NORTHWEST AFRICA 090: A CASE FOR REVISING MINERALOGICAL AND GEOCHEMICAL CRITERIA FOR CLASSIFYING PRIMITIVE ACHONDRITES. A. Stephant[1,2] C. Carli[1], M. Anand[2], J. Davidson[3], E. Bruschini[1], G. Pratesi[4], T. Cuppone[4], A. Néri[5], R.C. Greenwood[2], I.A. Franchi.[2], [1]IAPS-INAF, Roma, Italy. [2] School of Physical Sciences, The Open University, Milton Keynes, MK7 6AA, UK. [3]Buseck Center for Meteorite Studies, Arizona State University, Tempe, USA. [4]Dipartimento di Scienze della Terra, Università degli Studi di Firenze, Firenze, Italy. [5]Bayerisches Geoinstitut, University of Bayreuth, Germany.

Introduction: Acapulcoite-lodranite and winonaite meteorites are primitive achondrites, which are thought to have sampled partially-melted parent bodies, formed only a few Ma after CAIs [1]. As such, they provide a window into the early stages of protoplanetary differentiation. Some winonaites and acapulcoites contain relict chondrules, attesting to their links with a chondritic parent body. At least, based on the chemistry and mineralogy of these meteorites, the acapulcoite and lodranite parent body has been suggested to be close in composition to H ordinary chondrites [2]. In comparison, winonaite precursors would have formed in a more reduced environment, with the major-element composition lying in between enstatite chondrites and ordinary chondrites [3,4] and similarities in trace element abundances to CM carbonaceous chondrites [5]. As such, modal abundance, mineralogy and chemistry are typically used to distinguish acapulcoites from winonaites [3,4].

The meteorite Northwest Africa (NWA) 090 was classified as an acapulcoite [6] on the basis of its mineralogy and mineral chemistry. However, several lines of evidence suggest that NWA 090 could be a winonaite instead. In fact, several acapulcoites and ungrouped achondrites have been reclassified as winonaites on the basis of their oxygen isotopes [7,8], although their mineralogy and chemistry initially seemed consistent with the acapulcoites. Therefore, it is timely to revisit the criteria used for distinguishing between winonaites and acapulcoites. Here we studied NWA 090 to review these criteria and investigate the composition of its parent body.

Methods: Back-scattered electron (BSE) images and X-ray elemental maps of a NWA 090 thin section, as well as electron microprobe analyses (EMPA), were acquired at University of Arizona with a Cameca SX-100 and at the University of Firenze with a Zeiss Evo MA15 (MEMA Center) and with a JEOL-JXA 8230 (Department of Earth Sciences). EMPA data were acquired on olivine, clino- and ortho-pyroxene, feldspar, troilite, chromite, kamacite and taenite. Mineral modal abundances were calculated using XMapTools [9].

Results: *Petrography.* NWA 090 displays a proto-granular texture. Twelve relict chondrules were also identified in the section, with an average diameter of ~400 µm. Most chondrules contain porphyritic olivines, but radial pyroxene and granular varieties were also identified.

Modal abundances. NWA 090 is comprised of 14 % olivine (wt. %), 34 % low-Ca pyroxene, 4 % high-Ca pyroxene, 10 % feldspar, 0.5 % phosphates and 37 % opaques (including troilite, chromite, kamacite, taenite and alteration products) (Fig. 1).

Mineral chemistry. The compositions of olivine and low-Ca pyroxene in NWA 090 (Fa=6.1 and Fs=7.3, resp.) lie towards the higher range for winonaites and overlap with the lower range of values for acapulcoites, leading to some confusion in classifying this meteorite. Two pyroxene thermometry yields a metamorphic temperature of 970 ± 30 °C. No reduced accessory minerals were identified in the studied thin section, probably due to NWA 090 being a relatively FeO-rich sample.

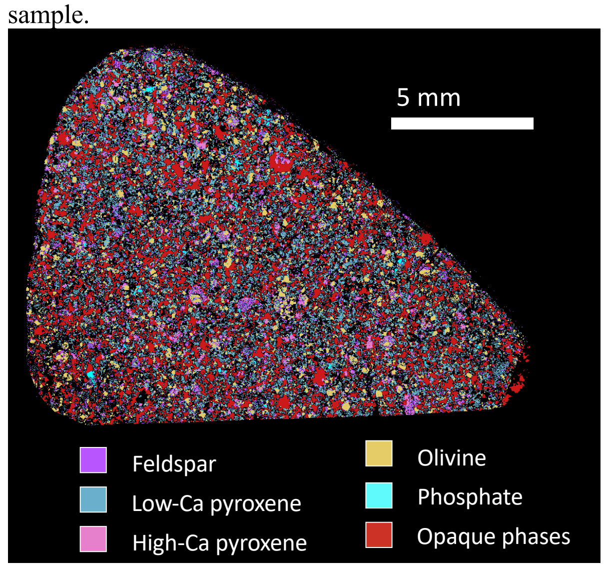

Fig 1 – Mineral modal abundances map of NWA 090 calculated with combined Si, Mg, Ca, Fe and P elemental X-ray maps.

Discussion: While the modal abundance of minerals in acapulcoites and winonaites overlap, winonaites typically have a lower ratio of olivine/opaque phases than acapulcoites [3] (Fig. 2). In fact, the modal abundance of opaques in NWA 090 (37%) is higher than the range recorded in acapulcoites (0.9 to 27 wt.% [10]). Similarly, the olivine content in NWA 090 (14 wt.%) is lower than the acapulcoite range (15 to 41 wt.% [10]). Consequently, on the basis of the olivine/opaque ratio, NWA 090 can be unambiguously identified as a winonaite (Fig. 2). It also follows that modal abundances alone can only be used to distinguish acapulcoite and winonaites in those cases where they have extreme olivine/opaque ratios, i.e., <0.8 for a winonaite or >3.3 for an acapulcoite.

Compositions of mafic minerals are generally used to classify primitive achondrites into either the acapulcoite or winonaite groups. A correlated variation plot between ferrosilite (Fs) content of low-Ca pyroxene and fayalite (Fa) content of olivine in primitive achondrites is often used for this purpose. However, while winonaites used to be restricted to Fa <5 [4], data from newly discovered winonaites necessitates a revision of this criterion. NWA 090 has Fs and Fa contents of 7.3 and 6.1, occupying a space where the previously reported ranges for winonaites and acapulcoites overlap (Fig. 3). In fact, NWA 090 plots together with other misclassified winonaite samples and highlights the fact that this criterion has to be used with caution, especially where olivine has a Fa value between 5 and 10. Besides, it has been stated previously [7] that using solely the silicate mineralogy as a distinguishing criterion between primitive achondrites is risky, leaving the oxygen isotopic composition as the only unambiguous way of distinguishing between winonaites and acapulcoites [4,8]. This could certainly be the case for the least reduced and more primitive winonaites, which appear to share compositional similarities with acapulcoites, although the presence of relict chondrules in these primitive achondrites favours a winonaite classification. Oxygen isotopic measurements of NWA 090 are in progress, which should help corroborate our deductions.

Most of the relict chondrules in NWA 090 are easily identified based on texture. This, together with the estimated metamorphic temperature of 970 ± 30 °C indicate that this winonaite is one of the least thermally metamorphosed samples from this group, since most winonaites recorded metamorphic temperatures between 950 °C and 1100 °C [5]. In fact, other relict chondrule-bearing winonaites exhibit similar metamorphic temperatures, which are close to the Fe-FeS eutectic temperature (around 990 °C). As such, NWA 090 and other primitive winonaites did not experience any significant partial melting and could be good proxies to investigate the primary signatures of the winonaite parent body.

The Fs and Fa signatures of NWA 090, the presence of taenite and the absence of other highly reduced accessory minerals attest to NWA 090 being less reduced than typical winonaites. In fact, most of NWA 090 features match other relict chondrule-bearing winonaites. These winonaite samples could have been derived from a more oxidized parent body, closer to acapulcoite composition than previously thought.

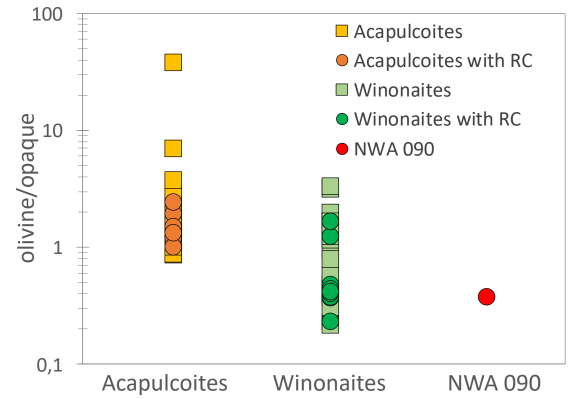

Fig. 2 – Ratio of modal olivine and opaque phases in acapulcoites and winonaites, with or without relict chondrules (RC). NWA 090 lies clearly in the winonaite range.

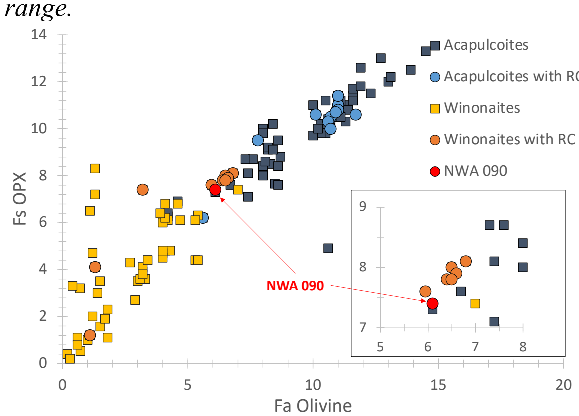

Fig. 3 – Ferrosilite content of low-Ca pyroxene vs fayalite content in olivine of acapulcoites and winonaites, with or without relict chondrules (RC).

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