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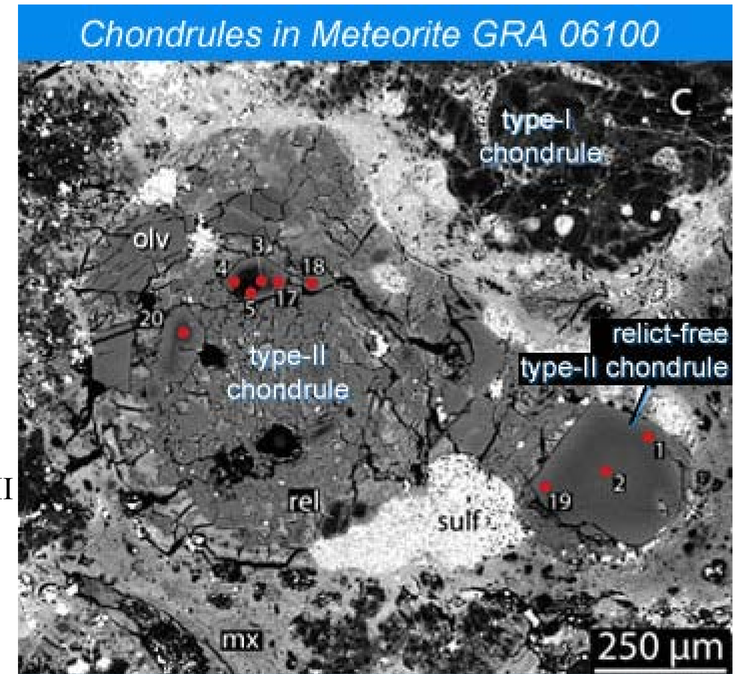
Chondrule Formation



(From Schrader, *et al.*, 2013, *Geochimica et Cosmochimica Acta*, v. 101, p. 302-327, doi: 10.1016/j.gca.2012.09.045.)

In this backscatter electron image of chondrules in meteorite GRA 06100, red dots indicate locations of O-isotope analysis spots in a type-II chondrule and in a fragment of a relict-free type-II chondrule. Other labels are olv = olivine, rel = FeO-poor relict grain, mx = matrix, sulf = sulfide.

The origin of ***chondrules***—the material from which they formed and their melting histories—has intrigued cosmochemists for decades and continues as an active research theme. Recent work by Devin Schrader (formerly at the University of Arizona and now at the University of Hawai‘i) and colleagues from Arizona, New York, and Hawai‘i, aims to constrain the formation conditions of the two main chondrule groups, designated ***type-I and type-II***, to answer whether or how their origins are related. Schrader and coauthors have studied the oxygen-isotopic compositions and oxidation states of olivine in type-I and type-II chondrules from three Renazzo-like carbonaceous (CR) chondrites. The meteorite samples (GRA 95229, GRA 06100, and QUE 99177; collected by the U.S. ***Antarctic Search for Meteorites program***), span a wide range of whole rock oxygen-isotopic compositions. Their detailed analyses of the major-and minor-element abundances and *in situ* oxygen-isotopic compositions of 21 chondrule olivines yielded interesting results, including:

- A relationship between the oxygen-isotopic composition and oxidation state (expressed as ***oxygen fugacity***) of chondrule olivines suggests the processes that controlled them are linked. Schrader and coauthors found that as the oxygen-isotopic composition increases to heavier values, a chondrule's apparent oxygen fugacity increases.
- The abundance of ice or the amount of reduced carbon that accreted with the material from which a chondrule formed may have created microenvironemnts (oxidizing or reducing) that led to a distinct oxygen fugacity for that chondrule during its formation. That is, more ice led to a more oxidizing environment, whereas more reduced carbon (because it bonds to oxygen) led to a reducing environment. Schrader and colleagues suggest the precursors of type-I chondrules contained more reduced carbon than type-II chondrules.
- A relationship between chondrule petrology and oxygen-isotopic composition is due to the degree of melting and exchange with ^{16}O-poor gas during melting. Schrader and colleagues found the partially melted, relict-grain bearing type-II chondrules are oxygen-isotopically heterogeneous, while the relict-free type-II chondrules are oxygen-isotopically homogeneous, and all are similarly ^{16}O-poor.
- The oxygen-isotopic composition of the gas that exchanged with chondrules in CR chondrites is distinct from the extremely-^{16}O-poor primordial water of the Solar System inferred from oxygen-isotopic data from the carbonaceous chondrite Acfer 094 by Naoya Sakamoto (Hokkaido University, Sapporo) and colleagues.

See:
· Schrader, D. L., Connolly Jr., H. C., Lauretta, D. S., Nagashima, K., Huss, G. R., Davidson, J., and Domanik, K. J. (2013) The Foramtion and Alteration of the Renazzo-like Carbonaceous Chondrites II: Linking O-isotope Composition and Oxidation State of Chondrule Olivine, *Geochimica et Cosmochimica Acta,* v. 101, p. 302-327, doi: 10.1016/j.gca.2012.09.045. [**abstract**]

For more:
· Sakamoto, N., Seto, Y., Itoh, S., Kuramoto, K., Fujino, K., Nagashima, K., Krot, A. N., and Yurimoto, H. (2007) Remnants of the Early Solar System Water Enriched in Heavy Oxygen, *Science,* v. 317, p. 231-233, doi: 10.1126/science.1142021. [**abstract**]
· Schrader, D. L., Franchi, I. A., Connolly Jr., H. C., Greenwood, R. C., Lauretta, D. S., and Gibson, J. M. (2011) The Formation and Alteration of the Renazzo-like Carbonaceous Chondrites I: Implications of Bulk-Oxygen Isotopic Composition, *Geochimica et Cosmochimica Acta,* v. 75, p. 308-325, doi: 10.1016/j.gca.2010.09.028. [**abstract**]

Written by Linda M. V. Martel, Hawai'i Institute of Geophysics and Planetology, for **PSRD**.