Isotopic evidence for primordial molecular cloud matter in metal-rich carbonaceous chondrites

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Bulk inner solar system reservoirs record positively correlated variability in mass-independent ^{54}Cr and ^{26}Mg*, the decay product of the short-lived ^{26}Al radionuclide. This correlation is interpreted as reflecting progressive thermal processing of in-falling ^{26}Al- and ^{54}Cr-rich molecular cloud material [1]. Planetesimals formed in the outer solar system could have accreted a significant fraction of primordial and, hence, thermally unprocessed molecular cloud matter. This material reflects the nucleosynthetic make-up of the molecular cloud prior to the last addition of stellar-derived ^{26}Al. Therefore, unlike inner solar system objects, the isotopic signature of the thermally unprocessed and ^{26}Al-poor primordial molecular cloud matter is expected to show a decoupling between their ^{26}Mg* and ^{54}Cr compositions.

To search for the signature of primordial molecular cloud material, we analyzed the magnesium and chromium isotope composition of metal-rich carbonaceous chondrites (CH, CB and CR) and their components, including 3 bulk samples, 13 chondrules and 5 hydrated lithic clasts. Several observations suggest that metal-rich chondrites may have incorporated primordial molecular cloud material of possible outer solar system origin, including enrichment in ^{15}N, high abundance of presolar grains and the presence of ^{26}Al-poor CAIs. Our results show that CH, CB and CR chondrites and their components have a unique ^{26}Mg* and ^{54}Cr isotope signature, falling off the solar system correlation line. Our samples define an array extending from the composition of CM chondrites to that expected for thermally-unprocessed and ^{26}Al-free molecular cloud material (μ^{54}Cr=160 ppm, μ^{26}Mg*=–16 ppm). This requires the presence of significant amount (25-50%) of primordial molecular cloud material in bulk metal-rich chondrites. Given that such high fractions of primordial molecular cloud material are expected to survive only in the outer solar system, we infer that, similarly to cometary bodies, metal-rich chondrites are samples of asteroids that accreted in the outer solar system. The lack of evidence for this material in other chondrite groups requires isolation from the outer solar system, possibly by the opening of disk gaps from the early formation of gas giants.

[1] K.K. Larsen *et al.* (2011) *Astrophys. J.* **735**, L37.