Relict refractory inclusions in chondrules from the metal-rich carbonaceous chondrites

ALEXANDER N. KROT[1], KAZUHIDE NAGASHIMA[1],
MARTIN BIZZARRO[2], GARY R. HUSS[1], FRED J. CIESLA[3]
AND ALEXANDER A. ULYANOV[4]

[1]HIGP/SOEST, University of Hawai‘i at Manoa, USA
[2]Geological Institute, Denmark
[3]Carnegie Institution, USA
[4]M. V. Lomonosov Moscow State University, Russia

We have recently concluded that the CH/CB-like chondrite Isheyevo and other CH chondrites contain multiple generations of chondrules (Krot *et al.* 2007a): (*i*) magnesian chondrules with cryptocrystalline and skeletal textures, similar to those in CB$_b$ chondrites, which may have formed from a gas-melt plume resulted from a large-scale asteroidal collision (Krot *et al*., 2005); (*ii*) ferromagnesium and Al-rich chondrules with porphyritic textures which appear to have formed by melting of solid precursors. Here**,** we report the discovery of abundant Ca,Al-rich inclusions (CAIs) inside porphyritic chondrules from Isheyevo and CH chondrites Acfer 182/214 and PAT 91546. These, now relict CAIs formed before the host chondrules, were subsequently mixed with the chondrule precursor materials and melted to various degrees during chondrule formation. About half of the relict CAIs belong to a population of ^{26}Al-poor, very refractory inclusions dominated by grossite and hibonite; other relict CAIs consist mainly of spinel. Grossite and hibonite of the relict CAIs and anorthitic plagioclase of the host chondrules show no evidence for ^{26}Mg excesses related to decay of the short-lived ^{26}Al radionuclide. The only two exceptions are grossite-rich CAIs having small ^{26}Mg* corresponding to an initial ^{26}Al/^{27}Al ratios of $(1.7\pm1.3)\times10^{-6}$ and $(3.3\pm3.0)\times10^{-7}$. The ^{26}Al-poor grossite-rich and hibonite-rich igneous CAIs comprise about 50% of all refractory inclusions in the metal-rich chondrites studied (Krot *et al.* 2007b,c). Such CAIs, however, are virtually absent in ordinary, enstatite and other carbonaceous chondrite groups. We infer that this isotopically and mineralogically unique population of CAIs was present in the region where ferromagnesian porphyritic chondrules of CH and CH/CB-like chondrites formed, suggesting that these chondrules formed at a different time or in a different nebular region than chondrules from other chondrite groups. Since most CAIs outside chondrules in Isheyevo and CH chondrites show no clear evidence for being affected by the chondrule-forming processes, we infer that either the scale of chondrule-forming event(s) was relatively small and a number of chondrule-forming events in a localized nebular region where these chondrules formed was limited, or chondrule-forming event(s) had little effect on compact objects, like CAIs.

References

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Pine Point, Canada Pb-Zn deposits: Better resolved S- isotope study

H. ROY KROUSE, YINGCHUN LI AND AKIRA UEDA

Isotope Science Laboratory, Department of Physics and Astronomy, University of Calgary, Calgary, AB, Canada T2N 1N4. Correspondence to (roystrains@hotmail.com)

Introduction

Insight on the formation of the Pine Point (NWT, Canada, 60^{0}41'N, 114^{o}30'W) Pb-Zn deposits was acquired four decades ago using traditional stable isotope methodology (Sasaki and Krouse, 1969; Fritz 1969; Fritz and Jackson, 1972). This presentation summarizes δ^{34}S data from better resolved sampling techniques. (1) Trace sulfate and sulfide in carbonate (Ueda and Sakai, 1983), (2) different organic components (Krouse *et al.*, 1987), and (3) laser probe produced SO$_2$ from mineral surfaces (Kelley and Fallick, 1990).

Results and Discussion

Fritz (1969) and Fritz and Jackson (1972) identified at least three dolomitization events in the deposits. In the current study, trace sulfide and sulfate from an early dolomite had δ^{34}S values of +18.5‰ (the mean value of the ore) and +25.7‰, consistent with partially reduced Devonian seawater sulfate. The δ^{34}S values of sulfide and sulfate in a vug were +28.0 and +57.7‰ respectively, consistent with low temperature bacterial sulfate reduction and sulfide loss.

Powell and Macqueen (1984) found unaltered bitumens to have lower S-content and bulk δ^{34}S values than altered bitumens. Below 300^{o}C, H$_2$S evolved during pyrolysis had low δ^{34}S values consistent with post ore deposition low temperature sulfate reduction. Most H$_2$S was evolved between 300^{o}C and 500^{o}C with δ^{34}S in the range associated with the ore. H$_2$S released at higher temperatures had δ^{34}S values found for unaltered bitumens. Altered bitumens released more H$_2$S in the 300^{o}C to 500^{o}C range than unaltered bitumens.

Laser probe produced SO$_2$ revealed systematic δ^{34}S variations in a single PbS crystal of the order of 2‰ which is comparable to data for hand specimens throughout the deposits (Sasaki and Krouse, 1969). This supports low temperature (<100^{o}C) estimates for ore deposition.

Conclusions

Better chemically and spatially resolved sampling provided δ^{34}S data which complement those of traditional stable isotope methodology at the Pine Point Pb-Zn deposits. Overall, the newer techniques better describe processes involved during and post ore deposition.

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