

## Zirconium isotopes in carbonaceous chondrites

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The isotopic composition of Zr mainly reflects a mixture of different *s*- and *r*-process nucleosynthetic components. The *s*-process is capable of producing  $^{90}\text{Zr}$ ,  $^{91}\text{Zr}$ ,  $^{92}\text{Zr}$  and  $^{94}\text{Zr}$ . The *r*-process is a more likely mechanism for producing  $^{96}\text{Zr}$ . Furthermore, presolar grains provide distinct abundance patterns that match the Zr isotopic compositions produced by the *s*- and *r*- process [1]. We have recently shown that the bulk rock Zr isotopic compositions of various solar system materials (e.g. chondrites, eucrites, moon and Earth) do not vary outside of the analytical error and concluded that Zr isotopes were distributed evenly in the solar system at the bulk rock and larger scale [2]. However, excess  $^{96}\text{Zr}$  has been observed in CAIs and ascribed to an *r*-process component [2-4]. Leachates of carbonaceous chondrites revealed nucleosynthetic anomalies for other isotopes such as  $^{54}\text{Cr}$ ,  $^{40}\text{K}$  and Mo isotopes [5-7]. Therefore, we analysed Zr isotopes in leachates of Allende (CV), Murchison (CM) and Orgueil (CI). The samples were sequentially leached with acids of increasing strength: 1. acetic acid, 2.  $\text{HNO}_3$ , 3. HCl, 4. HCl-HF, and 5. HF-HNO<sub>3</sub> in a teflon bomb. All measurement were performed by MC-ICPMS. The Zr isotopic compositions of all leachates were determined, except for Orgueil, where the acetic acid fraction and the teflon bomb dissolution contained little Zr. The results for these three carbonaceous chondrites show a consistent pattern: The acetic acid leachates of Murchison and Allende both display large  $\epsilon^{96}\text{Zr}$  excesses of  $48.6 \pm 1.5$  and  $10.0 \pm 1.5$ , respectively. In subsequent dissolution steps, the abundance of  $^{96}\text{Zr}$  decreases to the terrestrial value and even below this for Murchison ( $\epsilon^{96}\text{Zr} = -12.5 \pm 1.5$ ). For Allende, no variations in  $\epsilon^{91}\text{Zr}$  and  $\epsilon^{92}\text{Zr}$  are observed, whereas small variations were found for Murchison and Orgueil. The results agree with the Cr data [5], for which the isotopic variations in Allende are also small compared to the more primitive chondrites Orgueil and Murchison. While the homogeneity in Zr isotopic composition of bulk rock samples shows that the solar nebula was well mixed on a large scale, the new results on leachates provide evidence for an heterogeneous distribution of *r*- and *s*-process components on a smaller scale.

### References

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## Geochemical controls on Quaternary dating

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All dating methods assume a process *G* which generates a product *p* whose amplitude is a function of time, *p*(*t*). Generally, *p*(*t*) is dependent on concentrations, [*X*<sub>*i*</sub>], of elements and compounds within or in the neighborhood of the dated sample; these concentrations are also generally a function of time, and space. Here I consider the implications to two dating methods: U-series; and trapped charge dating (TCD). Element transport occurs during three stages in geological history of a site: *S*<sub>1</sub>:deposition, surface exposure; *S*<sub>2</sub>: burial; *S*<sub>3</sub>: exhumation.

### U-series

Only coralline aragonite and stalagmitic calcite approximate closed systems For all biological materials (teeth, bones, egg shells, mollusk shells and other skeletal carbonates) post-mortem U uptake dominates (*S*<sub>1,2,3</sub>), enhanced by the presence of an organic matrix, reduction of U(VI) to U(IV). Models of transport, fixation of U into bone fits observed gradients in [U] and isotope ratios.  $\gamma$ -ray whole-bone dating may give erroneous ages, but  $\gamma$  analyses of  $^{231}\text{Pa}$  allow some control of U uptake history and partial refinement of the age. U uptake followed by loss (*S*<sub>3</sub>?) is difficult to model.

### TCD

Dates are given by the ratio of accumulated dose (*D*<sub>c</sub>) to dose rate (*d*), mainly due to U, Th, and K in sample, matrix. For TL, OSL, sample and matrix compositions are stable; leaching of K, U during *S*<sub>2</sub> occurs in cave deposits associated with high initial content of ash and biogenic matter. U transport into/out of dental tissues (enamel, dentine) affect *d* for ESR dates (Grün *et al.*, 1988). On isochron plots of *D*<sub>c</sub> vs *d* for coeval samples intercept gives *t* \* *d*(external). Water content, affected by climate effects changes *d* and thus ages by 10-30%.

### References

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