Identification of primitive unequilibrated ordinary chondrites from four Antarctic dense collections areas (EET, GRO, LEW, and MET).

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Introduction: Unequilibrated ordinary chondrites (UOC) typically contain metal [1], primitive chondrules [2], pre-solar grains [3], organics [4], nebular materials in matrix [5], and isotopic records of early solar system processes [6], and are thus scientifically valuable samples that provide important information about the early solar system. UOCs from dense collection areas (DCA) like in the Transantarctic Mtns. pose several specific challenges. First, they are commonly part of large pairing groups for which preliminary studies are followed up by detailed studies that reveal differences among the pairs (e.g., [7,8]). Second, subsequent visits to the DCA identify and recover new members of the pairing group. Thus over time, the pairing groups must be re-assessed as new information becomes available for existing and new members of the larger pairing groups. Given the suggestion that many samples in these groups could be more primitive than L3.4 (e.g., [7]), we have undertaken a survey of 103 chondrites. Here we report olivine analyses from Type II (FeO-rich) chondrules with a goal of identifying primitive (<L3.20) UOCs using the Cr in olivine approach [9]. In the process of the detailed work, we identified 22 samples of petrologic grade 3.2 or lower that were previously unrecognized. Pairing relations of L3.x chondrites in these 3 areas are accordingly re-assessed.

Techniques: Type II chondrules were identified by optical and scanning electron microscopy (SEM) in thin sections from the JSC thin section library. Chemical analyses of the olivines from these chondrules were then made by wavelength dispersive X-ray spectroscopy using a Cameca SX100 electron microprobe at NASA-JSC, with an accelerating voltage of 15 kV and a beam current of 20 nA. The standards used for silicate and oxide analyses were chromite (Cr), rutile (Ti), rhodonite (Mn), oligoclase (Na, Al), Marjalahti pallasite olivine (Mg), fayalite (Fe), diopside (Ca), and natural glass K411 (Si, Al). Typically 30 to 50 random points on FeO-rich chondrules in one thin section were analyzed and a mean and 1 sigma calculated for each sample.

Results: *Elephant Moraine Icefield (EET):* Twenty-one L3 chondrites were recovered from Elephant Moraine in the 1982, 1983, 1987, 1990, 1992, and 1996 field seasons, and some have subsequently been re-classified to more primitive types [7,8]. Our work has revealed that there are 12 members of this group that are 3.00-3.15. *Lewis Cliffs Ice Tongue (LEW):* L3 chondrites from the Lewis Cliffs area include a total of 57 meteorites from the 1985, 1986, 1987, 1988, 1992, and 1997 seasons, with many individual members of pairing groups subsequently identified as primitive [7,9,10]. We have confirmed the primitive nature of LEW 86134, while also identifying LEW 97202 and LEW 87208 as L3.00 to 3.05, and several additional samples <3.20. *Grosvenor Mountains (GRO):* Fifteen L3 meteorites have been recovered in the Grosvenor Mountains area, with several of these identified as primitive based on natural thermoluminesence, Raman spectroscopy, olivine compositions [7,8,9]. Our new results are surprising and reveal a range of petrologic types, including four primitive UOCs (GRO 95558, GRO 06054, GRO 03015 and GRO 03061). *Meteorite Hills (MET):* Many low-grade ordinary chondrites were recovered in the 1996, 2000, and 2001 seasons, and initially classified as L3.4 to L3.6, but subsequent studies revealed the presence of primitive chondrites in this area [7,8,9], and the possibility of multiple pairing groups for the MET region. Our results confirm the primitive nature of MET 00452 and 00526, and suggest that MET 00621 be included with this pairing and L/LL3.05. The L3 chondrites MET 96503, 96515, 01051, 01056, and 01057 all have lower Cr_2O_3 contents in the olivine and appear to be L3.10 to 3.15. The H3 chondrites MET 00506, 00552, and 00607 have similar and low Cr_2O_3 contents in the olivine and appear to be H3.10. And finally, MET 01182, 00570, and 00489 all have very low Cr_2O_3 contents (< 0.09 wt. %) and are consistent with their current classifications of 3.6 or higher grade.

Potential pairing groups in EET, GRO, LEW and MET L chondrites: Our results confirm the primitive nature of EET 90161 and are consistent with its classification of L3.00, along with EET 90066, 90261, and 90909 (Table 1). On the other hand, EET 87735, 90080, 90519, and 90916 are all L3.05 chondrites, and EET 90628 is a lone L3.10 meteorite. LEW 86134 and LEW 87208, both identified here as L3.00, are likely too far apart – nearly 25 km – to be paired together, and thus are most likely two isolated finds. We have identified six L3.15's that are mostly on the northernmost ice tongue of LEW, but are more likely

part of two groups since they are ~ 25 km apart. Our analyses also reveal eight L3.2's from LEW that have olivine Cr contents between 0.1 and 0.15. Even though GRO 06054 and GRO 95558 are both L3.05, they are likely to be unpaired individual finds given the large distance between their recovery locations (~22 km). However, the masses of the samples, 1318 g for GRO 06054 and 202 g for GRO 95558, are substantial enough that it is difficult to completely rule out pairing. A close comparative analysis and terrestrial age dating of these samples would be appropriate and may increase the level of confidence in this pairing issue. GRO 03015 and 03061, on the other hand, were recovered 0.88 kilometers apart and could thus present an L3.10 pairing from a shower, while ten others from GRO appear to be of petrologic grade 3.2. MET 00452 and 00526 were previously classified as L/LL3.05, and our work indicates that MET 00621 may be paired together as well. There are five MET L3.10 specimens from the 1996 and 2001 field seasons, and three H3.10 from the 2000 field season.

Summary*:* Although the primary goal of this work was to identify primitive chondrites that may have been unrecognized in previous work, we have included a large number of samples from regions where pairing has not been re-assessed in decades and samples have been recovered over multiple and successive collection seasons. We have identified additional primitive members, and where possible updated or re-assessed pairing. Specifically, we have identified 23 additional primitive (3.10 or lower) ordinary chondrites that will be of interest to many meteoriticists who study nebular processes. However, because the measurement of Cr in olivine is not especially sensitive to identification of petrologic grade >3.2, we have not been able to fully update samples and pairings from every area. Detailed pairing assessments would benefit from cosmic ray exposure age dating; such studies would undoubtedly shed light on these groupings and thus be of some value in future work.

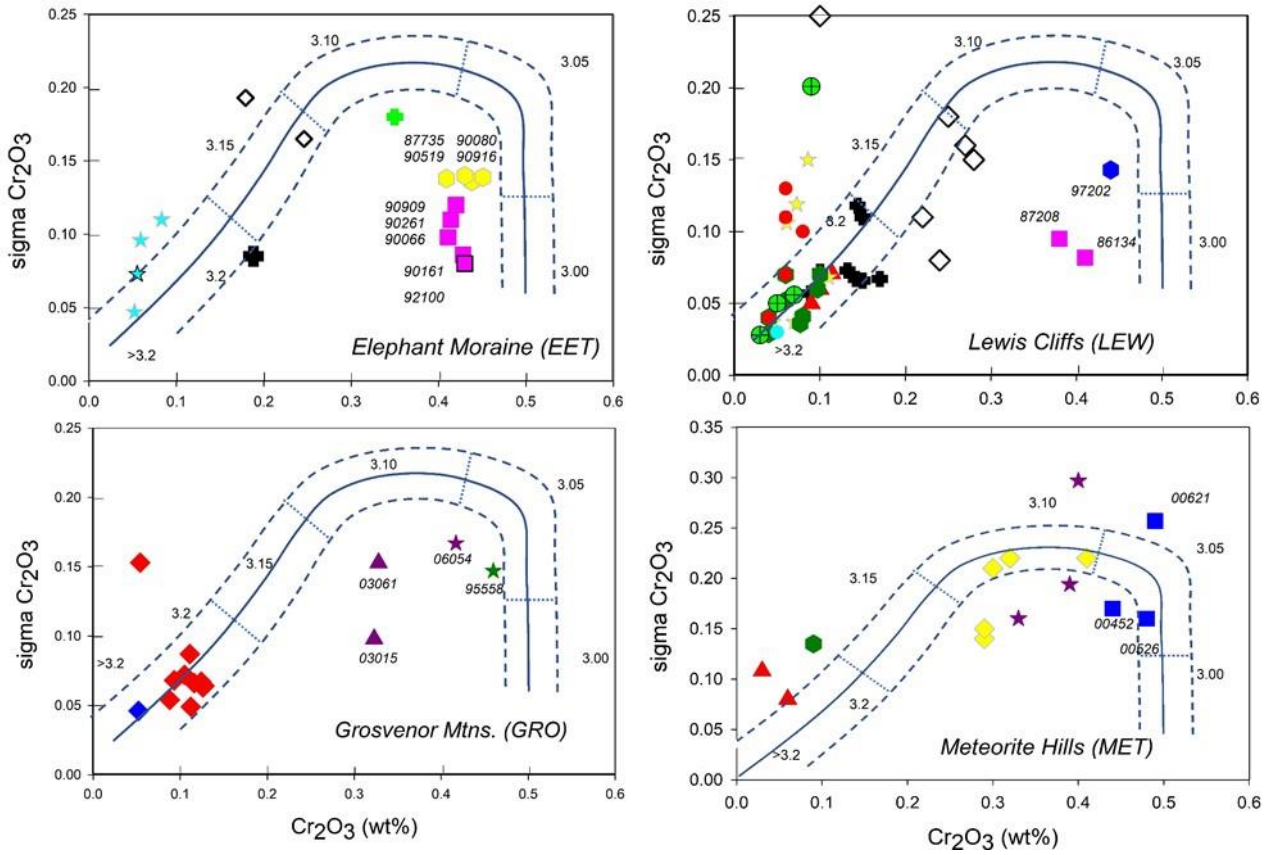

Figure 1. Summary of Cr_2O_3 analyses for olivines in Type II chondrules in unequilibrated ordinary chondrites from the four dense collection areas considered in this work: EET, LEW, MET and GRO. Petrologic grade boundary curves and labels are from Grossman and Brearley (2005)..

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