Mineralogy and Mn-Cr Extinct Radionuclide Dating of a Dolomite from the Pristine Tagish Lake Meteorite.
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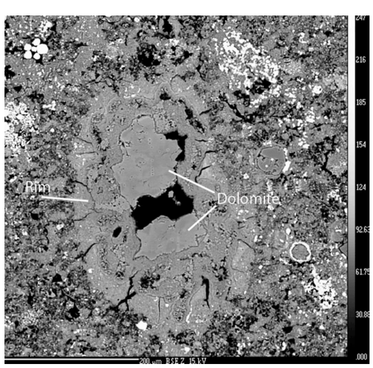
Introduction: Tagish Lake has been identified as an ungrouped Type 2 carbonaceous chondrite (CC) with affinities to CIs and CMs [1,2]. Four pristine specimens (5b, 11h, 11i, 11v) identified by [3] encompassing various degrees of alteration have been mineralogically described in previous works [3-5]. In summary, specimen 11h is an intermediate lithology between the less altered 5b specimen, containing abundant chondrule-like objects, and the more altered 11i and 11v specimens. We identified a large (~100 x 200 μm) dolomite grain in specimen 11h. Its size and composition allowed us for the first time the opportunity to use the ^{53}Mn-^{53}Cr chronometer ($t_{1/2}$ = 3.7 Ma) to investigate the time scales of carbonate formation on the Tagish Lake meteorite parent body.

Methodology: Mineral analysis of the carbonate was carried out with a JOEL8900 EPMA at the University of Alberta. The Mn-Cr measurements used a 10x10 μm rastered O^- beam using Carnegie's NanoSIMS 50L in multicollector mode. Each analysis took ~1 hr. As a standard for determining the relative Mn-Cr sensitivity factor, we used a Mn- and Cr-doped synthetic diopside. The ^{53}Cr/^{52}Cr isotopic ratios of the diopside and three matrix areas adjacent to the dolomite grain were also determined – the total variation was ~6 ‰.

Mineralogy: Specimen 11h has large quantities of chondrule-like objects similar to 5b (~ 20 vol%), but they are smaller in size and more altered than in specimen 5b [3,4]. The abundance of irregular lithic fragments (up to 10 vol %) is similar to that in specimen 11i [3,4]. Fine-grained magnetites are found both as isolated grains and in clusters (15 vol%). Fine-grained, porous to compact matrix that is rich in ribbon-like phyllosilicates [5] is similar in abundance to 11i (up to 40 vol%) [3].



On the TEM-scale, sulfides are relatively abundant in the matrix [5]. Also, Ca-rich phosphate has been identified in this specimen. Most of the carbonates are fine-grained with abundance up to 11 vol % [5].

Mineralogy of 11h dolomite grain. The carbonate grain is approx. 100 by 200 μm and set in a phyllosilicate-rich matrix. It is surrounded by an irregular, fine grained rim of 30 to 100 μm in thickness. The composition of the rim is dominated by Mg and Si with small random pockets of concentrated Mn and Ca, possibly phyllosilicates with sparse carbonates.

The average composition (Table 1) of this grain is dominated by Mg and Ca, but with up to 2 wt % of Mn. The chemical formula of the grain, based on 3 oxygens, is $(Mg_{1.3}Ca_{1.3}Fe_{0.3}Mn_{0.07})CO_3$.

	Average (wt %)	St. Dev.
MgO	19.5	1.3
CaO	26.8	1.2
MnO	1.8	0.8
FeO	7.8	0.8
CO_2 *	44.0	1.9

* calculated by difference

Table 1. Average chemical composition of 23 analyses of the dolomite grain from Tagish Lake specimen 11h.

The composition of each analysis (in mol %) is plotted on a ternary Ca-Mg-(Fe+Mn) diagram in Fig. 1, along with the approximate fields of CI and CM dolomites [6,7]. The composition of the 11h dolomite grain falls in the Ivuna field and slightly overlaps the fields of other CI and CM dolomites.

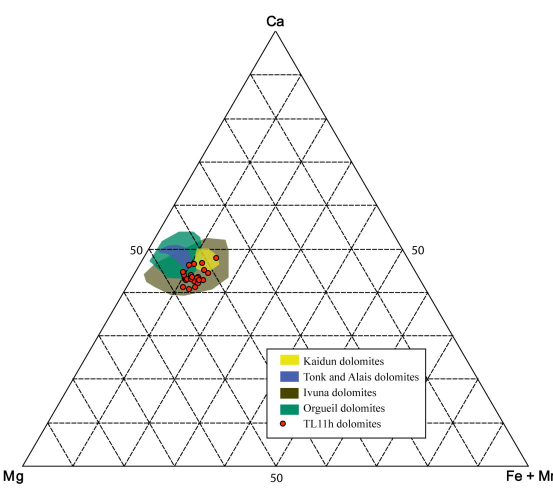


Figure 1. Ternary diagram showing the dolomite composition from Tagish Lake specimen 11h, along with dolomites from CI [6] and CM [7] chondrites.

Mn-Cr results: We measured five points on the dolomite and all exhibited enrichments in ^{53}Cr, with ^{53}Cr/^{52}Cr ratios ranging from 0.154 ± 0.004 to 0.178 ± 0.007. The large uncertainties in these ratios reflect the low and variable Cr contents of this dolomite (Cr_2O_3 = 0.004 ± 0.004 wt%). The excesses in ^{53}Cr are linearly correlated with the respective ^{55}Mn/^{52}Cr ratios (Fig. 2), indicative of the *in-situ* decay of ^{53}Mn and demonstrating that short-lived ^{53}Mn was present at the time of formation of this dolomite. This is the first reported presence of the ^{53}Mn daughter product in the Tagish Lake meteorite. On the ^{53}Mn – ^{53}Cr evolution diagram (Fig. 2) the regression through five dolomite and three matrix points gives the correlation line with the corresponding ^{53}Mn/^{55}Mn slope of 3.13 x 10^{-6} calculated using Isoplot.

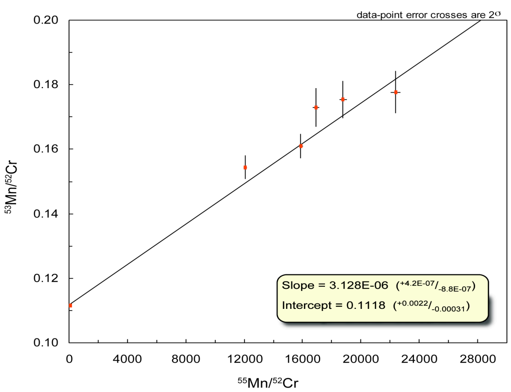


Figure 2. ^{53}Mn - ^{53}Cr evolution diagram for dolomite from the Tagish Lake specimen 11h.

Discussion and Conclusion: We calculate the absolute formation age of the 11h dolomite to be 4562.8± 0.94 Ma using the angrite LEW86010 as a time anchor. The absolute age of the 11h dolomite falls within the middle of the range of ages of Orgueil carbonates (Fig. 3) [8]. Carbonates from other CM1, CM2 and Kaidun [7,9,10] are >1 Ma older than the 11h dolomite, except for Y791198, which is similar within the error to the age of the oldest CAIs [11]

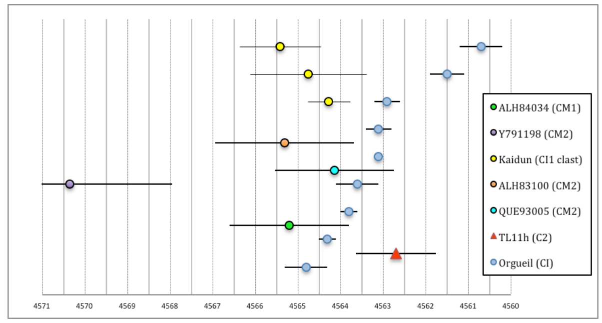


Figure 3. Absolute ages of carbonates in CI, CM1, CM2, Kaidun and Tagish Lake 11h (TL11h) based on Mn-Cr extinct radionuclide dating.

Assuming the solar system initial ^{53}Mn/^{55}Mn of ~3 x10^{-5} [12], the difference corresponds to a time interval of ~12 Ma between the formation of CAIs and the formation of the 11h dolomite. Such an extended time interval shows that this dolomite most likely grew on an asteroidal parent body during aqueous alteration in a similar setting and timescale to the CI parent body.

Several questions remain. Do carbonates from the other pristine Tagish Lake specimens (e.g., 5b, 11v, 11i) have a comparable initial ^{53}Mn/^{55}Mn ratio? How does this dolomite relate to the carbonates from the carbonate-rich lithology described by [2]? And what does it tell us about the duration of the aqueous alteration on the Tagish Lake parent body?

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References: [1] Brown P.G. et al. (2002) *Meteoritics and Planetary Science*, 37(5), 661-675. [2] Zolensky et al. (2002) *Meteoritics and Planetary Science*, 37(5), 737-761. [3] Blinova et al. (2009) *LPSC 40th*, Abstract #2039. [4] Blinova et al. (2010) *LPSC 41st*, Abstract #2140. [5] Blinova et al. (2011) *LPSC 42nd*, Abstract #2517. [6] Endress and Bichoff (1996) *Geochimica Cosmochimica Acta*, 60(3), 489-507. [7] Petitat et al. (2011) *Meteoritics and Planetary Science*, 46(2), 275-283. [8] Hoppe et al. (2007) *Meteoritics and Planetary Science*, 42(7/8), 1309-1320. [9] Brearley and Hutcheon (2000) *LPSC 31st*, Abstract #1407. [10] deLeuw et al. (2009) *Geochimica et Cosmochimica Acta*, 73, 7433-7442. [11] Bouvier and Wadhwa (2010) *Nature*, 3, 637-641. [12] Birck and Allegre (1985) *Geophysical Research Letters*, 12(11), 745-748.