HETEROGENEOUS DISTRIBUTION OF ^{26}AL AT THE BIRTH OF THE SOLAR SYSTEM: EVIDENCE FROM CORUNDUM-BEARING REFRACTORY INCLUSIONS. A. N. Krot[1*], K. Makide[1], K. Nagashima[1], G. R. Huss[1], E. Hellebrand[1], and M. I. Petaev[2] [1]University of Hawai'i at Mānoa, Honolulu, HI 96822, USA. [2]Harvard University, Cambridge, MA 02138, USA. *sasha@higp.hawaii.edu

Introduction: It is generally accepted that ^{26}Al in the early Solar System (SS) had an external, stellar origin [1]. However, the stellar source of ^{26}Al (an AGB star [2], a SN [3], or a wind from a massive star [4−6]) and the manner in which it was injected into the SS (injection into the protosolar molecular cloud (MC) [7], MC core [8] or protoplanetary disk (PPD) [9]) remain controversial. The inferred abundances of ^{26}Al in the earliest SS solids, CAIs and refractory grains, provide important constraints on its origin. At P_{tot} <10^{-3} bar, corundum (*cor*) is the first mineral predicted to condense from a gas of solar composition [10]. Most micron-sized *cor* grains from acid-resistant residues of unequilibrated ordinary (UOCs) and carbonaceous chondrites (CCs) have ^{16}O-rich compositions (Δ^{17}O ~ −23±7‰, 2SD) similar to the solar wind returned by the GENESIS spacecraft (Δ^{17}O ~ −28±2‰, 2 standard errors) [11], but show large variations of $(^{26}Al/^{27}Al)_0$ [12]: 52% of grains have no resolvable excess of radiogenic ^{26}Mg (^{26}Mg*): an upper limit on $(^{26}Al/^{27}Al)_0$ is 2×10^{-6}; 40% of grains have high $(^{26}Al/^{27}Al)_0$, $(3.0–6.5)\times10^{-5}$; 8% of grains have intermediate values of $(^{26}Al/^{27}Al)_0$, $(1–2)\times10^{-5}$. Here, we report on O and Al-Mg isotope systematics of the *cor*-bearing CAIs of Adelaide (ungrouped) and CM chondrites.

Cor-bearing CAIs in Adelaide: CAI *1344-50* has a hibonite (*hib) – cor* core surrounded by a grossite (*grs*) mantle with small inclusions of Ca-monoaluminate (*CMA*); *cor* is corroded by *hib*. The CAI is surrounded by the Wark-Lovering (WL) rim sequence of spinel (*sp*) and Al-diopside (*Al-di*) (Fig. 1a). CAI *1312-32* consists of *hib* enclosing *cor*, and tiny perovskite (*pv*) grains at the hibonite grain boundaries (Fig. 1b).

Cor-bearing CAIs in Murchison and Murray (CM): CAI *G7955-1* consists of several *hib* grains; one of them contains a small inclusion of *cor* (Fig. 1c). CAI *7-9-1* is composed of lath-shaped *hib* overgrown by *sp*, and secondary minerals, phyllosilicates (*phyl*) and carbonates, possibly replacing melilite (Fig. 1d,e). *Hib* grains contain small inclusions of *pv* and *cor*. The CAI is surrounded by a continuous layer of *Al-di*. CAI *7-9-4* consists of several concentrically-zoned objects with a *cor-hib* core surrounded by the layers of *sp*, *phyl,* and *Al-di* (Fig. 1f). CAI *UH68-1* is composed of small concentrically-zoned objects each having a *cor* core surrounded by the layers of *sp* and *Al-di* (Fig. 1g). CAI *3-9-1* consists of *hib* overgrown by *cor* (Fig. 1h). CAI *1769-9-1* consists of several *cor-hib* objects, in which *hib* is partly or completely surrounded by *cor*; one of the *cor* grains is overgrown by *sp* (Fig. 1i). CAI *G7955-2* is composed of lath-shaped *hib* overgrown by *cor*. CAI *986-2* consists of closely intergrown *cor*, *sp*, and *hib*.

A replacement of *cor* by *hib* in several *cor*-bearing CAIs studied (Figs. 1a−f) is consistent with equilibrium condensation from a gas of solar composition [10]. In contrast, the observed overgrowths of *cor* on *hib* (Figs. 1h,i), and *sp* on *cor* or *hib* (Figs. 1d−g), and the lack of melilite in the *cor*-bearing CAIs can not be explained by equilibrium condensation from a cooling gas of solar composition [10], suggesting that other processes (e.g., melting, evaporation, variable P_{tot}, and/or disequilibrium condensation) may have played an important role during their formation.

Oxygen-isotope compositions: Most *cor*-bearing CAIs are uniformly ^{16}O-rich (Δ^{17}O ranges from −17‰ to −25‰) and similar to the previously studied *cor*-bearing CAIs from CMs (*BB-5* [13], *M98-8* [14], and *Mur-P10* [15]), isolated *cor* grains in CM matrices, and *cor* grains from acid-resistant residues of UOCs and CCs [12] (Fig. 2), suggesting formation in a gas of approximately solar O-isotope composition. The only exception is the Adelaide CAI *1344-50*, in which mantle *grs* and *CMA* are ^{16}O-poor (Δ^{17}O ~ −2‰), whereas the WL-rim layers of *sp* and *Al-di* are ^{16}O-rich. In addition, one of the ^{16}O-rich matrix *cor* grains (Δ^{17}O ~ −24‰) is intergrown with an ^{16}O-poor (Δ^{17}O ~ 0‰) Y,Zr,Sc,Ti,Al-oxide.

Al-Mg system: There is a large spread in $(^{26}Al/^{27}Al)_0$ in the *cor*-bearing CAIs. The Adelaide CAIs *1312-32* and *1344-50* show no resolvable ^{26}Mg*: $(^{26}Al/^{27}Al)_0$ = $(0.6\pm2.0)\times10^{-6}$ and $(-0.9\pm1.2)\times10^{-6}$, respectively. Model Al-Mg isochrons in the CM CAIs *1769-9-1*, *3-9-1*, *UH68-1*, and *7-9-1* are $(4.4\pm0.2)\times10^{-5}$, $(4.1\pm0.3)\times10^{-5}$, $(3.9\pm0.4)\times10^{-5}$, and $(4.0\pm2.0)\times10^{-6}$, respectively. These values are lower than the canonical $(^{26}Al/^{27}Al)_0$ of $(5.23\pm0.13)\times10^{-5}$ inferred from the whole-rock measurements of CV CAIs [16], but similar to the $(^{26}Al/^{27}Al)_0$ of $(4.1\pm0.2)\times10^{-5}$ in the *cor*-bearing CAI *F5* from Murray [17]. Five other *cor*-bearing CAIs studied previously: *BB-5, GR-1,* and *M98-8* from Murchison, *Mur-P10* from Murray, and *s2* from Acfer 094 (ungrouped) show no resolvable ^{26}Mg* [15−21].

We conclude that *cor*-bearing CAIs, as well as solar *cor* grains from matrices and acid-resistant residues of UOCs and CCs [12], recorded heterogeneous distribution of ^{26}Al in the Solar System during an epoch of CAI formation. The duration of this epoch cannot be inferred from ^{26}Al-^{26}Mg systematics of CAIs. We suggest that ^{26}Al was injected into the collapsing protosolar MC core, possibly by a wind from a massive star, prior to formation of CAIs and refractory grains, and was later mixed and homogenized through the PPD [22].

[1] Duprat & Tatischeff (2007) *ApJ, 425,* 1495. [2] Wasserburg et al. (2006) *Nuc. Phys. A, 777,* 5. [3] Sahijpal & Goswami (1998) *ApJ, 509,* L137. [4] Gaidos et al. (2009) *ApJ, 705,* L163. [5] Tatischeff et al. (2010) *ApJ, 714,* L26. [6] Gounelle & Meynet (2011) Kauai Workshop, 9008. [7] Vasileiadis et al. Kauai Workshop, 9101. [8] Boss et al. (2008) *ApJ, 686.* L119. [9] Ouellette et al. (2007) *ApJ, 662,* 1268. [10] Petaev & Wood (2005) ASP 341, 373. [11] McKeegan et al. (2011) *Science, 332,* 1529. [12] Makide et al. (2011) *ApJ, 731,* L31. [13] Fahey (1987) *ApJL, 323,* L91. [14] Simon et al. (2002) *MAPS, 37,* 535. [15] Liu et al. (2009) *GCA, 73,* 5051. [16] Jacobsen et al. (2008) *EPSL, 272,* 353. [17] Fahey et al. (1988) PhD Thesis. [18] Bar-Matthews et al. (1982) *GCA, 46,* 31. [19] MacPherson et al. (1984) *JGR, 89,* C299. [20] Hinton et al. (1988) *GCA, 52,* 2573. [21] Sugiura & Krot (2007) *MAPS, 42,* 53. [22] Krot et al. (2011) Kauai Workshop, 9045.

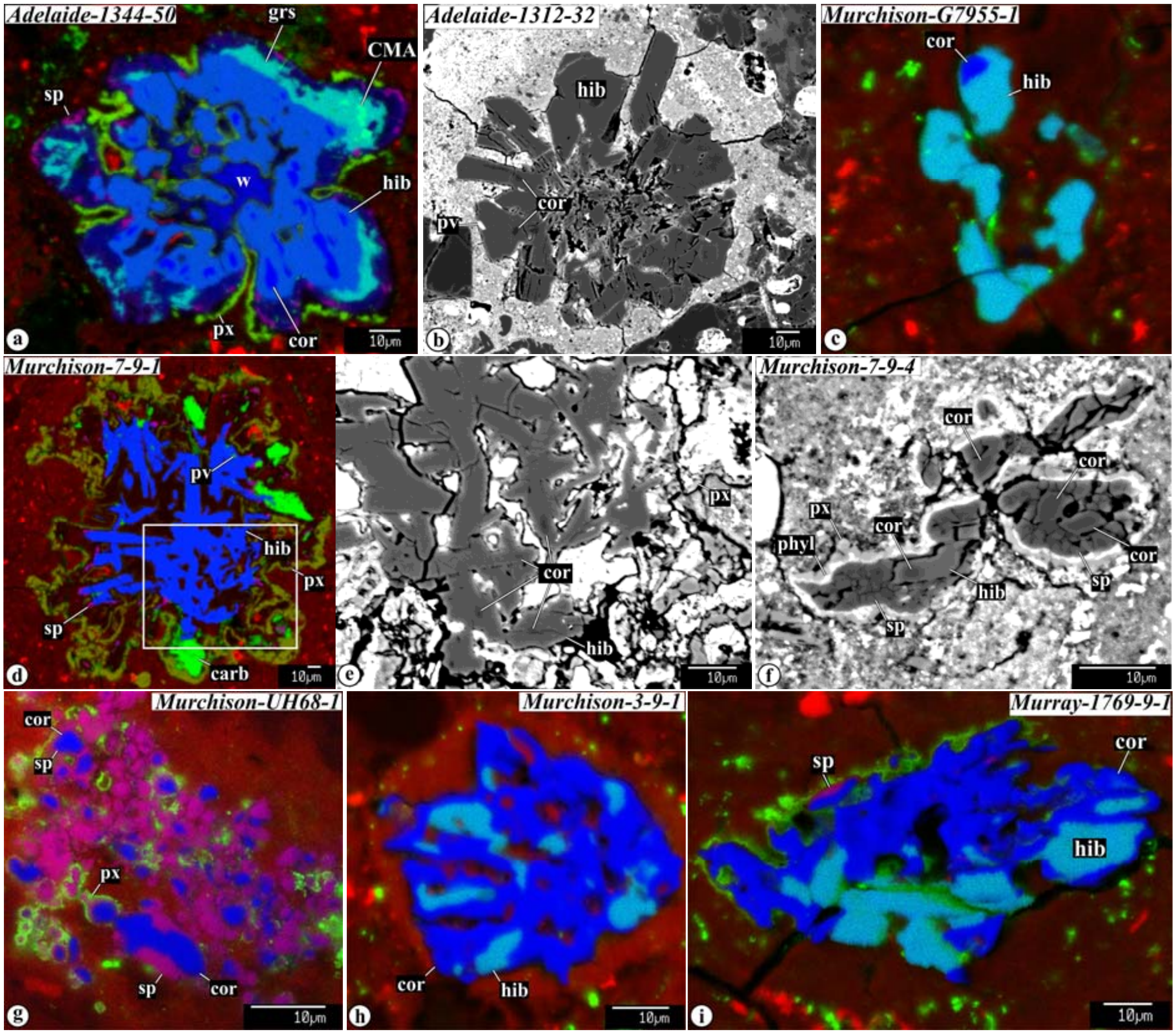

Fig. 1. BSE images and combined x-ray elemental maps (Mg, red, Ca, green, and Al, blue) of the *cor*-bearing CAIs studied.

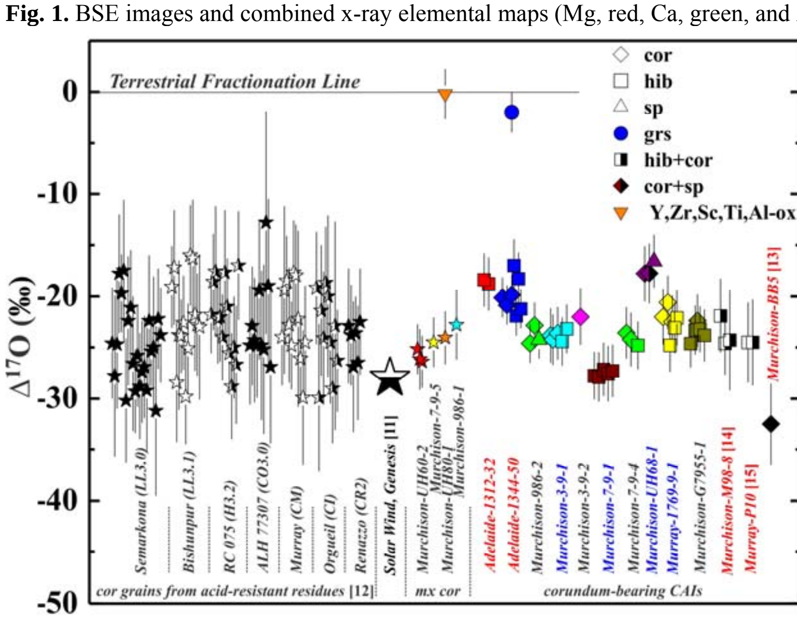

Fig. 2. $\Delta^{17}O$ values of the *cor*-bearing CAIs, *cor* grains in the Murchison matrix and from acid-resistant residues of unequilibrated ordinary and carbonaceous chondrites, and the Genesis solar wind. CMA = Ca-monoaluminate; cor = corundum; hib = hibonite; grs = grossite; mx = matrix; ox = oxide; sp = spinel; w = weathering products. Black-and-white symbols of CAIs and *cor* grains are literature data; colored symbols are from this study. Symbols of the same color correspond to a single object. Most *cor*-bearing CAIs are uniformly ^{16}O-rich; the only exceptions is the Adelaide CAI *1344-50*, in which *grs* and *CMA* are ^{16}O-poor. Matrix *cor* grains are ^{16}O-rich and isotopically similar to the *cor*-bearing CAIs; one of the grains, *UH80-1*, is intergrown with an ^{16}O-poor Y,Zr,Sc,Ti,Al-oxide. CAI with names highlighted in red and blue show no and detectable $^{26}Mg^{*}$. Al-Mg system in other CAIs is yet to be measured.