COMPOSITIONAL VARIATIONS IN OPAQUE PHASES WITHIN THE CV AND CK CARBONACEOUS CHONDRITES. J. Davidson, D. S. Lauretta, and D. L. Schrader. University of Arizona, Lunar and Planetary Laboratory (LPL), Tucson, AZ 85721, USA (davidson@lpl.arizona.edu).

Introduction: The composition of many of the metal [1] and sulphides [2] within chondrites was likely established during chondrule melting and subsequent cooling. Abundances of opaque minerals (metals, sulphides, chromite, and magnetite) vary among the CV and CK chondrites and their subgroups [3-5]. Oxygen isotopic compositions of the CK and CV subgroups are similar, suggesting that they may originate from a single, heterogeneous parent asteroid [5]. By determining the compositions of opaque phases within chondrules and matrix of the CV and CK chondrites it may be possible to determine the extent and origin of these heterogeneities.

Analytical Procedure: Silicate and opaque mineral assemblages within thin sections of RBT 04133, MET 01017, NWA 4676, A-881595, and a polished slab of NWA 4476 were studied using EMPA, and elemental X-ray mapping techniques (Si, Mg, Ca, Fe, Na, Al, P, Ni, P, Mn/Ti, and Cr; 15kV, 40nA). Analyses of Na, Si, Mg, Al, P, K, Ca, Mn, Ti, Fe, Cr, Ni, Zn (silicates) and Na, Mg, Al, Si, O, S, Ca, P, Cr, Mn, Ti, Fe, Ni, Co, Cu, Zn (opaques) were performed on the Cameca SX-50 EMP at LPL using a 1 µm beam, 15 kV, and 20 nA.

Results: *Classification.* The analysed samples are classified as [3-8]: RBT 04133, MET 01017 = CV3 reduced ($CV3_{Red}$); NWA 4676 = CV3 oxidised Allende-type ($CV3_{OxA}$); NWA 4476 = CV3 oxidised Bali-type ($CV3_{OxB}$); A-881595 = CK3 oxidised Karoonda-type (or $CV3_{OxK}$ [5]).

Petrography. Opaque mineral assemblages were located in both chondrules (Fig. 1) and matrix.

Metal Composition. The Ni content (wt.%) of Fe,Ni metal in the $CV3_{Red}$ chondrites (RBT 04133 and MET 01017) is bimodally distributed (Fig. 2), with both Ni-poor (<10 wt.% Ni) and Ni-rich (>30 wt.% Ni) metal. This is consistent with data from [3]. The Ni distribution inversely correlates with Co and the Ni/Co ratio is not solar. In contrast, only Ni-rich metal (>65 wt.% Ni) was observed in the $CV3_{OxA}$ (NWA 4676). No Fe,Ni metal was observed in the $CV3_{OxB}$ (NWA 4476), which is consistent with reports of only trace amounts of metal in this subgroup [4].

P-content of metal varies between subgroups (Fig. 3). It is more abundant in the CK3 (>0.1 wt.%) than the $CV3_{OxA}$ (<0.1 wt.%). All analyses of P in metal from the $CV3_{Red}$ samples are below detection limit of 0.04 wt.% (bdl). The abundance of Cr in metal varies between subgroups, being most abundant in the CK3. Ni-rich metal in the $CV3_{OxA}$ is relatively depleted in Cr compared to the CK3, but is comparable to the $CV3_{Red}$ chondrites.

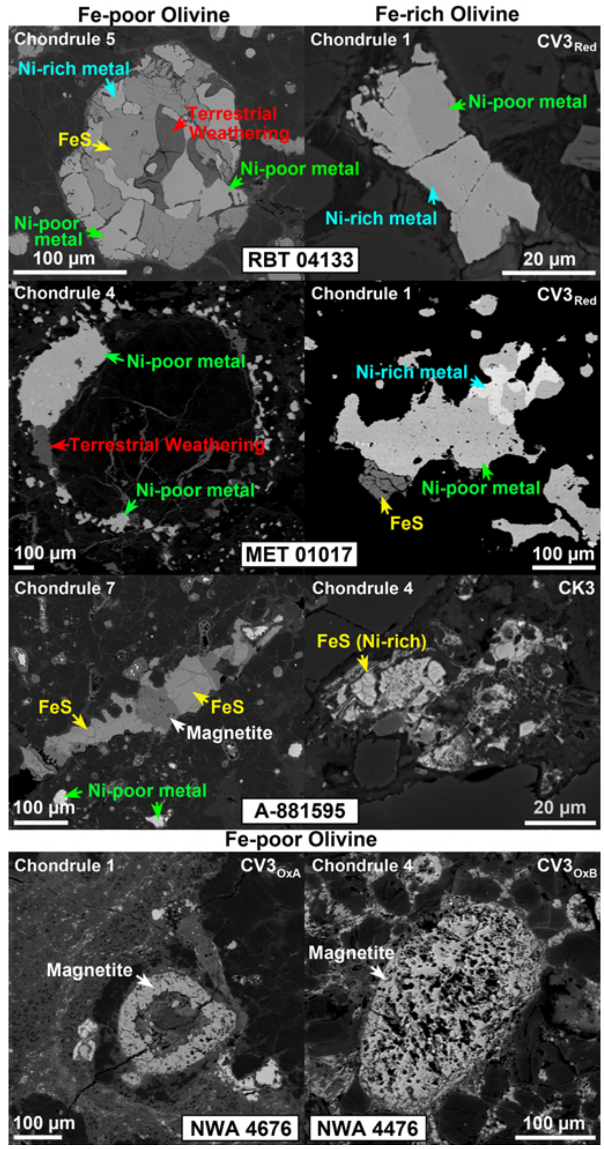

Fig. 1. BSE images of representative opaque assemblages in FeO-rich and FeO-poor chondrules from all CV3/CK3 chondrites studied. Only assemblages in FeO-poor chondrules are shown for the CV_{OxA} and $_{OxB}$; no assemblages in FeO-rich chondrules were seen.

Sulphide Composition. The Ni-content of sulphides varies between the CK and CV subgroups (Fig. 2). The $CV3_{Red}$ chondrites contain ≤4 wt.% Ni., whereas the $CV3_{OxA}$ and $CV3_{OxB}$ subgroups contain the more Ni-rich sulphide pentlandite (up to ~26 wt.% Ni), consistent with prior studies [3]. The majority of sulphide grains analysed in the CK3 contain Ni which is bdl (0.09 wt.%).

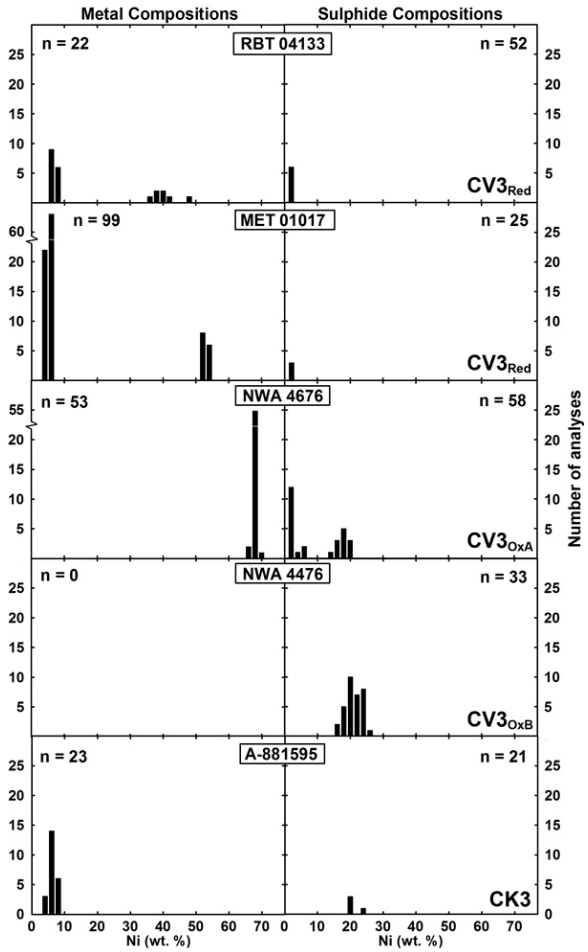

Fig. 2. Ni compositions (wt.%) of metal and sulphide phases in CV3 and CK3 chondrites analysed. No metal grains were found in the $CV3_{OxB}$. n = total number of analyses (not all opaque phases were Ni-bearing).

Discussion: The CV/CK chondrites have approximately bulk solar abundances of Fe, Ni, Co, P, and Cr [5]. Partitioning of elements is a function of chondrule cooling. Therefore, in order to understand the differences in opaque assemblages between the CK/CV subgroups it is necessary to fully characterise the distribution of elements in phases throughout each chondrite, i.e., within a chondrule, across chondrules of the same type, in FeO-rich vs. FeO-poor chondrules, and in chondrules vs. matrix.

Preliminary investigation suggests that variable Co-contents result from partitioning between metal and pentlandite (Fe-sulphide) which contains up to 2 wt.% Co in the CK3, and ~1 wt.% in the oxidised CV3s. Co is bdl (0.09 wt.%) in magnetite and pyrrhotite (Fe-sulphide), and is located exclusively within the metal of the $CV3_{Red}$ chondrites.

The paucity of P in the metal of the $CV3_{Red}$ compared to the $CK3/CV3_{Ox}$ may result from the presence/absence of phosphates or phosphides. Further study is required to test this hypothesis.

Variable Cr in metal is explained by the presence of chromites and Cr-bearing magnetites. The Cr-content of magnetite varies between the groups from 0.03-0.05 wt.% (~bdl) for the CK3, 0.16-2.69 wt.% for the $CV3_{OxB}$, to 0.97-3.87 for the $CV3_{OxA}$. As expected, the two $CV3_{Red}$ lack magnetite but contain chromites. No Cr-bearing sulphides were seen in any samples.

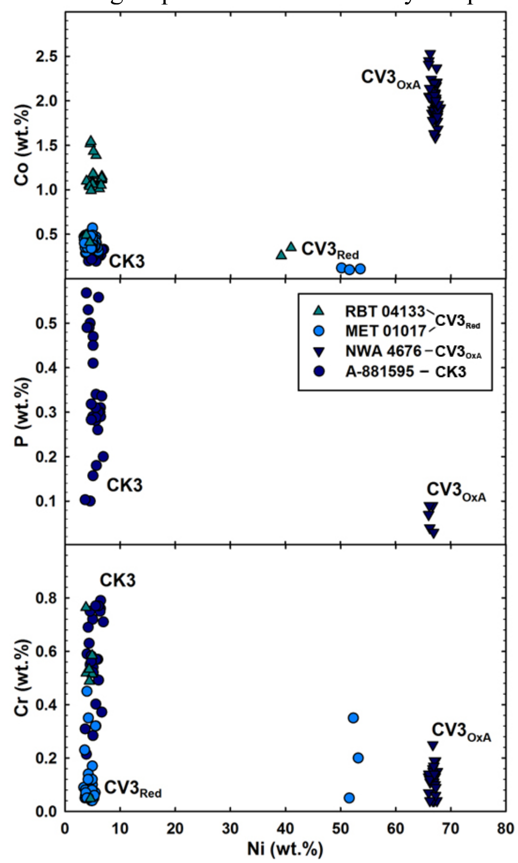

Fig. 3. Ni vs. Co, P, and Cr (all wt.%) for metal phases in CV3 and CK3 chondrites analysed. Bdl data not shown. P was bdl for all analyses within metal from $CV3_{Red}$ chondrites.

Conclusion: Clearly, the opaque populations in the CV/CK chondrites illustrate a large diversity. Systematic study of these assemblages will enable us to understand larger scale processes on the parent asteroid(s).

References: [1] Zanda B. et al. (1994) *Science* 265, 1846. [2] Lauretta, D. S. and Buseck, P. R. (2001) *MAPS* 36, A110. [3] McSween H. Y. (1977) *GCA* 41, 1777. [4] Weisberg M. K. et al. (1997) *MAPS* 32, A138. [5] Greenwood R. C. et al. (2010) *GCA* 74, 1684. [6] Davidson J. et al. (2009) *MAPS* 44, A57. [7] Busemann H. et al. (2007) *MAPS* 42, 1387. [8] Schrader D. L. et al. (2011) *GCA* 75, 308. The authors thank the JSC, MWG, and NIPR for samples and Ken Domanik for help with EMP analysis. This research was funded in part by NASA grant NNX10AI87G (DSL, PI).