STATISTICAL ANALYSIS OF THE NIPR (JAPAN) ANTARCTIC CHONDRITES: PATHS OF THERMAL EVOLUTION OF PARENT BODIES?

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On the basis of the new Catalog of Antarctic Meteorites (Yanai, Kojima, Haramura, 1995) we carried out statistical analysis on the bulk composition of chondrites (of the 2987 classified chondrites on 403 samples). From averages of van Schmus-Wood petrologic classes (vSW-pc) we have projected paths of thermal evolution of chondritic parent bodies of E, H, L and LL types. Transformations in the ferrous compounds were projected to the vSW-table, then their changes between the vSW-pc stages were projected to the compositional field of the Fe+FeS vs. Fe-oxides diagram. There the sequence of vSW-pc averages (representing higher and higher heat-impact with increasing vSW-pc numbers) formed an oxidation and reduction series from the initial reduction (for all types) through reoxidation (for H, L, LL types) till final outflow of iron (for L and LL types).
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INTRODUCTION

In the very early Solar System asteroid-sized objects may have been warm as shown by the spherical shape and zonal differentiation of many asteroids. In a warm open thermodynamic system 2 thermodynamic processes are inevitable: chemical transmutation and diffusion. These processes may have run parallel during the thermal evolution of chondrite parent bodies. Transmutation is possible in a Fe-C-FeO-H_2O system: reduction, or oxidation depending mainly on the ratio of C and H_2O, and other initial conditions (Fe/Si ratio, Fe/FeO ratio, etc. [1], [2]). Thermal diffusion in silicate minerals is mostly visible on chondrules, which gradually lose their sharp edges, fade and become obscured. ([3], [4]). Let us look for the signals of these processes on chondrites.

Both chondrite classifications (types & petrologic classes) implicitly involve the idea of thermal evolution. The plot of Fe+FeS vs. Fe-oxides ([1], [2], [5], [6]) used the exchange of Fe between silicate and metallic phases, and focused on Fe/FeO ratio, while the chondritic textural studies ([3], [4], [6]) mostly focused on a metamorphic process which slowly fades then obscures chondrite grain boundaries. The van Schmus-Wood table cross-multiplies the two thermal transformational lines: with the types E, H, L, LL and C "rows" this system contains the "metallurgic" classification, but adds new aspects of chondrule degradation and volatile loss and other monotonous processes, which could strengthen the evolutionary view.

The huge new database of the NIPR Antarctic Meteorite Collection [7] gives possibility to statistically analyse the bulk chemical evolution of different chondritic type parent bodies. The NIPR collection contains cca. 8000 meteorites, mainly Antarctic ones. The most recent report from them is Yanai, Kojima & Haramura [7]. Among the 3334 meteorites classified up to now there are 2987 chondrites of which bulk chemical analysis of 403 ones has been given, the overwhelming majority of them had been measured by Dr. Haramura, with a homogeneous method. This huge database may suggest statistical analysis of bulk composition of chondrite parent bodies.

THE TWO TRANSFORMATIONAL PROCESSES PROJECTED ONTO EACH OTHER

Let us project the "metallurgic" process (oxidation and reduction of Fe) and the textural metamorphic sequence (vSW-pc) onto each other. With data of [8] we could project carbon data to the Van Schmus-Wood table (absent, unfortunately, in the NIPR data). Taking FeO and Fe data from the NIPR set, we could correspond the average Fe-C-FeO triple-data to all van Schmus-Wood boxes. This way we could project the results of the suggested metallurgic transformational processes (i.e. the compositional position in the metallurgic field) onto the suspected temperature scale corresponding to petrologic classes.

We normalised the composition data to Si (we practically do not know processes extracting Si). Si generally remains in the silicates, except for minor reduction in E6 [9], and silicates are not volatile. As for dependence on petrologic class (heat impact) one can turn to colours which stretch a tripolar representation. Let 30 % metallic + sulphide Fe content (the maximum in stony meteorites) be represented by pure red, 30 % of FeO by pure green and 5 % of C by pure blue. Then, going from low petrologic classes to high and finally to achondrites, the picture is as follows: E's start from brick red through strawberry red until cherry red; the E achondrite is practically black. H3 is ochre yellow, H3-4 is exceptionally reddish, H4 and H5 are brownish, but H6 is greenish yellow. The H achondrite is not known. L's are oscillating between grayish green and greenish brown; the achondriite is rather green. LL's are all green, oscillating between grass green and olive green; the achondrite is deep green. Finally, C1's are bluish, C2's are grayish green, but then the colour becomes more and more green and C6 is deep green; the C achondrites are not identified, but ureilites show some similarities with C's and they are bluish [10], [11]. (Achondrites may be visualized as "beyond beyond petrologic class 7" and indeed, they can be obtained, at least for rough chemical composition, by removing molten Fe+FeS, which can be expected for high temperature in the presence of gravity.)

Then let us project the vSW-pc averages onto the metallurgic field. This way we can project *temperatures onto the metallurgic field, due to the gradual process of diffusion*. The sequences of these temperatures draw out paths of mainly reductional-oxidational transformations for E, H, L, LL. (Note that within one type the petrologic classes may correspond to temperatures, but it does not follow that the same petrologic class would correspond to the same temperature for different types. Petrologic class corresponds to the extent of chondrule-matrix interdiffusion.

The diffusion length is proportional to the square root of the diffusion coefficient, which depends on T, but it depends on chemical composition too. Now, the types E, H, L, LL differ mainly in the FeO content; the “missing” FeO of the silicate is “substituted” mainly by MgO. So different temperatures belong to the same diffusion coefficient in different types. If thermal impacts are the fundamental factors behind parent body and meteorite evolution, then chondrule obscuring and final vanishing is a rather smooth sequence. So then this sequence serves as a good background (a smooth frame of reference for events) to exhibit detailed steps in the metallurgic process in different chondrite parent bodies.

Reduction [12], [13], [14] and C loss is general for low petrologic classes, but an oscillation between oxides and non-oxides starts in middle petrologic classes. (Data for E5 and E6 are taken from [6]) As seen, a few Antarctic meteorites are classified in “transitional” petrologic classes, e.g. H3-4 represents 4 analysed meteorites. (Mg/Si distribution for chondritic types clearly shows the 3 groups (C;LL,L,H;E) which *cannot* evolve into each other because MgO practically cannot be reduced). Let us see the details of Fe-FeO oscillation. Fig. 1 shows the five chondritic types on the free Fe/Si vs. bound Fe/Si map; the petrologic classes are indicated as labels. Clearly “cycles” or “loops” are seen. At the ends of the LL, L and E lines total Fe loss is seen; maybe there the temperature reached the melting point of carbonised Fe, so global differentiation started.

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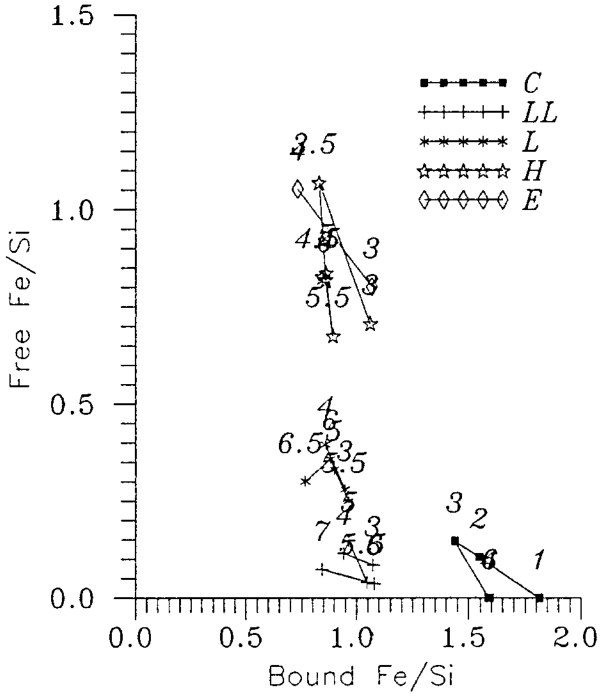

Fig. 1. Sequences of averages for petrologic classes in all chondritic types.