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Mineralogy and petrology of Al-rich objects and amoeboid olivine aggregates in the CH carbonaceous chondrite North West Africa 739

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Abstract

The aluminum-rich (>10 wt% Al_2O_3) objects in the CH carbonaceous chondrite North West Africa (NWA) 739 include Ca,Al-rich inclusions (CAIs), Al-rich chondrules, and isolated mineral grains (spinel, plagioclase, glass). Based on the major mineralogy, 54 refractory inclusions found in about 1 cm^2 polished section of NWA 739 can be divided into hibonite-rich (16%), grossite-rich (26%), melilite-rich (28%), spinel-pyroxene-rich (16%) CAIs, and amoeboid olivine aggregates, (AOA's, 17%). Most CAIs are rounded, 25–185 μm (average = 70 μm) in apparent diameter, contain abundant, tiny perovskite grains, and typically surrounded by a single- or double-layered rim composed of melilite and/or Al-diopside; occasionally, layers of spinel + hibonite and forsterite are observed. The AOAs are irregularly shaped, 100–250 μm (average = 175 μm) in size, and consist of forsterite, Fe,Ni-metal, and CAIs composed of Al-diopside, anorthite, and minor spinel. One AOA contains compact, rounded melilite-spinel-perovskite CAIs and low-Ca pyroxene replacing forsterite. The Al-rich (>10 wt% bulk Al_2O_3) chondrules are divided into Al-diopside-rich and plagioclase-rich. The Al-diopside-rich chondrules, 50–310 μm (average = 165 μm) in apparent diameter, consist of Al-diopside, skeletal forsterite, spinel, ±Al-rich low-Ca pyroxene, and ±mesostasis. The plagioclase-rich chondrules, 120–455 μm (average = 285 μm) in apparent diameter, are composed of low-Ca and high-Ca pyroxenes, forsterite, anorthitic plagioclase, Fe,Ni-metal nodules, and mesostasis. The isolated spinel occurs as coarse, 50–125 μm in size, subhedral grains, which are probably the fragments of Al-diopside chondrules. The isolated plagioclase grains are too coarse (60–120 μm) to have been produced by disintegration of chondrules or CAIs; they range in composition from nearly pure anorthite to nearly pure albite; their origin is unclear. The Al-rich objects show no evidence for Fe-alkali metasomatic or aqueous alteration; the only exception is an Al-rich chondrule fragment with anorthite replaced by nepheline. They are texturally and mineralogically similar to those in other CH chondrites studied (Acfer 182, ALH85085, PAT91467, NWA 770), but are distinct from the Al-rich objects in other chondrite groups (CM, CO, CR, CV). The CH CAIs are dominated by very refractory minerals, such as hibonite, grossite, perovskite and gehlenitic melilite, and appear to have experienced very low degrees of high-temperature alteration reactions. These include replacement of grossite by melilite, of melilite by anorthite, diopside, and spinel, and of forsterite by low-Ca pyroxene. Only a few CAIs show evidence for melting and multilayered Wark-Lovering rims. These observations may suggest

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that CH CAIs experienced rather simple formation history and escaped extensive recycling. In order to preserve the high-temperature mineral assemblages, they must have been efficiently isolated from the hot nebular region, like some chondrules and the zoned Fe,Ni-metal grains in CH chondrites.
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Keywords: Ca, Al-rich inclusions; Amoeboid olivine aggregates; Al-rich chondrules; Solar nebula; CH carbonaceous chondrites

1. Introduction

The CH carbonaceous chondrites are a recently defined group of primitive meteorites (Bischoff et al., 1993), which appear to have escaped post-accretion thermal metamorphism and aqueous alteration. Recent discovery of the zoned Fe,Ni-metal condensates in CH chondrites (Meibom et al., 1999, 2000, 2001) sparked significant interest to this and the related (CB_b[1]) subgroup of meteorites (Krot et al., 2000a, b, 2001a, 2002a; Petaev et al., 2001; Greshake et al., 2002; Campbell et al., 2001, 2002; Campbell and Humayun, 2003). In spite of the potential significance of the CH chondrites for understanding high-temperature nebular processes, only two of them — ALH85085 and Acfer 182 — have been previously studied in detail (Grossman et al., 1988; Scott, 1988; Weisberg et al., 1988; Bischoff et al., 1993). Systematic studies of the CH CAIs and chondrules are also limited (MacPherson et al., 1989; Kimura et al., 1993; Weber et al., 1995a; Krot et al., 1999a, b, 2000a, b). Preliminary data on the mineralogy of CAIs from the CH chondrite PCA91467 suggest that they are similar to those from ALH 85085 (Weber et al., 1995b). These studies revealed several unusual characteristics of the CH CAIs, such as small sizes (5–80 μm in ALH85085 and up to 450 μm in Acfer 182), commonly spherical shapes, fine-grained textures, refractory mineralogy dominated by hibonite, grossite, perovskite, and melilite, rarity of isotopic anomalies in Ca and Ti, and general lack of ^{26}Mg excesses (^{26}Mg*) in the hibonite-rich and grossite-rich CAIs. Subsequently, Sahijpal et al. (1999) reported a bi-modal distribution of oxygen isotopic compositions in the Acfer 182 CAIs and the lack of oxygen isotopic heterogeneity within an individual CAI, which had not been previously observed in CAIs from other chondrite groups (e.g., Clayton et al., 1977; McKeegan et al., 1998).

There are several fundamental questions concerning the origin of CAIs, which remain to be answered: (i) Is there any relationship between CAIs and Al-rich chondrules? (ii) Do CAIs show evidence for thermal processing during chondrule formation? (iii) Did CAIs and chondrules from the same chondrite group experience size-sorting together or separately? (iv) Is the lack of ^{26}Mg* in many CH CAIs due to the heterogeneity of ^{26}Al distribution in the solar nebula or their late stage formation? (v) Do the ^{26}Mg*-free CH CAIs contain ^{10}B excesses due to decay of ^{10}Be?

In order to answer these questions, we started a systematic survey of Al-rich (>10 wt% Al_2O_3) objects (Bischoff and Keil, 1984) in CH chondrites. Here we report the mineralogical and petrologic studies of the CAIs, AOAs, Al-rich chondrules and isolated grains in the recently discovered CH chondrite NWA 739 (Meteoritical Bull, 2002). Isotopic studies of these objects are in progress.

2. Analytical techniques

A polished section of NWA 739 made out of the chip M48977 was mapped in Ca, Al, Mg, Ti, and Na Kα X-

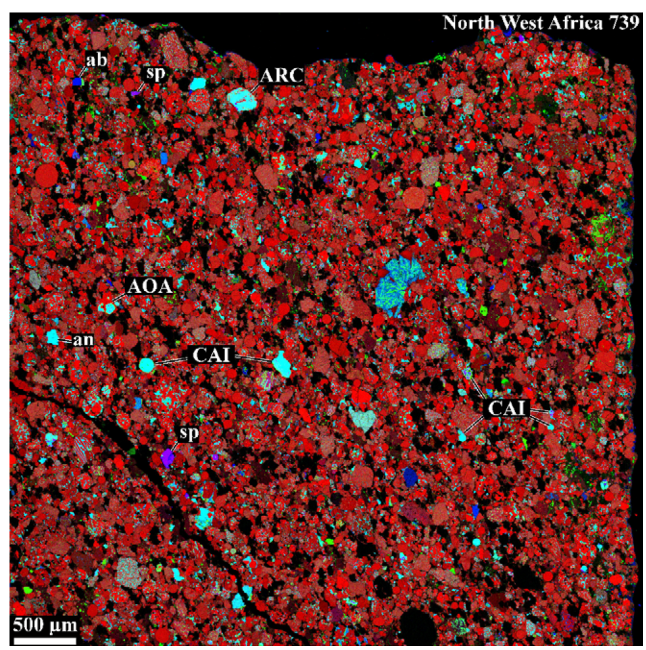

Fig. 1. Combined elemental map in Mg (red), Ca (green) and Al Kα (blue) X-rays of the CH carbonaceous chondrite North West Africa 739. The meteorite contains <2 vol% of Al-rich objects, including Ca,Al-rich inclusions (CAI), amoeboid olivine aggregates (AOA), Al-rich chondrules (ARC), and isolated spinel (sp), albitic (ab) and anorthitic (an) plagioclase grains.

[1]The CB (Bencubbin-like) chondrites are subdivided into two subgroups — CB_a, that includes Bencubbin, Gujba, and Weatherford, and CB_b, that includes Hammadah al Hamra 237 and QUE94411 (for details see Weisberg et al., 2001; Krot et al., 2002a).

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