NWA 1465* AND NWA 1665*: TWO UNUSUAL CARBONACEOUS CHONDRITES FROM NORTHWEST AFRICA. Ansgar Greshake[1], Robert N. Clayton[2], Toshiko K. Mayeda[2] and Matthias Kurz[3], [1]Museum für Naturkunde, Institut für Mineralogie, Humboldt-Universität zu Berlin, Invalidenstr. 43, 10115 Berlin, Germany, email: ansgar.greshake@rz.hu-berlin.de, [2]Enrico Fermi Institute, University of Chicago, Chicago, Illinois 60637, USA, [3]Schillerstraße 7, 34626 Neukirchen, Germany.
*provisional names not yet confirmed by the Nomenclature Committee of the Meteoritical Society

Introduction. Over the past decades numerous interesting new meteorites were found in the north African and Arabian sand deserts of Libya, Algeria, Morocco, and Oman. The new findings include many basaltic and primitive achondrites, e.g., Martian and Lunar meteorites, Eucrites, Howardites, and Acapulcoites as well as rare types of carbonaceous chondrites, e.g., Rumuruti, CH, CK and CM chondrites [e.g., 1-3]. Additionally, several of the meteorites found could not be unambiguously assigned to one of the known meteorites classes [e.g., 1-3]. Some of these samples contributed significantly to our understanding of processes in the early solar nebula and on the meteorite's parent bodies [e.g., 4, 5].

We report here on two unusual carbonaceous chondrites which were recently recovered from the Moroccan Sahara.

Methods. One polished thin section of each meteorite was studied using optical and scanning electron microscopy. Mineral compositions were determined with a JEOL JXA-8800L electron microprobe operating at an accelerating voltage of 15 kV and a probe current of 15 nA. Measurements of oxygen isotopic compositions were made using techniques described by [6, 7].

NWA 1465. The meteorite is a type 3 carbonaceous chondrite with up to several mm sized chondrules, CAIs, forsterite-rich refractory objects, and mineral fragments set into a dark, fine-grained matrix (Fig. 1). The chondrule olivines have a mean fayalite content of 5.5 mol% (range $Fa_{0.4-41.9}$). Chondrule pyroxenes are less Fe-rich with a mean Fs-content of 2.8 mol% (range $Fs_{0.8-5.5}$). Plagioclase ($An_{83.5}$, range $An_{79.6-86.8}$) and glassy mesostasis are present in several chondrules. Ca,Al-rich inclusions are frequently found in NWA 1465. They are often highly irregularly-shaped and composed of spinel, Ti-rich Ca-pyroxene, melilite, and forsterite. While the refractory objects in the samples studied here had a maximum size of about 4 mm, much larger CAIs ≥1 cm in size were reported from other fragments of this meteorite.

The dark, fine-grained matrix of NWA 1465 is composed of Fe-rich olivine ($Fa_{43-57.6}$), Ca-rich pyroxene, enstatite, forsterite, troilite, FeNi-metal, magnetite and weathering products. Microprobe analyses using a 10 µm defocused electron beam reveal totals up to 100 wt%, thus excluding the presence of significant amounts of anhydrous phases and proving a very low porosity of the matrix.

NWA 1465 also contains large (up to several cm-sized) dark objects which seem to be macroscopically similar to dark inclusions known from various other chondrites (Fig. 1), [e.g., 8]. However, microscopic investigations reveal significant differences between the two materials. While typical dark inclusions often resemble C1/C2-like material with magnetites, carbonates and sulfides set in a porous, phyllosilicate-dominated matrix, the dark material in NWA 1465 represents an extremely compact anhydrous assemblage of Fe-rich olivine, abundant kirschsteinite, Ca-pyroxene, magnetite, FeNi-metal, few forsterite-rich

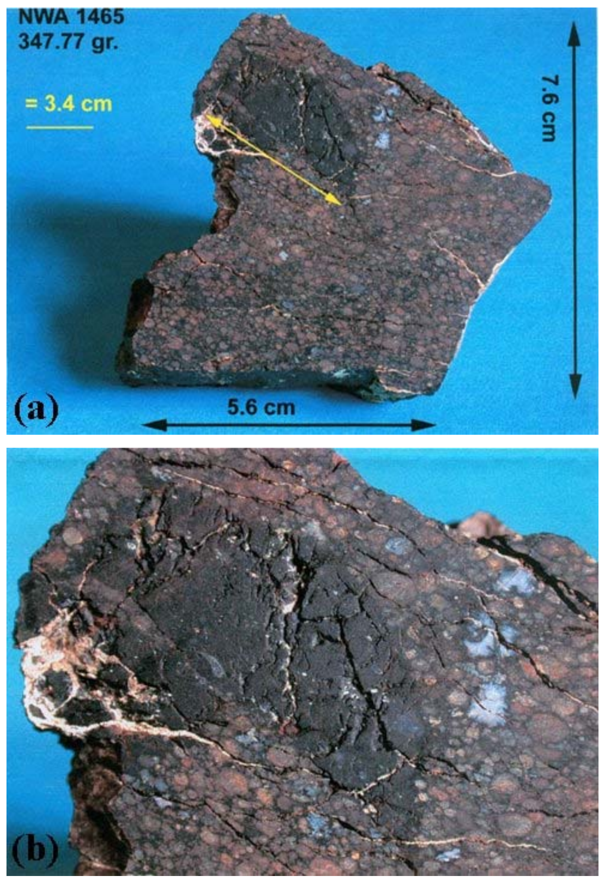

Fig. 1. (a) Overview of a sawn surface of NWA 1465; (b) close up of a large area of dark material and CAIs. Photographs courtesy of S. Kambach.

refractory objects, and very rare sulfides. The more coarse-grained interchondrule matrix of NWA 1465 and the fine-grained dark material are clearly distinguishable. In contrast to typical dark inclusions they are not separated by a sharp boundary. Instead they mostly exhibit a smooth gradual contact (Fig.2).

Texturally, NWA 1465 is remarkably similar to the Leoville CV3 carbonaceous chondrite [8-10] and is characterized by a clearly visible foliation defined by flattened ellipsoid-shape chondrules and refractory objects (Fig. 1). The deformed objects have a mean aspect ratio of 1.5 (long axis/short axis). Olivine in NWA 1465 displays a high density of planar fractures and mosaicism attesting moderate shock metamorphism (shock stage S4). Some chondrules show additional evidence for shearing. Chondrules, refractory objects and the interchondrule matrix frequently contain melt veins and pockets while the dark inclusion material remains free of any shock effects. Additionally, opaque phases in the interchondrule matrix, i.e. FeNi-metals and sulfides show notable elongation.

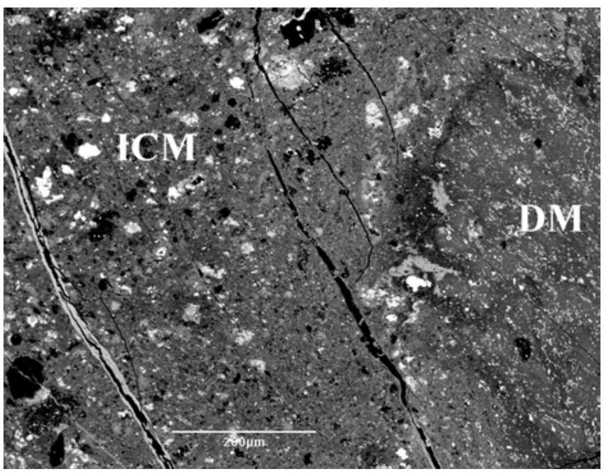

Fig. 2. Contact between coarse-grained interchondrule matrix (ICM, left) and dark material (DM, right).

The meteorite is moderately to heavily weathered (weathering degree W3) with most metals especially in chondrules being replaced by oxides and strong oxide veining.

While mineralogy and mineral compositions of NWA 1465 are consistent with a classification as a CV3 carbonaceous chondrite, the oxygen isotopic composition of $\delta^{18}O = 4.89$ and $\delta^{17}O = 0.71$ most closely match that of CR chondrites. Their range is also inconsistent with typical dark inclusions from CV chondrites which have more negative $\Delta^{17}O$ values.

Measurements of the O-isotopic composition of the dark material in NWA 1465 reveal a $\delta^{18}O$ of 13.72 and a $\delta^{17}O$ of 6.15. The inclusion is obviously not equilibrated with the host meteorite. The point lies on an extrapolation of the CR line, very near the composition of Al Rais matrix (see Fig. 6 in [11]). It is also near the upper end of dark inclusions in Belgica 7904, and Leoville and Vigarano (see Fig. 10 in [11]). In all these cases, the heavy-isotope enrichment is probably the result of low-temperature aqueous alteration, in some cases followed by thermal dehydration, which does not introduce much additional isotopic change.

According to our results, NWA 1465 is thus classified as a C3 carbonaceous chondrite with some affinities to the groups of CV and CR chondrites.

NWA 1665. This meteorite is also a type 3 carbonaceous chondrite composed of chondrules, irregular-shaped olivine-rich objects, and mineral fragments set into a fine-grained matrix. Olivines and pyroxenes are highly unequilibrated with $Fa_{25.7}$ (range $Fa_{0.7-37.6}$) and Fs_{12} (range $Fs_{2.5-48.3}$), respectively. Chondrules are 200-400 µm in size and mostly porphyritic olivine and pyroxene chondrules. The matrix consists of Fe-rich olivine, Ca-pyroxene, troilite, and FeNi-metal. The meteorite is basically unshocked (shock stage S1) and only moderately weathered (weathering degree W2).

Measurements of oxygen isotopic compositions give a $\delta^{18}O$ of –1.03 and a $\delta^{17}O$ of –4.95, similar to the data obtained for the ungrouped type 3 carbonaceous chondrite Dar al Gani 055 [11]. These values fall in the range of CO and CK chondrites, where there is also overlap with reduced CV chondrites. Chondrule size and the meteorite's texture clearly argue against a classification as a CV or CO chondrite while some similarities with CK3 chondrites may be suggested. However, since NWA 1665 cannot be unambiguously assigned to one of the known meteorite classes, it should be classified as an ungrouped type 3 carbonaceous chondrite.

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