Mg/Si fractionation of chondrules: Heating energy input rate and physical separation rate

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Recent studies for ^{26}Al-^{26}Mg ages and bulk chemical compositions of chondrules in ordinary chondrites have shown that bulk compositions of chondrules would have evolved with time: from Si- and volatile-poor older chondrules to Si- and volatile-rich younger chondrules. These chemical variations could be formed by evaporation of Si and volatiles and partial physical separation of chondrules from a chondrule-forming region.

Combining the age-Mg/Si correlation with literature data for the bulk Mg/Si and the frequency of each chondrule type (e.g., type IA, IIA..), we estimated the age distribution with a peak at ~1.8 My after Ca-Al-rich inclusions for chondrules in ordinary chondrites. We made a two-box (chondrules and dust) model for chondrule formation and reported that the age distribution is explained by a heating energy input rate (a fraction of material heated in a unit time) decreasing exponentially with time. In oher words, older chondrules are less abundant due to high frequency of heating events (age-resetting), while younger ones are less abundant due to rarely happening chondrule forming events.

We develop the model in order to explain the observed age-Mg/Si distribution. The boxes for chondrules and dust (matrix) are divided into "chondrule Mg", "chondrule Si", "matrix Mg" and "matrix Si", respectively. We also introduce a physical separation rate of chondrules (S), which is defined as a fraction of chondrules separated from the system in a unit time, and a Mg/Si chemical fractionation factor. Separation of chondrules is required for Mg/Si variations observed in chondrules. However, the S should not be large in the earlier epoch of chondrule formation in order to keep older chondrules in the system and reset their ^{26}Al-^{26}Mg ages by subsequent heating, which explains the observed age distribution.

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Size-normalised test weights, Mg/Ca and Sr/Ca of planktonic foraminifera from the Arabian Sea

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Weights of narrow-ranged planktonic foraminifera tests have been proposed as an indicator of carbonate ion concentration in bottom water (Broecker and Clark, 2001; Rosenthal and Lohmann, 2002). However, the dissolution of tests in sediments may bias estimated carbonate ion concentrations. To investigate this dissolution effect, we analysed test weights, Mg/Ca (paleothermometer) and Sr/Ca of planktonic foraminifera (*Globigerinoides ruber* and *Globigerinoides sacculifer*) from a well-characterised core MD900963 (5°N, 74°E, 2446 m water depth) in the Arabian Sea. The primary productivity at the studied site varied with precession cycles during the last 300 ka (Beaufort *et al.*, 1997; Rostek et al., 1997; Pailler *et al.*, 2002). We selected the samples from high and low productivity periods of the last 130ka.

The results show that tests lose 20-30% of the total weights during the high productivity periods. Mg/Ca of *G. ruber* varies between 3.8 and 4.9 mmol/mol during the MIS 5 (which corresponds to 25 to 28°C) in spite of a narrow alkenone SST range of 27.5±0.3 °C (Rostek *et al.*, 1993). Sr/Ca of both species are systematically lower during the high productivity periods but to a lesser extent than Mg/Ca. All the results suggest the dissolution of tests in sediments influences test weights and chemistry. Correcting this dissolution effect to Mg/Ca using the weight change (Rosenthal and Lohmann, 2002), reconstructed Mg/Ca SST of *G. ruber* agrees well with alkenone SST during the MIS 5.

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