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ALUMINUM-MAGNESIUM ISOTOPE DATING OF METASOMATIC ALTERATION OF CORUNDUM-BEARING REFRACTORY INCLUSIONS FROM CK3 CARBONACEOUS CHONDRITES

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Introduction: Corundum (Al_2O_3) is one of the most refractory minerals in a gas of solar composition. It is found in Ca,Al-rich inclusions (CAIs) from carbonaceous and non-carbonaceous chondrites and appears to have formed by condensation and melt evaporation [1–5]. Most corundum-bearing CAIs have uniform, solar-like O-isotope compositions ($\Delta^{17}O \sim -24‰$), but show a bi-modal distribution of the inferred initial $^{26}Al/^{27}Al$ ratio [$(^{26}Al/^{27}Al)_0$]: $(4–5)\times10^{-5}$ and $<\sim5\times10^{-6}$. Hydrothermally-formed µm-sized corundum grains associated with secondary nepheline, alumoåkermanite, grossular, and spinel have been described in Fluffy Type A and Type B1 CAIs from Allende [6,7]. Here, we describe the mineralogy, petrology, O- and A-Mg isotope systematics of 4 corundum-bearing CAIs from the CK3 (Karoonda type) carbonaceous chondrites Northwest Africa (NWA) 4964 (CK3.8), NWA 5343 (CK3.7), and Larkman Nunatak (LAR) 12002 (CK3). We conclude that corundum grains in CK3 CAIs studied resulted from metasomatic alteration of the host meteorites by a hydrothermal fluid with $\Delta^{17}O$ of ~–4±2‰ 3–5 Myr after their formation.

Mineralogy and petrography: *NWA 4964 #1* is a CAI fragment, 795×900 µm in size, composed of ferroan spinel, hibonite, perovskite, corundum (up to 30 µm in size), CaNa-plagioclase ($An_{71–97}$) and ilmenite; it is surrounded by a multilayered Wark-Lovering (WL) rim of spinel+ilmenite, plagioclase, and AlTi-diopside. *NWA 4964 Homer* is an igneous CAI, ~1 cm in diameter, previously described by [8,9]; it consists of ferroan spinel, hibonite, corundum (up to 200 µm in size), grossular, CaNa-plagioclase ($An_{47–99}$), and ilmenite, and is surrounded by a WL rim. There are two textural types of corundum in the NWA 4964 CAIs: compact grains zoned in cathodoluminescence (CL) and porous grains without CL; the former are overgrown by the latter. *NWA 5343 #1* is a FTA CAI, ~ 5 mm in size, composed of spinel, gehlenitic melilite ($Åk_{0.2–7}$), perovskite, corundum (up to 30 µm in size), grossular, FeAl±Ti-diopside, CaNa-plagioclase ($An_{29–95}$), and andradite; the corundum grains have compact and porous textures and show no CL. *LAR 12002 #1* consists of several CAI fragments, up to 400×600 µm in size, composed of ferroan spinel, corundum (up to 50 µm in size), hibonite, perovskite, CaNa-plagioclase ($An_{32–94}$), and ilmenite; corundum grains have bright CL.

Oxygen isotopes: All four corundum-bearing CAIs studied have heterogeneous $\Delta^{17}O$. Hibonite, spinel intergrown with hibonite, spinel with numerous inclusions of ilmenite and perovskite, a hibonite inclusion inside corundum in *NWA 5343 #1*, and a perovskite inclusion inside spinel in *NWA 4964 #1* have solar-like $\Delta^{17}O$, ~ –24‰. Melilite in *NWA 5343 #1*, most perovskite grains, ilmenite, corundum, and spinel replacing corundum in *NWA 4964 Homer* are ^{16}O-depleted ($\Delta^{17}O \sim -7$ to ~ –2‰); most analyses have $\Delta^{17}O$ of ~ –4‰.

^{26}Al-^{26}Mg systematics: Singe hibonite grains in *LAR 12002 #1* and *NWA 4964 #1* plot along the canonical isochron with $(^{26}Al/^{27}Al)_0$ of $\sim5\times10^{-5}$. Hibonites data in *NWA 4964 Homer* having a large range of $^{27}Al/^{24}Mg$ (25–375) define an isochron with $(^{26}Al/^{27}Al)_0$ of $(4.5\pm0.2)\times10^{-5}$. Melilite data in *NWA 5343 #1* define an isochron with $(^{26}Al/^{27}Al)_0$ of $(4.6\pm0.8)\times10^{-5}$. Compact corundum grains with bright CL in *LAR 12002 #1*, *NWA 4964 #1*, and *NWA 4964 Homer* define internal isochrons with $(^{26}Al/^{27}Al)_0$ of $(3.1\pm0.5)\times10^{-6}$, $(3.0\pm0.2)\times10^{-6}$, and $(2.7\pm0.2)\times10^{-6}$, respectively. Porous corundum grains without CL in *NWA 4964 #1* and *NWA 4964 Homer* show resolvable $^{26}Mg^*$ and plot below the isochrones defined by the compact corundum grains and show no correlation with $^{27}Al/^{24}Mg$. Compact and porous corundum grains without CL in *NWA 5343 #1* define an isochron with $(^{26}Al/^{27}Al)_0$ of $(3.5\pm1.2)\times10^{-7}$.

Conclusions: CAIs in CK3s experienced extensive metasomatic alteration by a hydrothermal fluid with $\Delta^{17}O$ of ~ –4‰ in the CK parent asteroid that resulted in replacement of melilite, anorthite, perovskite, and AlTi-diopside by ^{16}O-poor ($\Delta^{17}O \sim -4±2‰$) corundum, ferroan spinel, FeAl-diopside, grossular, ilmenite, CaNa-plagioclase, and andradite [10,11, this study]. Melilite and perovskite experienced O-isotope exchange with the fluid; hibonite and spinel avoided it. ^{26}Al-^{26}Mg systematics of hibonite and melilite suggest that corundum-bearing CAIs belong to a population of canonical CAIs with $(^{26}Al/^{27}Al)_0$ of $\sim5\times10^{-5}$. There are two generations of secondary corundum: compact grains, with CL have $(^{26}Al/^{27}Al)_0$ of $\sim3\times10^{-6}$ and porous grains without CL have $^{26}Al/^{27}Al \le 5.7\times10^{-7}$. The former apparently precipitated from a hydrothermal fluid; the latter may have formed by transformation of diaspore [AlO(OH)] at ~525–550°C [12,13]. We conclude that ^{26}Al-^{26}Mg systematics of corundum in CK3 CAIs studied dates metasomatic alteration of their host meteorites: it started ~3 Myr after canonical CAIs and lasted for ~2 Myr.

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