LOSS OF CHROMIUM FROM OLIVINE DURING THE METAMORPHISM OF CHONDRITES. J. N. Grossman, U.S. Geological Survey, 954 National Center, Reston, VA 20192, USA, jgrossman@usgs.gov.

Introduction: Identifying chondrites that have experienced the least parent-body processing is an important goal of meteorite research. The current classification scheme for ordinary chondrites (OCs) assigns the most primitive meteorites to type 3.0, whereas those showing limited evidence of metamorphism are designated as type 3.1 or higher [1]. Distinguishing between type 3.0 and 3.1 OCs is challenging. The primary thermoluminescence (TL) parameters used by [1] do not resolve 3.0 from 3.1, as both types have very low TL sensitivity and similar TL vs. temperature profiles. Other methods that can be used to distinguish among these types include measuring the abundance of presolar grains [2], the distribution of minor elements in kamacite and associated phases [3], and cathodoluminenscence plus compositional properties of chondrule mesostases [4]. These methods are labor intensive and are not always possible on small or weathered meteorites, resulting in confusion over which meteorites are the most primitive (e.g., [5]).

The Cr_2O_3 content of olivine was shown in several previous studies to be different in type-3.0 Semarkona than in several higher petrologic type OCs [4, 6] (although Cr in chondrule olivine may be partly to mostly divalent [7], data are traditionally reported as Cr_2O_3). A systematic study of a wide variety of highly unequilibrated chondrites was done to investigate this phenomenon and to compare it with other metamorphic effects in the same meteorites.

Experimental: A suite of ~15 OCs listed as candidates for being type 3.0-3.1 (mostly by [5]), 4 type 3.3-3.6 OCs, 5 type 3.0-3.2 CO chondrites, and several other carbonaceous chondrites were analyzed. For the OCs, 50-75 chondrules were selected at random, and the core of one representative olivine in each chondrule was analyzed by electron microprobe. In the carbonaceous chondrites, 50 ferroan olivines were located by BSE imaging, in chondrules if possible, but also occurring as isolated grains. Again, no more than one grain was analyzed per chondrule.

Results: In all chondrites studied, olivine tends to be low in Cr in FeO-poor grains. In low-petrologic-type samples, Fe and Cr are roughly correlated in grains with FeO <2 wt% and Cr is generally low in abundance; Cr-rich grains, if present, mainly occur at higher FeO contents, i.e., in type II chondrules. Figure 1 shows histograms of Cr_2O_3 contents in 10 type 3.0-3.2 OCs plus Tieschitz as a representative of all higher types, all 5 CO3 chondrites analyzed, and Vigarano (CV3). The Cr_2O_3 distribution is clearly related to petrologic type in both OCs and CO chondrites. Type 3.0 tends to show a single peak centered around 0.5 wt% Cr_2O_3 in OCs and 0.3-0.4 wt% Cr_2O_3 in CO chondrites. For type 3.1-3.2 (e.g., GRO 95502) and higher, almost all Cr_2O_3 values are below 0.2 wt% in both types of chondrites. Type 3.1 chondrites tend to show a broad distribution, with grains ranging in composition between those found in types 3.0 and 3.2, although some 3.1's, like Krymka, no longer possess any indication of the type 3.0 peak.

X-ray maps for three OCs show that loss of Cr from olivine occurs in a complex way (Fig. 2). Primary igneous zoning profiles are found in type 3.0 olivines in Semarkona. MET 96503, a meteorite showing a complex distribution of Cr in olivine, has cores of optically clear grains with wormy Cr distributions suggestive of exsolution. Zones of olivine depleted in Cr occur just inside Cr-rich rims (probably chromite) around every grain. In higher petrologic-type chondrites, olivine grains are uniformly low in Cr and all grains have Cr-rich rims.

Discussion: The Cr content of olivine changes dramatically between petrologic types 3.0 and 3.2. Identical effects are observed in the two unrelated classes of chondrites that have well-described metamorphic sequences. Cr-rich ferroan olivine has been noted in other types of chondrites that have experienced little metamorphic heating, including CI, CM, and CR [8]. Apparently, the high-temperature, short-duration processes that produced type-II chondrules in the early solar system *invariably* gave rise to Cr-rich compositions that survived to the time of accretion, prior to metamorphism. Because Cr in olivine is easy to measure in most chondrites, is not susceptible to alteration during weathering, and shows dramatic differences in concentration among the lowest petrologic types, it is an excellent classification tool. Present data suggest: several OCs have a similar Cr distribution to Semarkona and are indeed type 3.0 (QUE 97008, MET 00526, and possibly a borderline case, EET 90161; other data indicate that Semarkona is the least metamorphosed of these); Krymka is better described as type 3.2; NWA 1756 is clearly type 3.1; highly weathered Colony is not quite as primitive as ALHA77307 and Y81020 because it contains a small population of low-Cr ferroan olivine; Vigarano is at least type 3.2.

The mechanism by which Cr is lost from olivine remains unclear, but is certainly more complex than the simple diffusive process envisioned by [9]. Future work will attempt to clarify this mechanism, and quantify the possible use of Cr in olivine to model the conditions and duration of chondrule formation and metamorphism.

References: [1] Sears et al. (1980) Nature 287, 791; [2] Huss (1990) Nature 347, 159; [3] Zanda et al. (1994) Science 265, 1846; [4] DeHart et al. (1992) GCA 56, 3791; [5] Benoit et al. (2002) MAPS 37, 793; [6] McCoy et al. (1991) GCA 55, 601; [7] Sutton et al. (1996) LPS 27, 1291; [8] Brearley and Jones (1998) Chapter 3 in *Planetary Materials* (Papike, Ed.); [9] Jones and Lofgren (1993) Meteoritics 28, 213.

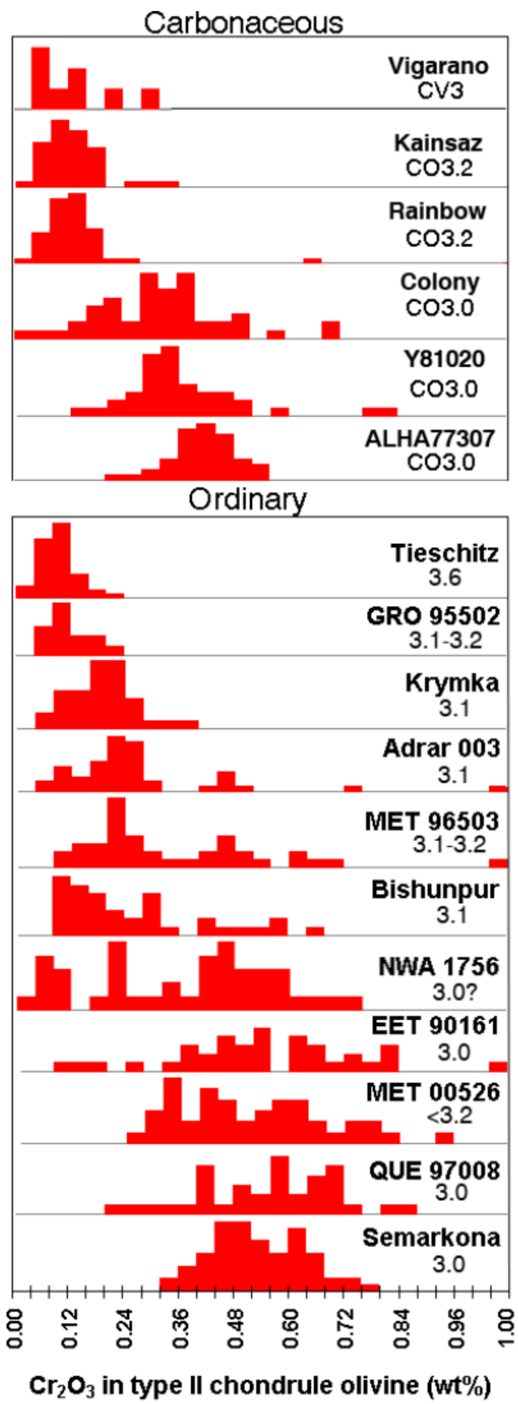

Figure 1. Distribution of Cr in olivine from type II chondrules and isolated grains in ordinary and CO chondrites. All histograms include 35-60 points except for Vigarano, which has only 8.

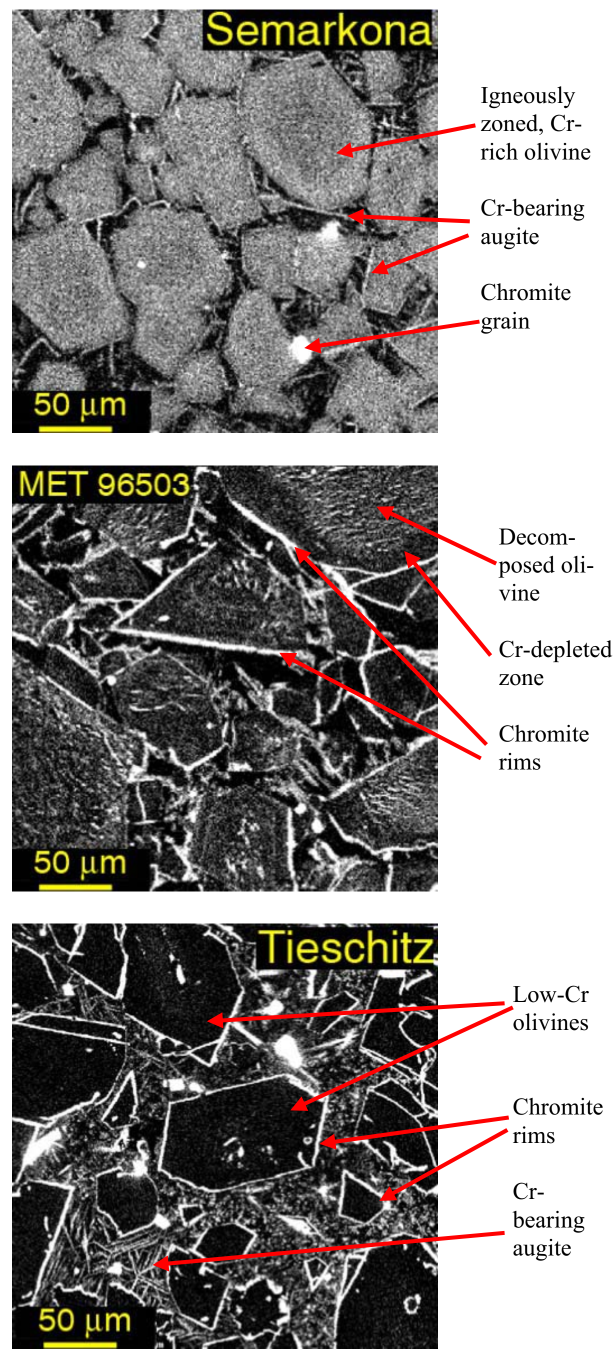

Figure 2. Cr Kα x-ray maps of type II chondrules in ordinary chondrites illustrating the loss of Cr from olivine during metamorphism.