NEW KIND OF CHONDRITE: A CLAST WITH CARBONACEOUS, ORDINARY AND UNIQUE CHARACTERISTICS IN THE NORTHWEST AFRICA 10214 LL3 BRECCIA. A. E. Rubin[1], J. P. Breen[2], J. Isa[1] and S. Tutorow[3], [1]Earth, Planet. & Space Sci., UCLA, [2]Chem. & Biochemistry, UCLA, [3]eegooblago meteorites.

Introduction: Dark clasts in type-3 ordinary-chondrite (OC) breccias were derived from several sources. Some probably agglomerated along with chondrules during accretion (e.g., matrix lumps in H/L3 Tieschitz and a microchondrule-bearing clast in LL3 Krymka), others likely formed by collisions on the parent body (e.g., melt-rock clasts in the H3 Dimmitt regolith breccia), and a few may be fragments of foreign projectiles (e.g., a black inclusion in Krymka).

Northwest Africa (NWA) 10214 is an LL3.7 breccia found as a single 1816-g stone. It contains sharply defined chondrules of all textural varieties ranging in diameter from ~150 – 6500 µm and averaging ~500 µm. Also present are numeorus chondrule fragments and isolated mineral grains. The rock is shock-stage S2 and contains 8 vol.% clasts 4-40 mm in size. The clasts include metamorphosed LL clasts, shock-darkened LL clasts, and a unique chondritic clast (dubbed Clast 6) that possesses incongruous properties characteristic of different chondrite groups. We describe Clast 6 as "chimeric" because of its metaphorical resemblance to the Chimera, a mythological monster made up of three different animals – a lion, a goat and a snake – that rightfully should not be part of a single beast.

Description of the Chimeric Clast: Clast 6 is a dark-colored, subrounded inclusion, 6.1×7.0 mm in size, consisting of 60 vol.% fine-grained matrix material, 32 vol.% coarse silicate grains (including low-Ca-pyroxene-rich porphyritic chondrules and a single CAI), and 8 vol.% coarse opaque grains (including kamacite, taenite, troilite and terrestrially produced limonite). (NWA 10214 is weathering-stage W3.) The matrix consists mainly of submicrometer-size silicate grains and minor ~0.3-µm-size troilite grains; the matrix contains (in wt.%) 31.6% SiO_2, 2.0% Al_2O_3, 37.6% FeO, 1.6% NiO, 21.8% MgO, 0.42% S and <1% TiO_2, Cr_2O_3, MnO, CaO, Na_2O and P_2O_5, and totals 97.1%.

Chondrules: The apparent diameters of intact chondrules in the clast range from 120 – 810 µm (mean 330±160 µm; n=27). Twenty-four of these chondrules are PP or PPO; only three are POP. There are no PO, BO, RP, GOP or C chondrules. All intact chondrules are low-FeO types (i.e., Type I). None of the chondrules is surrounded by an igneous rim. The chondrules contain devitrified mesostasis; none has clear, isotropic glass. Low-Ca clinopyroxene phenocrysts in the chondrules exhibit polysynthetic twinning. The O-isotopic compositions of low-Ca pyroxene in four chondrules (mean $\Delta^{17}O$ = 0.52±0.58‰) are in the OC range.

Mineralogy and Petrologic Subtype: Olivine and low-Ca pyroxene in the clast are unequilibrated. Olivine ranges from Fa 4.2 – 31.6 with a mean composition of Fa 13.6±5.9 (n = 68) and a percent mean deviation (PMD) for FeO of 32.8%; low-Ca pyroxene ranges from Fs 1.8 – 10.7 Wo 0.1-2.9 with a mean composition of Fs 4.3±2.2 Wo 0.4±0.3 (n = 72) and a PMD for FeO of 40.3%. Also present in the clast are a few augite grains: Fs6.3±3.4 Wo36.8±2.9 (n=3).

The olivine data for Clast 6 correspond to petrologic subtype 3.4-3.5, the low-Ca pyroxene data to subtype 3.0-3.6. The presence of devitrified mesostasis in the chondrules is characteristic of subtype 3.6-3.9. The presence of polysynthetic twinning in low-Ca clinopyroxene is indicative of subtype ≤3.9. From these data, the best estimate for the subtype of Clast 6 is 3.6.

Calcium-Aluminum-rich Inclusion: The sole CAI constitutes 0.6 vol.% of the clast; it is 450×600 µm in size and has an irregular shape. It is a simple spinel-pyroxene-olivine inclusion fragment similar to those in CM chondrites that have undergone only minor aqueous alteration (i.e., QUE 97990 and Paris; [1,2]). Nevertheless, the mean FeO contents of the phases in the CAI are higher (and, in the case of spinel, much higher) than those in spinel-pyroxene-olivine inclusions or spinel inclusions in Paris – olivine: 2.9±1.0 vs. 0.76±0.10 wt.%; diopside: 0.73±0.37 vs. 0.63±0.18 wt.%; spinel: 10.9±2.9 vs. 0.63±0.17 wt.%. The grains within the CAI range from ~2 to ~30 µm; some clusters of small (2-3 µm) grains have 120º triple junctions. Spinel grains tend to occur in 60-100-µm-size clusters throughout the inclusion. Diopside in the CAI ($\delta^{17}O$ = -45‰; $\delta^{18}O$ = -46‰; $\Delta^{17}O$ = -23‰) plots along the CCAM line. It is very similar in composition to that of mafic silicates in many unaltered CAIs from primitive chondritic meteorites [3].

Incongruous Properties of the Chimeric Clast: Clast 6 possesses a unique set of properties: (a) The high modal abundances of matrix and CAIs are characteristic of many carbonaceous chondrites (and closest to those in CM and CR chondrites); (b) The O-isotopic compositions of the chondrules are similar to some LL3 chondrules and to the Sharps H3.4 whole rock ($\Delta^{17}O$ = 0.65‰; [4]); (c) The low-Ca-pyroxene/olivine ratio of the chondrules (4:1) is higher than that in H chondrites (0.7:1) or the chondritic clasts in the Netschaevo IIE-an iron (2:1) and lower than those in EH3 and EL3 chondrites (14:1, 27:1) [5-7]; and (d) The calculated CI- and Mg-normalized Al abundance ratio of the clast (0.79) is lower than that of all major chondrite groups, although it is appreciably closer to those of ordinary chondrites (0.89-0.90) than carbonaceous chondrites (1.00 – 1.35) [8].

Origin of the Chimeric Clast: Whereas the NWA 10214 host is clearly a brecciated LL3 chondrite, Clast 6 has a different provenance. Because neither the clast nor the host is appreciably shocked, it seems likely that the clast is a fragment of a projectile that collided with the LL parent asteroid at low relative velocity.

A hypothetical "H3" chondrite with 60 wt.% matrix and 20 wt.% chondrules (and the same modal abundances of metal, sulfide, AOIs and CAIs and the same component compositions as H3 Sharps) would contain 9.26 mg/g Al and 134.1 mg/g Mg. This yields a CI- and Mg-normalized Al abundance ratio of 0.78, almost identical to the 0.79 value of Clast 6. This exercise supports the idea that Clast 6 is an OC that acquired an unusually high allotment of matrix material.

A viable model for the origin of the clast must account for its relatively high CAI abundance (0.6 vs. ~0.02 vol.% in typical OC). The correspondence between a high matrix abundance and a high CAI abundance in a chondrite may be a result of radial drift processes in the solar nebula that affected porous multi-millimeter-to-centimeter-size dustballs (matrix precursors) to about the same extent as smaller, more-compact CAIs [8]. The rate of radial drift in the nebula is a function of the product of the size and density of an entrained object [9,10]. Large porous dustballs made of matrix material and smaller, dense CAIs would be aerodynamically concentrated in the same nebular regions [8]. Dustballs (like the one that gave rise to the matrix of Clast 6) and CAIs (physically similar to the one in Clast 6) may have independently drifted to the particular portion of the OC region where this clast agglomerated. This scenario is consistent with the positive correlation among chondrite groups between the modal abundances of matrix and CAIs [8].

An anomalous characteristic of the clast is the high low-Ca-pyroxene/olivine modal ratio in chondrules and chondrule fragments: 4:1. Among the major chondrite groups, high low-Ca-pyroxene/olivine ratios are found only in enstatite chondrites. This is because so little of the metallic Fe in these reduced rocks has been oxidized to FeO that the ratio of divalent cations to Si remains close to unity (as in $MgSiO_3$), stabilizing low-Ca pyroxene. In more-oxidized chondrites (with higher FeO), the divalent-cation/Si ratio climbs toward 2 (as in $(Mg,Fe)_2SiO_4$), stabilizing olivine. With increasing degrees of reduction, the low-Ca-pyroxene/olivine modal ratio in chondritic materials increases. R chondrites comprise the most oxidized non-CI group with a mean low-Ca-pyroxene/olivine modal ratio of 0.06 [11] and an olivine Fa content of ~39 mol%. Among ordinary chondrites, the low-Ca-pyroxene/olivine modal ratio is 0.3 in LL (mean Fa 29.4 mol%), 0.5 in L (mean Fa 24.7 mol%) and 0.7 in H (mean Fa 18.8 mol%) [5,12]. Chondrule-bearing silicate clasts in the Mont Dieu IIE iron are more reduced than H chondrites, but plausibly are still members of the OC clan. The low-Ca-pyroxene/olivine modal ratio in the Mont Dieu clasts is 0.9 (mean Fa 15.7 mol%) [13]. Chondritic clasts in the Netschaevo IIE-an iron also appear to be members of the OC clan and are even more reduced. The low-Ca-pyroxene/olivine modal ratio in the Netschaevo clasts is 2.0 (mean Fa 14.3 mol%) [6,12]. A hypothetical chondrite somewhat more reduced than Netschaevo would be expected to have a lower mean olivine Fa value and a higher low-Ca-pyroxene/olivine modal abundance ratio, roughly comparable to the properties of Clast 6.

The chimeric clast can be modeled as a type-3 OC, somewhat more reduced than H chondrites and the chondritic clasts in Netschaevo. It formed in a nebular region where aerodynamic radial-drift processes had deposited a relatively high abundance of matrix material and CAIs. At some point a collision jettisoned material off this asteroid; some of it eventually impacted the LL-chondrite parent asteroid at low relative velocity. A fragment of this projectile became Clast 6. Along with shocked and metamorphosed clasts derived from different regions of the LL body, Clast 6 was incorporated into previously unconsolidated LL3 material. The entire assemblage was subsequently lithified by impact-induced compaction and (perhaps during a subsequent collision) was launched off the LL parent body.

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