

THE TRACE ELEMENT CHEMISTRY OF NORTHWEST AFRICA 5958, A CURIOUS PRIMITIVE CARBONACEOUS CHONDRITE. R. D. Ash¹, R. J. Walker¹, I. S. Puchtel¹, W. F. McDonough¹ and A. J. Irving², ¹Department of Geology, University of Maryland, College Park, MD20742 USA (rdash@geol.umd.edu), ²Department of Earth and Space Sciences, University of Washington, Seattle, WA 98195.

Introduction: The Sahara Desert has yielded something in excess of 6000 meteorite finds. This has significantly added to our collections of rare meteorites and some unique materials have been identified. Amongst the latter is a recently described carbonaceous chondrite, Northwest Africa (NWA) 5958, that exhibits several unique characteristics. Most striking is a bulk oxygen isotopic composition that is ¹⁶O-rich ($\Delta^{17}\text{O} = -6.8$ to -7.2‰) and lies on the CCAM line [1]. Since the CCAM line is defined by anhydrous minerals it may suggest that the meteorite has escaped parent body hydrous alteration and initial thoughts were that it may contain a high abundance of CAIs.

We have undertaken the determination of minor and trace element concentrations including some highly siderophile elements (HSE: Re, Os, Ir, Ru, Pt, Pd) as well as Re-Os isotopic composition.

Samples: NWA 5958 is clastic, dominated by a porous matrix containing lumps of clearly defined fine grain clasts. Chondrules (porphyritic and barred olivine 100 μm to 250 μm diameter), rare POIs and CAIs [Fig.1] are also present. Metal and sulphide grains are present in chondrules and at their edges, and also as free grains in the matrix [1].



Figure 1. NWA 5958 in reflected light

There are clear signs of minor, but pervasive, weathering. Veins of iron oxide infiltrate from the surface and the surface itself has iron oxide staining. Most metal grains are well preserved, but some have been partially or wholly replaced by oxide/hydroxide.

Methods: Samples were prepared for trace element analysis by solution and laser ablation ICPMS (ThermoFinnigan Element2). Bulk samples for solution analysis, along with blanks and standards BIR and BCR, were dissolved in HF/HNO₃ at 180°C, followed by HClO₄, then HCl and finally analysed in HNO₃.

For *in situ* analysis a chip was prepared for EPMA to determine major and minor element concentrations,

followed by laser ablation (New Wave UP213) for minor and trace element abundances. Bulk trace element concentrations were determined by rapid rastering of the 80-100 μm diameter laser beam over the sample surface (after cleaning by a pre-analysis ablation pass). Ablated material was entrained in a stream of He for analysis by ICPMS. Individual matrix spots (80-100 μm diameter), chondrules, POIs and CAIs (30-80 μm) were also analysed by laser ablation. Data reduction was carried out using LAMTRACE.

HSE abundances and ¹⁸⁷Os/¹⁸⁸Os were measured in two bulk samples (41mg and 182mg) using our standard methods [2,3].

Results: *Trace elements* Elemental concentrations determined by both laser ablation and solution methods are in excellent agreement, although laser ablation gives marginally higher concentrations for some refractory trace elements, (*e.g.* Th, Hf, W) which we attribute to the dominant carrier being incompletely dissolved refractory minerals that are ablated by the UV laser.

Figure 2 shows results for the laser ablation analysis of bulk, matrix and clast spots in NWA 5958. All data has been normalized to CI chondrite and Lu. Lutetium was chosen as a refractory element that is largely unaffected by weathering and for which there are reliable data available in the literature for a range of carbonaceous chondrite groups. The bars on the data for NWA 5958 are variations around the mean composition and represent the range of compositions. Data for points within 200 microns of the sample edge were not included in the mean (see below).

HSE and Os isotopes Absolute abundances of HSE between the two pieces differ by ~20%, but the elemental ratios are generally well reproduced.

¹⁸⁷Os/¹⁸⁸Os ratios are 0.1317 and 0.1326, differing significantly more than analytical uncertainties (0.1%), and are considerably higher than for any other measured carbonaceous chondrites (Figure 3). The present day isotopic composition, coupled with Re/Os require minor open system movement of Re or Os, which suggests that the desert weathering had a minor, but significant, effect on at least one of the HSE.

Discussion *Geochemical effects of weathering* There are clear effects of chemical weathering. Most pronounced are huge enrichments over CI for some elements; U (up to 300x), Ba (up to 60x), Sr (up to 20x) and B (up to 100x). Light REE are also enriched

(up to 3x for La) and there is a small positive Eu anomaly, but returning to a flat pattern at near CI levels for the HREE. Toward the outer edge of the sample, the alteration and enrichment effects are most extreme, although the porous nature (see Figure 1) of the sample results in ubiquitous chemical alteration.

This style of alteration has been noted in the desert taphonomy of fossil bone [10]. These chemical changes occur rapidly, within months or years through interaction with surface or ground water.

Chemistry of NWA 5958 Despite some elements being adversely affected by the meteorite's sojourn in the Sahara there is still much information that can be gleaned from these analyses.

Figure 2 shows the bulk trace element composition for a variety of refractory and volatile trace elements. It is clear that it mimics closely that of CI chondrites. We find no correlation between any of the elements affected by the weathering (U, Ba, Sr, B) and the most volatile elements (Sn, Zn, Pb, Bi, In, Tl, Cd), the distinctive chemical feature of the CIs, hence we are confident that the high volatile content is indigenous.

The ratio of the cosmochemical 'twins' Nb and Ta exhibit a limited range in chondrites (19.9 +/-0.6 [6]), except CVs where Nb/Ta is low, down to 15.8, an effect attributed to the high abundance of CAIs compared with other groups [6]. The low Nb/Ta in CAIs has been confirmed several times, reaching unity in extreme cases [7, 8]. In NWA 5958 the ratio is indistinguishable from CI chondrite values (Nb/Ta=19.6), confirming that the ¹⁶O enrichments observed are not due to the overwhelming presence of CAIs.

HSE and Os isotopes The radiogenic Os compositions show that the Re/Os does not necessarily correlate with the volatile content. Hence, conclusions about water delivery to the Earth and other planets do not appear to be justified based upon the Os isotopic composition of the terrestrial mantle [e.g. 9].

Conclusions: 1) NWA 5958 is a uniquely primitive carbonaceous chondrite that has CI-like chemistry, but contains chondrules and other 'normal' anhydrous chondritic components. 2) It has a unique ¹⁶O-rich bulk composition that suggests that it is largely unaffected by parent body alteration 3) the porosity and mineralogy have made the sample susceptible to terrestrial weathering and it has suffered significant chemical alteration with several elements compromised by either addition (e.g. U, Ba, B, Sr, LREE) or loss (e.g. Re).

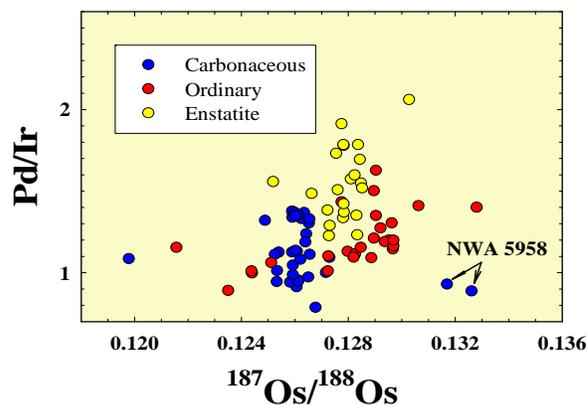


Figure 3. ¹⁸⁷Os/¹⁸⁸Os vs. Pd/Ir for three main groups of chondrites. NWA 5958 is more radiogenic than any measured carbonaceous chondrite. Data are from [2-5].

References: [1] Bunch T.E. et al. (2011) *LPS XXXVII* this conference [2] Walker R. J. et al. (2002) *GCA*, 66, 4187 [3] Horan M. F. et al. (2003) *Chem. Geol.* 196, 5 [4] Fischer-Gödde M. et al. (2010) *GCA*, 74, 356-379. [5] Brandon A. D. et al. (2005) *GCA*, 69, 1619-1631. [6] Munke C. et al. (2003) *Science*, 301, 84 [7] Ash R.D. et al., (2005) *LPS XXXVI*, Abstract #2168; [8] Friedrich et al. (2005) *LPS XXXVI*, Abstract #1985 [9] Drake M. J. (2005) *MAPS* 40, 567-579. [10] Koenig A.E. et al. (2009) *Geology* 37, 511 [11] Lodders K. (2003) *Ap.J* 591, 1220

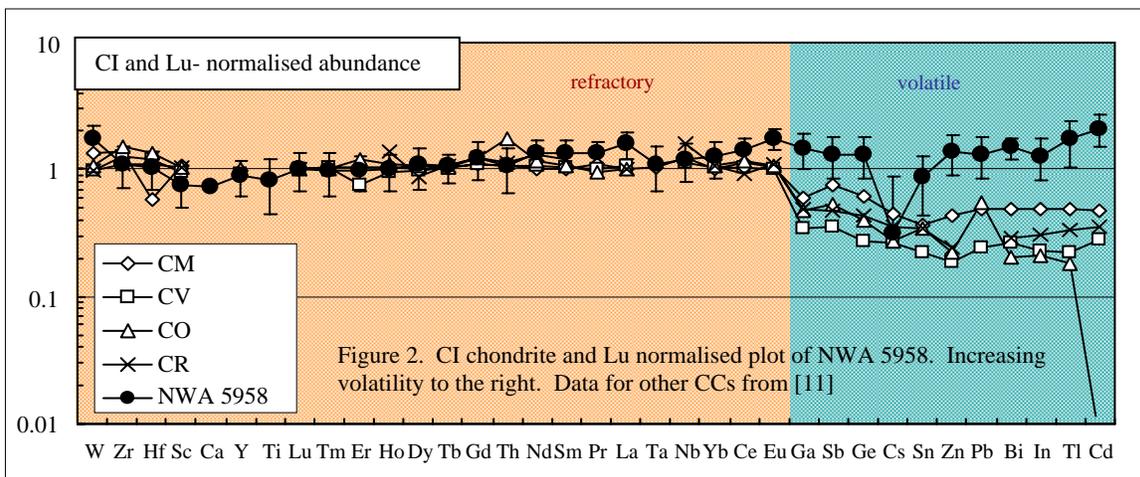


Figure 2. CI chondrite and Lu normalised plot of NWA 5958. Increasing volatility to the right. Data for other CCs from [11]