USING MAGNETITE COMPOSITIONS TO EXAMINE A POSSIBLE GENETIC RELATIONSHIP BETWEEN THE CV AND CK CHONDRITES.

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Introduction: Traditionally, CK and CV chondrites have been viewed as two distinct groups representing different parent bodies, each with their own history of alteration [1, 2]. However, similarities between the CV and CK groups are numerous, ranging from mineral composition and bulk rock composition to oxygen isotopes [3]. In light of these similarities, [3] has proposed that the CK and CV groups are not derived from two distinct parent bodies, but from a single thermally-stratified asteroid (as suggested for the ordinary chondrites) [4]. If this is the case, then the CV and CK chondrites should represent a continuous metamorphic sequence from CV_{ox} to unequilibrated CK chondrites to equilibrated CK chondrites.

MgO and Cr_2O_3 content in magnetite have typically been used to distinguish between CV and CK chondrites [5]. [3] observed that magnetite compositions in unequilibrated (type 3) CK chondrites overlap the CV and CK magnetite fields, which they interpreted as evidence of a single parent body. TiO_2 in magnetite can also be used to distinguish between the CV and CK chondrites [3], as TiO_2 in magnetite is higher in CK chondrites. [6] attributed the higher TiO_2 content in CK chondrites to metamorphic heating of a CV-like precursor under oxidizing conditions [6]. If the CV and CK chondrites represent a continuous metamorphic sequence, then TiO_2 content should increase from the CV_{ox} to the CK3 to the CK4-6 chondrites.

Here we examine previously collected magnetite data in CV [5, 7, 8, 9, 10] and CK chondrites [6], along with magnetite in several additional CK chondrites of various petrologic types [11] (Table 1), to determine if Cr_2O_3 and TiO_2 content are indicative of a genetic relationship between the CV and CK chondrites.

Table 1. CK chondrites analyzed in this study

Sample	Abbreviation	Petrologic Type	WI*
Dar al Gani 431	DaG 431	CK3-an	6
Allan Hills 85002	ALH 85002	CK4	1
Elephant Moraine 87526	EET 87526	CK5	nm
Elephant Moraine 87860	EET 87860	CK5/6	1
Lewis Cliff 87009	LEW 87009	CK6	1

*from [12]

Methods: In order to determine if magnetite compositions are indicative of a parent-body relationship between the CV and CK chondrites [3], the data used to create Figure 5 (Cr_2O_3 vs. MgO) from [3] was re-plotted. We then analyzed magnetite in five additional CK chondrites of various metamorphic grade (type 3 to type 5/6), including an additional CK3-an chondrite, DaG 431 (Table 1). Thin sections of the chondrites were loaned from the Smithsonian Institution and the Natural History Museum London.

Though the equilibrated CK chondrites selected for analysis have experienced little terrestrial weathering [12], it is difficult to find unweathered CK3 chondrites due to their limited numbers. As a result, CK-an chondrite Dar al Gani 431 has been significantly weathered (wi-6) [12]. However, weathering of CK chondrites does not affect Cr_2O_3 or MgO abundances [12], so our analyses should not be adversely affected by terrestrial weathering.

Magnetite compositions were determined using a JEOL JXA 8200 electron microprobe at Washington University in St. Louis, MO. Synthetic and natural standards were used. Standard operating conditions during analyses included 15 kv potential, 25 nA beam current, and 5μm beam size. At least 8 magnetite grains were analyzed per sample.

Results: Magnetite compositions of the CK chondrites analyzed in this study are plotted in terms of weight percent Cr_2O_3 and MgO on Fig. 1. Boxes represent the range of magnetite compositions in CV chondrites (left) and CK chondrites (right), as determined by [3]. Magnetite from the equilibrated CK chondrites analyzed in this study plots within the range defined by [3], while magnetite from CK3-an chondrite DaG 431 overlaps the CV and equilibrated CK fields. This is consistent with magnetite analyses from CK3-an chondrite Watson 002 [3].

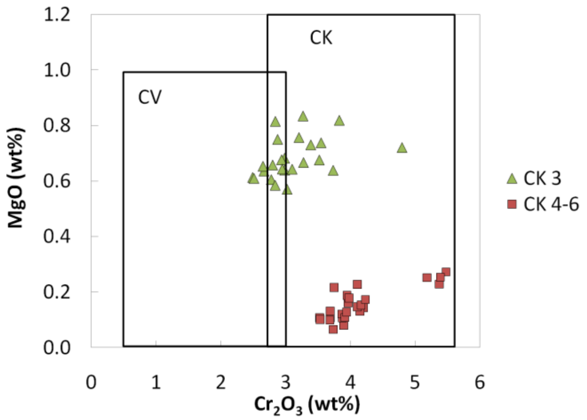

Fig. 1. MgO and Cr_2O_3 (wt%) of magnetite in five CK chondrites analyzed in this study. Boxes represent the range of magnetite compositions for the CV (left) and the CK (right) chondrites as determined by [3].

Magnetite compositions of our CK chondrites, along with CV chondrites Yamato-86751 [8] and Allende [7], are plotted in terms of weight percent TiO_2 and MgO on Fig. 2. The CK3 and CK4-6 chondrites form two distinct clusters. Though magnetite compositions in the CV chondrites occur over a limited range of TiO_2 and MgO, they are more scattered than the CK chondrites (Fig. 2). Magnetite in the CK4-6 chondrites has lower TiO_2 than the CK3 chondrites, with the exception of magnetite from [13]. It is not clear why magnetite from [13] plots outside the main CK4-6 cluster, and further analysis is required to understand the discrepancy.

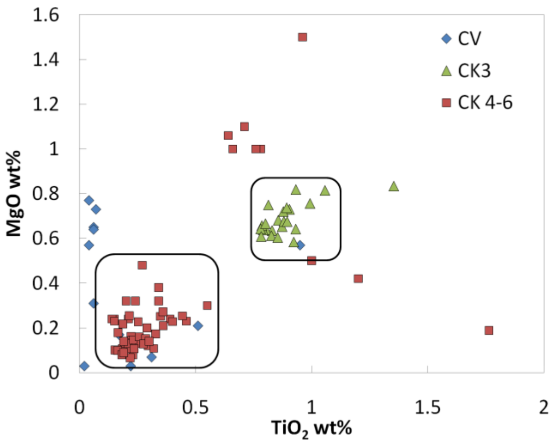

Fig. 2. TiO_2 and MgO (wt%) of magnetite from our CK chondrites plotted along with previously collected magnetite in CK4-6 [13] and oxidized CV chondrites [7, 8]. Boxes represent clusters of analyses.

Discussion: Though our magnetite compositions (as Cr_2O_3 vs. MgO) are consistent with those from [3], we suggest that there is an alternative interpretation of the Cr_2O_3 vs. MgO plot. In Fig. 3, oxidized CV chondrite data [5, 7, 8, 9, 10] and CK data [6, 11] used to create the original Cr_2O_3 vs. MgO figure [3] is plotted along with data from this study. With the exception of a few high-MgO analyses from [13], magnetite compositions in the CK chondrites form two distinct clusters, one for the CK3 chondrites and one for the CK4-6 chondrites. Magnetite compositions in the CV chondrites [5, 7, 8, 9, 10] contain less Cr_2O_3 and are more heterogeneous than magnetite in the CK chondrites. Despite the heterogeneity, most CV chondrite magnetite compositions plot outside of the CK3 and CK4-6 chondrite clusters. There are clearly three distinct magnetite clusters in Fig. 3, and we suggest that does not support a single parent body for the CV and CK chondrites.

TiO_2 content also does not appear to support the suggestion that the CV and CK chondrites represent a single parent body. [6] suggested that distinctly higher TiO_2 content of the magnetite in CK chondrites, relative to magnetite in the CV chondrites, was the result of metamorphism of a CV like precursor under oxidizing conditions. If the CV and CK chondrites represent a single thermally-stratified parent body, they should form a metamorphic sequence from CV_{ox} to CK3 to CK 4-6. As Fig. 2 shows, TiO_2 content in the CK3 chondrites is higher than that of the CV_{ox} chondrites. However, TiO_2 content decreases from the CK3 to the CK4-6 chondrites. The metamorphic sequence of the CK chondrites is well-defined, so it is not possible that TiO_2 increases during metamorphism, as suggested by [6]. Instead, Fig. 2. demonstrates that TiO_2 in magnetite decreases during progressive metamorphism. Because TiO_2 content of magnetite in CV_{ox} chondrites is lower than the CK3 chondrites, TiO_2 content does not support a continuous metamorphic sequence from the CV to the CK chondrites.

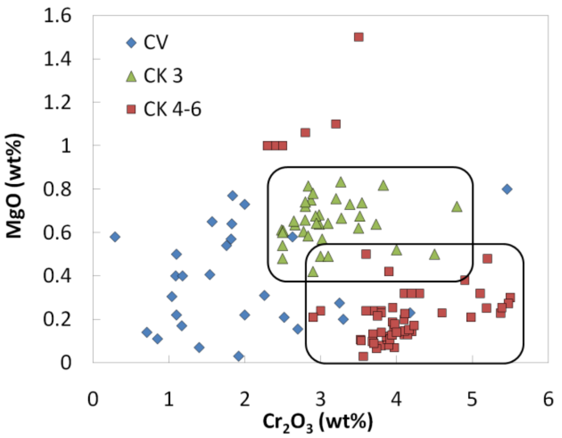

Fig. 3. Magnetite compositions from our study plotted along with the original CV [5, 9, 10, 12, 13] and CK magnetite analyses [6, 11] used to create the plot in [3]. Boxes indicate range of compositions for CK3 and CK4-6 chondrites.

Our examination of magnetite compositions in CK and CV chondrites suggests that the CV and CK chondrites cannot represent a single, thermally-stratified parent body. However, further analysis of the CK chondrites (especially the CK3s) is required before any possible relationship between the groups can be confirmed or denied.

References: [1] Kallemeyn G.W. et al. (1991) *GCA, 55*, 881-892 [2] Guimon R. et al. (1995), *Meteoritics*, *30*, 704-714. [3] Greenwood R.C. et al. (2010), *GCA*, *74*, 1684-1705. [4] Wood J.A. (2003) *Nature*, *422*, 479-481. [5] Ivanova et al. (2003), *LPSC XXIIII*, abstract #1226. [6] Geiger T. & Bischoff A. (1995), *Planet. Space Sci.*, *43*, 485-498. [7] Haggerty S.E. & McMahon B.M. (1979), *Proc. Lunar Plan. Sci. Conf.*, *10*, 851-870. [8] Murakami T. & Ikeda Y. (1994), *Meteoritics*, *29*, 397-409. [9] Rubin A.E. (1991), *GCA*, *48*, 1779-1789. [10] Simon S.B. et al. (1995), *Meteoritics*, *30*, 42-47. [11] Van Schmus W.R. and Wood J.A. (1967) *GCA*, *31*, 747-765. [12] Rubin A.E. & Huber H. (2005), *MAPS*, *40*, 1123-1130. [13] Rubin A.E. (1993), *Meteoritics*, *28*, 130-135.