Al-RICH CHONDRULES FROM UNEQUILIBRATED ORDINARY AND CO CARBONACEOUS CHONDRITES: EVIDENCE FOR ^{16}O-ENRICHED REFRACTORY PRECURSORS

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Introduction: Meteorites carry the cosmological information and history of the first particles formed, evolved, and accreted into larger planetesimals. Refractory inclusions [Ca,Al-rich inclusions (CAIs) and amoeboid olivine aggregates (AOAs)] are considered to be the oldest components [1] and are embedded together with chondrules, metals, and sulfides within matrix materials of chondrites. The connection between CAIs and chondrules has been insufficiently clarified until today. Ebert and Bischoff [2] showed that Na-Al-rich chondrules, a variety of Al-rich chondrules [3,4], have volatility controlled bulk rare earth element (REE) patterns, similar to CAIs [5]. Ebert and Bischoff suggested that CAIs or CAI-like material were a main part of the precursor material for Al-rich chondrules. However, the Al-rich chondrules in ordinary chondrites (OCs) show no enrichment in ^{50}Ti, which is in contrast to Al-rich chondrules from CO chondrites and CAIs from carbonaceous and ordinary chondrites [6]. They concluded that a refractory precursor - similar in mineralogy, but different in their ^{50}Ti - was part of the precursor of these chondrules in OCs. To gain more information about the origin of the Al-rich chondrule’s precursor, additional mineralogical, petrological, and oxygen isotopic investigations on Al-rich chondrules from unequilibrated OCs and the CO3.1 chondrite Dar al Gani (DaG) 083 were performed.

Results: 17 Al-rich chondrules from unequilibrated OCs and 4 Al-rich chondrules from DaG 083 were investigated. The Al-rich chondrules consist of olivine, low- and high-Ca pyroxenes, and, occasionally, spinel phenocrysts embedded in Na-rich mesostasis. In one chondrule, hibonite is also present. Al-rich chondrules from OCs have heterogeneous oxygen isotopic compositions with Δ^{17}O values ranging from −4.5 to +5.8‰, but no ^{16}O-enriched (Δ^{17}O < -20 ‰) relict grains are found (Fig. 1). Their O-isotope heterogeneity is mineralogically controlled: chondrules glassy mesostasis is ^{16}O-depleted compared to chondrule phenocrysts, which themselves have a homogeneous O-isotope composition within an individual chondrule. The Al-rich chondrules from the CO3.1 chondrite DaG 083 have a heterogeneous O-isotope composition with Δ^{17}O ranging from −24.6 to –0.3 ‰.

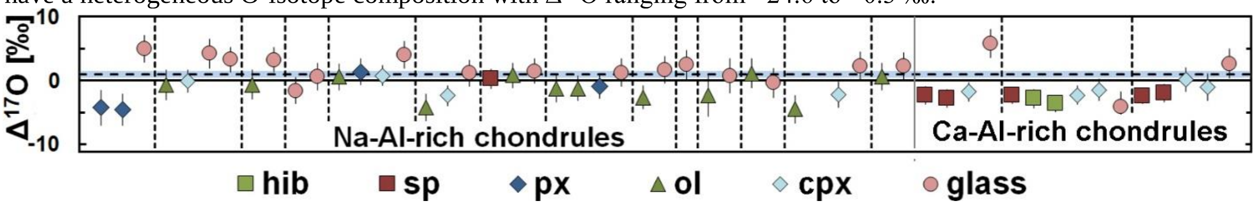

Fig. 1: Δ^{17}O values of the Al-rich chondrules from unequilibrated ordinary chondrites studied. In general, chondrules glasses are ^{16}O-depleted compared to chondrules phenocrysts. No ^{16}O-rich relict grains have been observed.

Discussion and Conclusions: The vast majority of the investigated Al-rich chondrules have heterogeneous O-isotopic compositions: Chondrule glasses are ^{16}O-depleted compared to chondrule phenocrysts. The Δ^{17}O values of chondrule glasses in unequilibrated OCs approach those of aqueously-formed fayalite and magnetite, ~ +5‰ [7]. We infer that the chondrule glasses experienced O-isotopic exchange with an aqueous fluid on the OC parent asteroids. One Al-rich chondrule from DaG 083 contains relict spinel grains with a Δ^{17}O value of −24.3±1.3‰, indicative of ^{16}O-rich precursor refractory material, similar to CAIs and AOAs. No relict grains were present within Al-rich chondrules from OCs. However, embedded phenocrysts prevent totally equilibration with the surrounding gas during chondrule formation and are still ^{16}O-enriched with Δ^{17}O values ranging from −4.5 to –1.3‰. Therefore, the OC region cannot be the formation region of the Al-rich chondrule precursor material. The relict grain, in an Al-rich chondrule from the CO3 chondrite, with a similar O-isotopic composition as CAIs/AOAs [8] and the in general ^{16}O-enriched phenocrysts in Al-rich chondrules from OCs and the CO clearly show the present of refractory material similar to CAIs/AOAs, which were part of the Al-rich chondrule’s precursor materials.

References: [1] MacPherson G. J. (2014) *Treat. Geochem.* 1:139–179 [2] Ebert S. and Bischoff A. (2016) *Geochim. Cosmochim. Acta* 177:182–204. [3] Bischoff A. and Keil K. (1983) *Nature* 303:588–592. [4] Bischoff A. and Keil K. (1984) *Geochim. Cosmochim. Acta* 48:693–709 [5] Mason B. and Martin P. M. (1977) *Smithsonian Contribution to the Earth Sciences* 19:84–95 [6] Ebert S. et al. (2018) *Earth Planet. Sci. Lett.* 498:257–265. [7] Krot A.N. et al. (2022) *Meteorit. Planet. Sci.* 55:2519–2538. [8] Ebert S. et al. (2020) *Geochim. Cosmochim. Acta* 282:98–112.