OXYGEN ISOTOPIC COMPOSITIONS OF THE AL-RICH CHONDRULES IN THE CR CARBONACEOUS CHONDRITES: EVIDENCE FOR A GENETIC LINK TO CA-AL-RICH INCLUSIONS AND FOR OXYGEN ISOTOPE EXCHANGE DURING CHONDRULE MELTING.

A. N. Krot[1], G. Libourel[2,3], and M. Chaussidon[2], [1]Hawai'i Institute of Geophysics and Planetology, SOEST, University of Hawai'i at Manoa, Honolulu, HI 96822, USA (sasha@higp.hawaii.edu), [2]CRPG-CNRS 15, Rue Notre-Dame des Pauvres BP20 54501 Vandoeuvre les Nancy; [3]ENSG-INPL, BP40 54501Vandoeuvre les Nancy, France.

Introduction: Al-rich (>10 wt% Al_2O_3) chondrules are compositionally most similar to CAIs and can potentially provide a clue for understanding genetic relationship between CAIs and Fe,Mg-chondrules. Based on the mineralogical and textural observations, it was previously inferred that Al-rich chondrules in carbonaceous chondrites formed by melting of CAIs largely composed of spinel, anorthite, and diopside, and ferromagnesian precursors compositionally similar to Type I chondrules [1,2]. This model, however, appears to be inconsistent with O-isotopic compositions of Al-rich chondrules from unequilibrated ordinary chondrites (UOCs) Chainpur (LL3.4), Inman (L3.4), Quinyambie (L3.4), and Sharps (H3.4), which on a three-oxygen isotope diagram define a slope of ~0.8, distinct from a slope of ~1 along which most CAIs plot [3]. In order to minimize possible effects of isotope exchange during thermal metamorphism and to test the model of [1,2], we measured *in situ* O-isotopic compositions of the Al-rich and Fe,Mg-chondrules in CR carbonaceous chondrites, which although experienced varying degrees of aqueous alteration, show no evidence for thermal metamorphism [4].

Results: Ferromagnesian Type I chondrules in CRs have porphyritic textures and consist of forsteritic olivine and low-Ca pyroxene phenocrysts and glassy or microcrystalline mesostasis; some chondrules are surrounded by silica-rich igneous rims [5]. Al-rich chondrules in CRs have porphyritic textures and consist of spinel, anorthitic plagioclase, high-Ca and low-Ca pyroxenes, forsteritic olivine and glassy or fine-grained mesostasis composed of silica, anorthitic plagioclase and high-Ca pyroxene [1]. Based on the textures, the Al-rich chondrules can be subdivided into two groups: with and without relict CAI-like regions; the latter were more extensively melted than the former. The Al-rich chondrules with relict CAIs have heterogeneous O-isotopic compositions with spinel and ±anorthite enriched in ^{16}O compared to the phenocrysts of forsterite, low-Ca and high-Ca pyroxene (Fig. 1a). The Al-rich chondrules without relict CAIs and most ferromagnesian Type I chondrules have rather similar O-isotopic compositions and are isotopically uniform (Fig. 1b,c). The only exception is chondrule MAC87320 #11 with an olivine grain (possibly relict) enriched in ^{16}O compared to the other olivine and low-Ca pyroxene grains analyzed. In contrast to O-isotopic compositions of the Al-rich chondrules in UOCs [3], those in CR chondrites plot along Allende CAI line and form a continuum with O-isotopic compositions of ferromagnesian chondrules and CAIs.

Discussion: Oxygen isotopic compositions of the Al-rich chondrules in CR chondrites together with mineralogical and textural observations indicate that these chondrules formed by melting of ^{16}O-rich Ca,Al-rich precursors and ^{16}O-depleted ferromagnesian precursors, supporting model of [1,2]. Because O-isotopic heterogeneity in the Al-rich chondrules is due to the presence of unmelted, relict grains and because the Al-rich chondrules without relict grains have similar O-isotopic compositions to ferromagnesian Type I chondrules (Fig. 1), we infer that the Al-rich chondrules experienced varying degrees of oxygen isotope exchange with an ^{16}O-depleted nebular gas during chondrule melting. The CR AOAs and CAIs, which appear to have been unmelted, are uniformly enriched in ^{16}O (Fig. 2a), indicating formation in an ^{16}O-enriched gaseous reservoir [7,8]. Two of the igneous, compact Type A CAIs in CRs have similar ^{16}O-rich compositions (Fig. 2b), suggesting that they were probably melted in the same O-isotopic reservoir. The existence of ^{16}O-poor gaseous reservoir in the CR chondrule-forming region contrasts the existence of ^{16}O-rich gas in the CR CAI-forming region. The igneous, Type C CAIs in the CR and CO chondrites are ^{16}O-depleted and have O-isotopic compositions similar to the Al-rich chondrules. Some of these CAIs retained oxygen isotope heterogeneity, largely due to the presence of unmelted ^{16}O-rich spinel grains. Based on these observations, we infer that Type C CAIs experienced melting and oxygen isotope exchange in an ^{16}O-poor nebular gas, most likely during chondrule melting. If this is the case, Al-Mg systematics of the ^{16}O-depleted Type C CAIs can provide a key information for understanding time difference between CAI and chondrule formation.

References: [1] Krot A. and Keil K. (2002) *MAPS*, *37,* 91. [2] Krot A. et al. (2002) *MAPS*, *37,* 135. [3] Russell S. et al. (2000) *EPSL, 184,* 57. [4] Krot A. et al. (2002) *MAPS*, *37,* 1451. [5] Krot A. (2003) *MAPS, submitt.* [6] Krot A. et al. (2004) *EPSL, in prep.* [7] Aléon J. et al. (2002) *MAPS*, *37,* 1729. [8] Krot A. et al. (2002) *Science*, *295,* 1051. [9] Itoh S. et al. (2004) *GCA, 68,* 183-194. [10] Marhas K. et al. (2001) *MAPS, 36,* A121. [11] Russell S. et al. (1998) *GCA, 62,* 689.

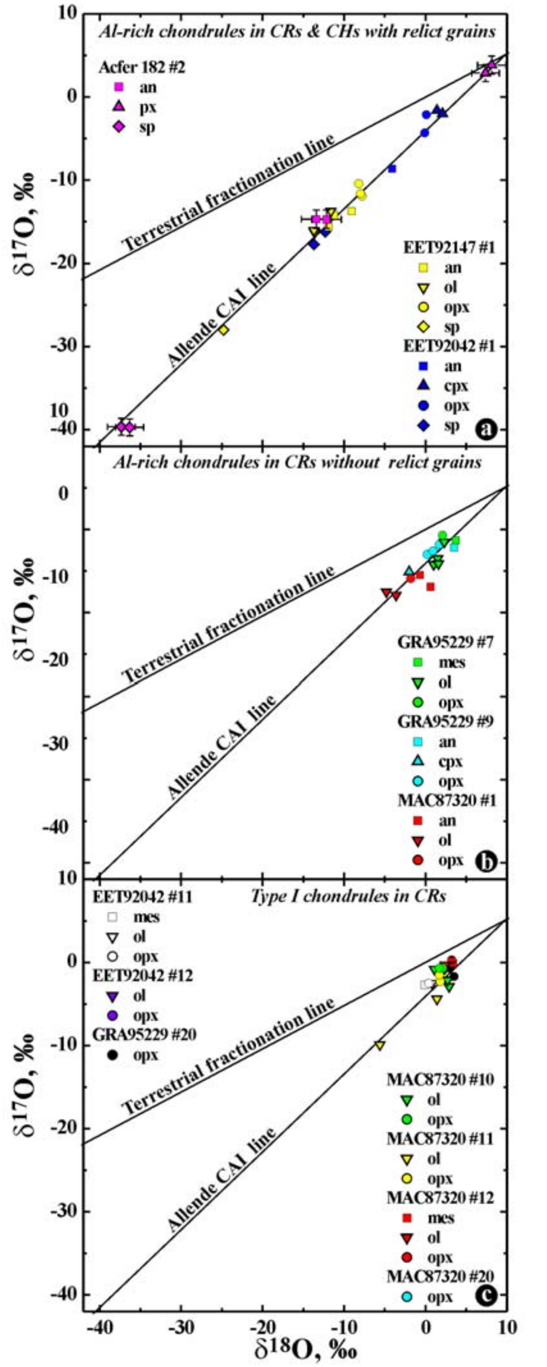

Fig. 1. Oxygen isotopic compositions of Al-rich chondrules with (a) and without (b) relict grains, and Fe,Mg Type I chondrules (c) in CRs. Data for Al-rich chondrule #2 with a relict CAI in the CH chondrite Acfer 182 are from [6]. The Al-rich chondrules with relict CAIs have heterogeneous O-isotopic compositions with spinel and anorthite enriched in ^{16}O compared to the phenocrysts of Fe,Mg-silicates. The Al-rich chondrules without relict CAIs are isotopically uniform; their O-isotopic compositions are similar to those of Fe,Mg-chondrules, suggesting oxygen isotope exchange during chondrule melting.

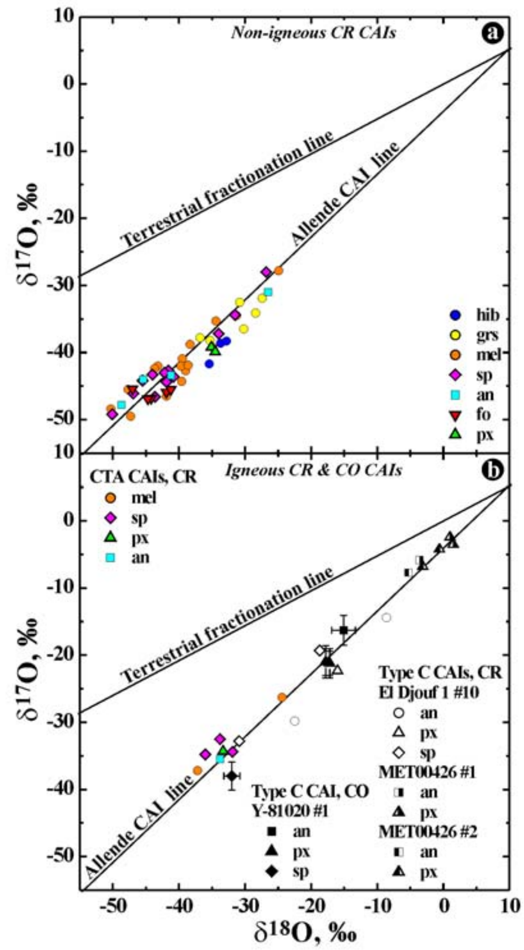

Fig. 2. Oxygen isotopic compositions of CAIs and AOAs in CRs [7]. AOAs and CAIs, which appear to have been unmelted, are uniformly enriched in ^{16}O, suggesting formation in an ^{16}O-rich gaseous reservoir (CAI-forming region). Two igneous, compact Type A CAIs have similar ^{16}O-rich compositions, indicating that they were melted in the same gaseous reservoir. Three igneous, Type C CAIs in CR chondrites and a Type C in Y-81020 (CO3.0) [9] are ^{16}O-depleted and isotopically heterogeneous; spinel grains are ^{16}O-enriched compared to anorthite and diopside. This suggests that these Type C CAIs experienced oxygen isotope exchange in an ^{16}O-poor gaseous reservoir, possibly chondrule-forming region. Because most non-igneous, ^{16}O-rich CAIs in CR [10] and primitive CO [11] chondrites have a canonical ^{26}Al/^{27}Al ratio, the Al-Mg systematics of the ^{16}O-poor Type C CAIs can potentially provide a time difference between CAI and chondrule formation.