THE FORMATION CONDITIONS OF CHONDRITES: INSIGHTS FROM NORTHWEST AFRICA 10850 – AN OXIDIZED CV3 CHONDRITE. M. M. Jean1,2, A. Patchen1, M. B. Sueilem3, L. A. Taylor4. 1Planetary Geoscience Institute, Dept. Earth and Planetary Sciences, University of Tennessee Knoxville. 2University of Alaska-Anchorage, Dept. of Geological Sciences, Anchorage, AK 99508. 3Smara Refugee Camps of Western Sahara, Tindouf, Algeria. (mmjean@alaska.edu)

Introduction: For the first time, data are presented from a detailed investigation of all components of the Northwest Africa (NWA) 10850 carbonaceous chondrite. NWA 10850 is a newly classified meteorite collected from Algeria, in the Tindouf province. Approximately 50.3 g were recovered on August 2015, and acquired by us shortly thereafter. Its classification as a carbonaceous chondrite was recently approved [1].

![Combined Mg Kα (blue) + Al Kα (green) + Ca Kα (red) X-ray maps showing chondrules, CAIs (calcium-aluminum inclusions), amoeboidal olivine aggregates (AOA), and other features found in NWA 10850 matrix](#)

Figure 1. Combined Mg Kα (blue) + Al Kα (green) + Ca Kα (red) X-ray maps showing chondrules, CAIs (calcium-aluminum inclusions), amoeboidal olivine aggregates (AOA), and other features found in NWA 10850.
We have undertaken a comprehensive study to provide an overview of the petrography and geochemistry of this meteorite. Based on these results, we add NWA 10850 to the Allende-like subgroup (CV3skiA), which typically contains approximately 40 vol % matrix material (with little phyllosilicate), 40–50 vol % intact chondrules, and ~ 0.2 vol % metallic FeNi.

**Petrography:** NWA 10850 consists of an ~20-30 % fine grained matrix and an assemblage of well-defined chondrules, large CAI’s (up to 2 mm), and amoeboidal olivine aggregates (AOA: Fig. 1). Chondrule types include barred-olivine and granular-olivine and/or pyroxene (Fig. 1). Most chondrules have been enriched in FeO along the rims and to some extent also along interior grain boundaries. The CAIs host zoned spinels and aluminous clinopyroxene. Spinel zonation is seen as Mg-rich cores with increasing Fe towards the margins in all examples. Melilite (gehlenite) is present in two CAIs, one is compact and spherical with a possible ‘wark-loving’ rim; the other is more altered. Many also contain small (<5 µm) perovskite grains, and a few contain hibonite. Many CAIs in this sample are highly altered, containing abundant nepheline, hedenbergite, calcite, and sodalite. Olivine and anorthite may also be present within some CAI. The AOA generally demonstrate considerable Fe-enrichment around each olivine grain. Fayalite content of the OA olivines span a similar range as the chondrules. The matrix is predominately fayalitic olivine (Fa38-48) and hedenbergite. There has been speculation that AOA form a bridge between CAIs and chondrules [2]. Other phases in the matrix include pentlandite, awaruite, barite, calcite, magnetite, anadrade, and chromite.

**Methods:** Major- and minor-element compositions were determined with a Cameca SX-100 electron microprobe at the University of Tennessee. The microprobe was calibrated for each session using both natural and synthetic standards.

**Results:** Olivine is zoned to varying degrees with compositions ranging from Fa0.35 up to Fa42 (Fig. 2). It is uncertain if olivines in this meteorite ascribe to the nebular model [3, 4] or have asteroidal origins [5, 6, 7]. Pyroxenes are represented by enstatite (Wo0.03En0.88 to Wo2.89En0.66), diopside (Wo0.35En0.66 to Wo0.49En0.48), and hedenbergite (Wo0.46 to Wo0.49), with rare pigeonite (Fig. 2). Al-rich diopsides (Wo<0.5) occur in Al-rich chondrules. These compositions overlap those of typical CV chondrites. Plagioclase ranges from An0.77 to An0.9 (Fig. 2). Glass may also be present.

The Fe/Mn values of olivine and pyroxene indicate redox conditions and volatility [8, 9, 10]. The Fe/Mn systematics from NWA 10850 are typical of CV chondrites, e.g., Vigarano and Allende [11, 12]. Differences in Fe/Mn values between different chondrite groups could be caused by factors such as variability in the abundances of metal, sulfide and/or silicate in chondrule precursor material, or by open system processes during chondrule formation [12].

Metal and sulfides within chondrules are small (<10 µm) and uncommon. Metals are predominately awaruite and sulfides are pentlandite (12-20 wt. % Ni and 0.6-1.1 wt. % Co). Troilite and kamacite also infrequently present. Minor chromite occurs in limited regions. Other metals observed include kamacite; native gold and silver; argentite; iodium; and carbon (as graphite?). We highlight the rare occurrence of awaruite (ideally Ni2Fe), which occurs in several highly oxidized chondritic meteorites [13]. Its occurrence has previously been explained either as formed from a melt or by the transformation of taenite at temperatures of <500 °C [14].

**Summary:** Based on its texture, petrography, mineralogy, and phase chemical composition, NWA 10850 is a typical example of a CV chondrite. The chondrules hosted within the meteorite likely formed by different mechanisms: 1) melting of solid precursors, including chondrules of earlier generations and refractory inclusions, and 2) melting, evaporation, and condensation of solids during large-scale collision between planetary-size bodies. Based on the textures and mineralogy, two populations of CAIs are identified: 1) very refractory, compact spherules composed of hibonite, grossite, Al-rich pyroxene, perovskite, gehlenitic melilite, and spinel, and 2) less refractory, igneous and non-igneous inclusions composed of melilite, Al-Ti diopside, anorthite, and olivine. There is no evidence to indicate that all the components of NWA 10850 formed in a single nebular reservoir as a result of a single stage process. Rather, the diversity of chondrules and CAIs makes possible that many components of NWA 10850 have their own individual histories.