

## Incomplete mixing in the solar nebula: Implications for early Earth

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In order to interpret isotopic differences observed between the Earth and meteorites it is imperative to know the initial ratio of the parent nuclide and bulk daughter reference values in both Earth and meteorite parent bodies. Carbonaceous chondrites have been found to have a negative  $^{142}\text{Nd}$  signature (averaging 20 ppm) compared to the bulk silicate Earth [1]. One of the hypotheses to explain this is that it is due to early Sm-Nd fractionation, decay from now extinct  $^{146}\text{Sm}$  and subsequent burial of an enriched layer that has remained hidden over the past 4.5 Ga. Here we show that a hidden reservoir is not necessary to explain the 20 ppm variation seen.

$^{146}\text{Sm}$  and  $^{144}\text{Sm}$  are both p-process nuclides. The cited initial  $^{146}\text{Sm}/^{144}\text{Sm}$  ratio of 0.008 is not supported by a wide data review. Instead, we see an early Solar System with an average initial  $^{146}\text{Sm}/^{144}\text{Sm}$  of 0.009 at 4.567 Ga with a large uncertainty of 0.002. If this variation seen is due to incomplete mixing of fresh  $^{146}\text{Sm}/^{144}\text{Sm}$  it can lead to differences in  $^{142}\text{Nd}/^{144}\text{Nd}$  of over 1.4‰ units between planetary bodies. It has been shown that there are stable  $^{144}\text{Sm}$  (p-process) heterogeneities in Carbonaceous Chondrites [2] which may further complicate this issue.

Isotopic differences in bulk meteorites have now been found for a variety of elements. We have measured Ba and Nd isotopic compositions in individual CAIs and with other data have found striking correlations between isotopic anomalies. Isotopes which are made in a neutron burst or supernova have positive correlations with each other and negative correlations with s-process isotopes. Three components mixing is also seen in some correlation diagrams between CAIs, OCs, and CCs having a large amount of refractory inclusions. Here Earth does not lie in the mixing space. All other isotopes with anomalies except for  $^{142}\text{Nd}$  cannot be due to planetary differentiation processes and are nucleosynthetic in nature. Since  $^{142}\text{Nd}$  correlates with these isotopes as expected if it was due to incomplete mixing of material from a supernova the  $^{142}\text{Nd}$  anomalies between the Earth and meteorites can also be thought of as nucleosynthetic which negates the need for a hidden reservoir in the mantle.

- [1] Boyet M. & Carlson R.W. (1995) *Science* **309**, 576-581.  
[2] Andreasen R. & Sharma M. (2006) *Science* **314**, 806-809.

## Isotopic interpretations for abundant carbonates in the Tertiary red clay of the Chinese Loess Plateau

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Why carbonate contents are higher in the Tertiary red clay than in the Quaternary paleosols of the Chinese Loess Plateau is still controversial [1, 2]. In order to explore the cause, we determine Sr isotope ratios and Ca contents of carbonates in the Lingtai profile (Table 1) [3].

| Period     | Layer (n)    | $^{87}\text{Sr}/^{86}\text{Sr}$ | Ca content |
|------------|--------------|---------------------------------|------------|
|            |              | Mean                            | Mean       |
| Quaternary | Loess (33)   | 0.710990                        | 2.6%       |
|            | Palesol (32) | 0.711313                        | 0.8%       |
| Tertiary   | Red clay (9) | 0.711517                        | 3.8%       |

**Table 1:** Sr isotope ratios and Ca contents of carbonates in the Lingtai profile (n denotes the number of samples).

$^{87}\text{Sr}/^{86}\text{Sr}$  ratios and Ca contents of carbonates are higher in the Tertiary red clay than in the Quaternary loess and paleosols, as shown in Table 1.

$^{87}\text{Sr}/^{86}\text{Sr}$  ratios of carbonates are a good proxy of chemical weathering in the Chinese Loess Plateau [3]. High  $^{87}\text{Sr}/^{86}\text{Sr}$  ratios of carbonates thus show strong chemical weathering in the Tertiary red clay. However, high contents of carbonates in the Tertiary red clay can not indicate weak summer monsoon at that period. The Tertiary red clay is finer than the Quaternary loess and paleosols, thus should have more primary carbonates according to the reference [4]. Most primary carbonates could be *in situ* evolved into secondary carbonates during the development of the Tertiary red clay.

Therefore, high contents of carbonates in the Tertiary red clay were mainly a result of primary carbonate redistribution under strong chemical weathering.

- [1] Chen *et al.* (2007) *Sci. Sini.* **50**, 392-403. [2] Guo *et al.* (2001) *PPP*. **170**, 11-26. [3] Yang *et al.* (2000) *PPP* **157**, 151-159. [4] Wang *et al.* (2005) *Atmos. Environ.* **39**, 2631-2642.