and siderophiles are depleted relative to C1 abundances. This behaviour is generally similar to chondrules from unequilibrated ordinary chondrites (UOC). A detailed comparison of compositional trends in chondrules from E3 chondrites (Parsa and Quingzhen) with UOC's indicates that some of the precursor components of chondrules of E3's are different from those of UOC's.

1. INTRODUCTION

There has been considerable debate about the origin of the chondrules and questions such as whether these are primordial nebular condensates or melt products of some pre-existing material have been discussed extensively. In particular, Wood (1984) has favoured formation of chondrules by aerodynamic drag heating of interstellar grains in the primitive solar nebula. Recent compositional and petrological studies of chondrules from UOC's belonging to H3, L3 and LL3 classes indicate that they are melt products of some pre-existing solid components (Gooding et al, 1980; Grossman and Wasson, 1982, 1983). As E-chondrites show remarkable differences in their degree of reduction, mineralogy, chemistry and oxygen isotope systematics, we have measured the elemental abundances in chondrules from Parsa. We compare the results in Parsa and Quingzhen (Rambaldi et al, 1983; Grossman et al, 1985) with the trends observed from chondrules from UOC's.

2. MATERIALS AND METHODS

Parsa fell on 14th April, 1942 in Muzaffarpur District of Bihar, India. One of the two fragments recovered has a P shaped white enstatite nodule and several smaller enstatite grains distributed throughout the matrix. Chemical and petrological characteristics of Parsa have been described by Bhandari et al. (1980) and Nehru et al. (1984). Several millimeter

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to submillimeter size chondrules weighing 27 mg were seperated from a gently crushed fragment of Parsa. The largest chondrule was found to weigh 9.8 mg. The chondrules alongwith standards BCR-1 and Allende (split 4, position 24) were irradiated at Cirus reactor of BARC,Bombay

TABLE 1. MEAN ELEMENTAL COMPOSITION OF PARSA CHONDRULES

REE	SIDEROPHILES	LITHOPHILES
La 1.21±0.07	Fe 4.0±0.012	Na 0.92±0.04
Sm 0.485±0.012	Ni 0.15±0.03	Ca 1.97±0.15
Eu 0.16±0.03	Co 48±0.2	Sc 18.8±0.02
Yb 0.49±0.05	Ir 82±2	
Lu 0.09±0.009		

Concentrations are in wt% for Na, Ca, Fe and Ni, in ppb for Ir, and in ppm for rest.

for a fluence of $\sim 10^{19} n/cm^2$. The elemental determinations were made by INAA using a high purity Ge detector (148 cc), situated in a 10 cm lead shield. The FWHM resolution of the detector is 2.1 KeV for 1333 KeV peak of ^{60}Co.

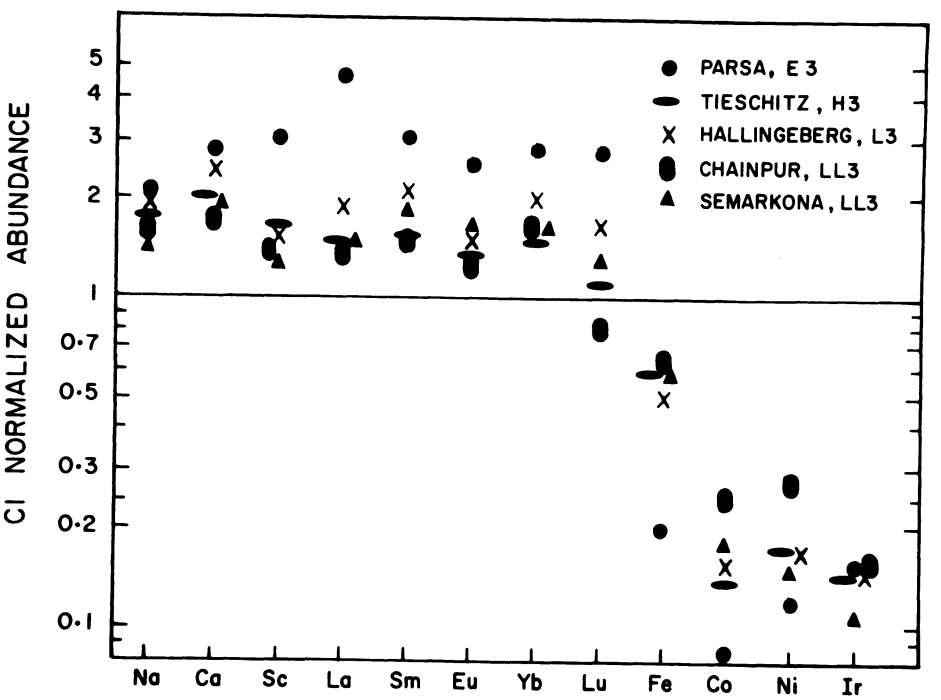

Figure 1. Normalised abundances showing enrichment of lithophile and rare earth elements and depletion of siderophile elements in chondrules from type 3 chondrites. The data for UOC's are from Gooding et al (1980).

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3. RESULTS AND DISCUSSION

The trace element data for rare earth elements (La,Sm,Eu,Yb and Lu), siderophiles (Fe,Co,Ni and Ir) and other lithophiles (Na,Ca and Sc) for Parsa chondrules are given in the Table 1. The errors mentioned in the Table represent statistical errors due to counting only. We compare the

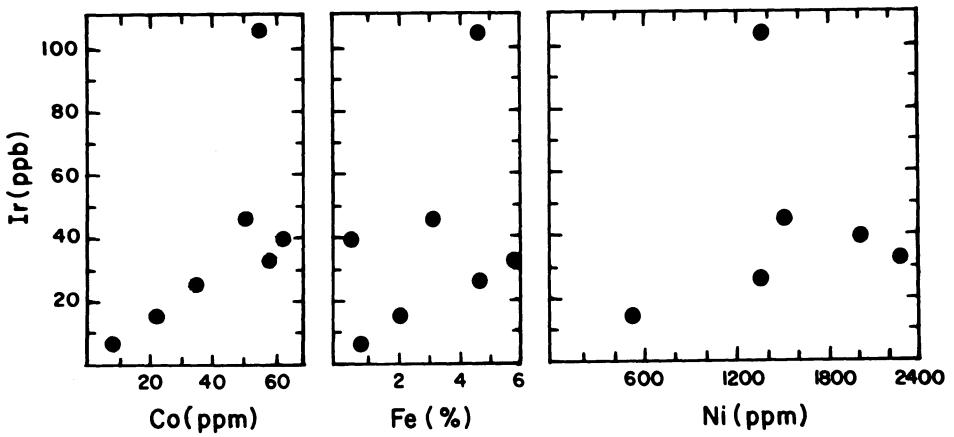

Figure 2. Inter-elemental correlations, Ir-Co, Ir-Fe, Ir-Ni in single Parsa chondrules.

trends in Parsa chondrules with those of other UOC chondrules from Tieschitz, H3, Hallingeberg, L3, Chainpur, LL3 and Semarkona, LL3 studied by Gooding et al (1980). The trace elements for Parsa and other UOC's (C1 normalised abundance) are plotted in Fig. 1. From Fig. 1 the following observations can be made. In both the cases viz. Parsa and UOC the refractory rare earth elements (La,Sm,Eu,Yb and Lu) as well as lithophiles, both volatile and refractory (Na,Ca,Sc) are enriched in chondrules relative to C1 chondrites and the siderophiles (Fe,Co,Ni and Ir) are depleted. Similar trends have been observed for chondrules from Quingzhen (Grossman et al, 1985) but the REE values for Parsa chondrules are higher by a factor of 2 to 3. The C1 normalised ratios such as La/Lu or Sm/Yb for chondrules of the two enstatites also agree within $\pm$25%. Average value of Ca/Sc and Eu/Sc in chondrules is also similar. We have also measured siderophiles (Fe,Co,Ni and Ir) and other elements like Sc,Eu and Zn in seven individual chondrules. All the four siderophile elements show a positive correlation among themselves as shown in Fig. 2. Eu/Sc in individual chondrules ranges between 0.004 to 0.008 for Parsa and 0.005 to 0.011 for Quingzhen. Thus some of the differences observed between Parsa and Quingzhen may be only due to limited number of chondrules analysed. When compared to UOC's the Ca/Sc and Eu/Sc also show similar values. Even the refractory/volatile element ratio Na/Sc is same for both the sets of chondrules within a factor of 2. Thus the gross general pattern of these elements is the same in chondrules from both sets of unequilibrated chondrites: enstatite and ordinary and some of the chondrules of E3's appear to have a refractory lithophile precursor component (Ca,Sc,REE and Na) similar to those of UOC's.

Inspite of the fact that the trends are broadly similar between both sets of chondrules, there are important differences. As can be seen in Fig. 1 the enrichment factor for Sc and REE in case of Parsa chondrules are marginally higher (within a factor of 2) as compared to the mean value of other UOC's. It has been pointed out by Grossman et al (1985) that contrary to chondrules from UOC's the Quingzhen chondrules show little variation in their abundance of refractory lithophile elements. However, in case of Parsa chondrules we find that Sc shows a range of variation of about a factor 3, similar to UOC's. La is found to be 1.5 times more than even the highest value observed for UOC's whereas other elements (Sc,Sm,Eu,Yb and Lu) fall within the range. Among siderophile elements Fe is highly depleted in case of Parsa chondrules (1/5) compared to other UOC's where the mean depletion factor is 1/2. Further the Fe concentration in individual chondrules of Parsa is highly variable and changes by as much as a factor of 10. Mineralogically Parsa chondrules have been found to be almost similar to Parsa bulk except that the chondrules are depleted in metal and sulfide phases (Nehru et al, 1984). Similarly various inter-elemental correlations (Na-Al-REE-Hf, Ca-Se-Eu etc.) observed in case of chondrules from unequilibrated Quingzhen enstatite chondrite are not observed in case of UOC's (Grossman et al, 1985). These differences indicate that some precursor components of chondrules in case of unequilibrated E chondrites are not similar to those of the UOC's. Thus it appears that the chondrules in E3 chondrites, like in UOC's, have also undergone some melting process and some of the precursor components of E3 chondrules are different from those of chondrules in ordinary unequilibrated chondrites.

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