

Large enantiomeric excesses in primitive meteorites and the diverse effects of water in cosmochemical evolution

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The Renazzo-type (CR) carbonaceous chondrites are a group of primitive asteroidal stones that have the distinguishing characteristic of containing an abundant soluble organic suite made up predominantly of water-soluble molecules [1]; thanks to good curatorial keeping, and a bit of luck in their Antarctica findings, several of these meteorites have also shown very little terrestrial contamination. CRs, therefore, have offered the most desirable sample so far to study the organic compounds of the early Solar System and their distribution and evolution in small planetesimals.

We recently studied the organic composition of selected CR meteorites of different petrographic classification and found that several organic compounds such as amino acids and sugar alcohols are fully represented in stones with no or minimal water exposure indicating a formation that, if solar, preceded parent body processes. The most pristine CRs also revealed natal enantiomeric excesses (*ee*) up to 60%, much larger than ever recorded.

Thus far, *ee* in meteorites had been detected for the most part in amino acids that are not very common on the Earth [2] and cannot racemize¹, *i.e.*, have a methyl attached to C2 and cannot change their configuration in water. The new CR *ee* values were detected instead in a particular group of 2-H amino acids, isoleucine (*ile*, common in proteins) and *alloisoleucine* (*allo*), which also appear reduced in altered stones in proportion to the extent of their level of aqueous exposure. Based on the knowledge that the amino acids in meteorites may derive from aldehydes and, in particular, that the aldehyde precursor to these compounds showing large *ee* would also be chiral, it was proposed earlier [1] that aldehydes could be the carriers of the original asymmetry. The new data support that inference and allow two further conclusions.

The first is that, because the precursor aldehyde racemizes readily, in fact, much more rapidly than amino acids, for CR amino acids to show *ee* at all, their synthetic window must have been short and icy, *e.g.*, in early parent body, proto-planetesimal aggregates, or protoplanetary disc environments, with the ammonia abundance that characterizes these type of stones [3] providing a lower freezing point of water. The second surprising finding is that *ee* in extraterrestrial environments can be much larger than previously recorded. Until now, these were detected up to 20% for isovaline [4][5] and 14% for *ile/allo* amino acids [1]. That 2-H amino acids' *ee* were racemizeable and reduced during the aqueous phase, validates the large *ee* of less altered stones as primitive and further support their formation ahead of parent body processes.

References. [1] Pizzarello S. et al. *Proc. Nat. Acad. USA* **105**:3700 (2008); [2] Cronin J.R. and Pizzarello S. *Science* **275**:951 (1997); [3] Pizzarello S. et al., *Proc. Nat. Acad. USA* **108**:4303 (2011); [4] Pizzarello S. et al. *Geochim Cosmochim Acta* **67**:1589 (2003); [5] Glavin D.P. and Dworkin J.P. *Proc. Nat. Acad. USA* **106**:5487 (2009).

¹*Racemization* is a process by which a chiral amino acid having a H- attached to the 2C in the C-chain may lose and reacquire this H in water; because each reacquisition may lead stochastically to either D-, or L- configuration, the process leads with time to *ee* loss and a *racemic* compound.