NORTHWEST AFRICA 12563 CM2-AN, AND THE DIFFERENT ALTERATION STYLES IN C2 CHONDRITES.

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Characteristics of chondrite: Northwest Africa 12563 (NWA 12563**)** contains 14% chondrules and 86% matrix, consistent with a CM2 chondrite, but has abundant magnetite framboids and lacks TCI in the matrix. The magnetic susceptibility ($\log\chi = 4.67$) and oxygen isotope data ($\delta^{18}O=12.61‰$ and $\delta^{17}O=5.26‰$) are close to the values for Bells and Essebi C2-ung, and higher than those of most CM2 chondrites [1,2]. The magnetite content of 6.8 wt% is high, as in Bells and Essebi, while the average CM chondrite contains ~1 wt%. It contains 0.72 wt.% H (i.e. 6.5 wt.% H_2O) with $\delta D = -57.5$ ‰, resembling heated CM chondrites [3]; 2.13 wt.% C with a normal CM ‰ $\delta^{13}C$ of -12.2 [4]; and 0.095 wt.% N. The C/H ratio is very high and also resembles that of heated CMs, though we have no evidence of dehydration in NWA 12563. We consider it to be an anomalous CM2 chondrite.

Chondrules: There are Type IA, IABm, and IIA chondrules. Olivine is unaltered but pyroxene shows incipient alteration on cleavage planes. Mesostases are replaced by fibrous to lathy Mg-rich serpentine-saponite and more ferroan chlorite. Chondrule metal ovoids are largely pseudomorphed by serpentine, as in WIS 91600 [5], sometimes with Ni-Cr-bearing P-rich sulfide speckles, and resemble serpentine micro-spherules in CR chondrule rims [6].

Matrix mapping and mineralogy: We quantified the modal abundance and bulk matrix composition using the ACADEMY method [7] (250 nm-sized pixels). The matrix groundmass consists of amorphous silicates and phyllosilicates with embedded sulfides, oxides, anhydrous silicates, carbonates and organic compounds, with ~77% amorphous/phyllosilicate material, and ~23% other discrete phases. TEM shows that abundant amorphous silicate regions with nanosulfides and organics are juxtaposed with well-ordered phyllosilicate areas. Amorphous silicates contain much less Fe than in other chondrites [8,9], and slightly lower Mg than adjacent phyllosilicates, due to the higher magnetite content. In particular areas, well-ordered phyllosilicates of intermediate composition are embedded within amorphous silicates, from which they must be derived. STXM-XANES at the Fe-L edge indicates that the amorphous silicate and phyllosilicate have a high $Fe^{3+}/\sum Fe$ ratio (~70%). Raman spectroscopy and STXM-XANES at the carbon C-edge show that the organic matter resembles that in CM chondrites.

Comparison to other chondrites: NWA 12563 is an unusual meteorite with a high abundance of magnetite. The main matrix alteration assemblage is Mg-rich phyllosilicates and magnetite, which is different from the typical CM association of serpentine, cronstedtite and tochilinite, and suggests different alteration conditions than for other CM chondrites. Though magnetite is associated with heavy alteration, it occurs here with olivine and amorphous silicate in the matrix. Both magnetite and Mg-rich phyllosillicates are stable over wide temperature ranges, and have been suggested to replace cronstedtite and tochilinite at higher temperatures [6,11,12]. Nonetheless, Raman and XANES results indicate that the temperature remained relatively low and comparable to other CM chondrites. A slightly higher alteration temperature for NWA 12563 than for CM2 chondrites would suggest formation in a large asteroid or by impact heating.

[1] proposed a new magnetite-rich chondrite group including Tagish Lake, Adelaide, Bells, Essebi, and Niger (C2). On the other hand, [10] considered Bells and Essebi to be CM/CI transitional types and indeed magnetite abundance and oxygen isotope composition for these three meteorites are intermediate between those of CI and CM chondrites. However, the D/H and C/H ratios of NWA 12563 resemble those heated CM chondrites, although the mineralogy is different. The metal alteration is like that in the TCI-free, magnetite-rich WIS 91600 chondrite [5], while mesostasis alteration is like that of CR chondrules. There seem to be different types of anomalous or ungrouped C2, consistent with the large number of C-complex asteroids [13].

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