THE METAMORPHIC HISTORY OF TWO MAJOR NEW FINDS OF ANTARCTIC CO CHONDRITES (DOM 08004 AND MIL 07531) DETERMINED FROM THERMOLUMINESCENCE DATA. Derek W. G. Sears, Space Science and Astrobiology Division, NASA Ames Research Center, MS245-3, Moffett Field, Mountain View, CA 94035. (Derek.Sears@NASA.gov).

Introduction: Large numbers of low metamorphic grade CO chondrites are currently being recovered in Antarctica at the Dominion Range and the Miller Range. At the time of writing, there are five meteorites in the DOM 08004 pairing group and 29 meteorites in the MIL 07531 pairing group [1].

Like the UOCs and the CV chondrites, the CO chondrites display a very wide range of metamorphic alteration, from the little- or unmetamorphosed Colony to the relatively heavily metamorphosed ALH82101. Many mineralogical and petrographic changes result from the metamorphism [2]. Minerals and phases homogenize, amorphous phases crystalize, phase transformations occur, fine grains coarsen, volatile elements are lost, many elements are mobilized. The formation of feldspar by the crystallization of feldspathic glass has long been recognized as an important result of metamorphism. Induced thermoluminescence measurements can detect the formation of even trace amounts of feldspar dispersed in an amorphous medium and the technique has a unique sensitivity and dynamic range. It is therefore an especially effective means of quantifying metamorphism in chondrites [3], including CO chondrites [4].

Method: Two 50 mg chips were obtained for each meteorite, ensuring different lithologies were sampled if present. These were crushed, magnetic material removed with a hand magnet, gently ground again until the powder flowed without clumping (~200 µm grains). Four milligram aliquots were placed in 5 mm Cu pans for TL. The natural and induced TL were measured in an adapted Daybreak TL system using the procedures frequently described in the literature [e.g. 3]. A 200 mCi ^{90}Sr beta source was used for irradiations. At this point I have examined the induced TL properties of all the DOM group and 20 of the MIL group.

Results: Representative TL glow curves for the two pairing groups are shown in Figs 1 and 2. The natural TL of the DOM 08004 group is present in the glow curve only at temperatures in excess of 350°C while the natural TL for the MIL 07531 group is much stronger, appears at ~200°C in the glow curve and above (in which it resembles most ordinary chondrites), has structure (i.e. evidence for multiple resolvable peaks) and is relatively intense.

"Natural TL" values can be obtained by determining the ratio of low-temperature TL (240°C) to high-temperature TL (400°C) and then using an empirical calibration used for the natural TL Antarctic Survey (ref 5). These meteorites yield natural TL values of <1 krad for the DOM 08004 pairing group and 19.1±7.6 krad for the MIL 07531 pairing group.

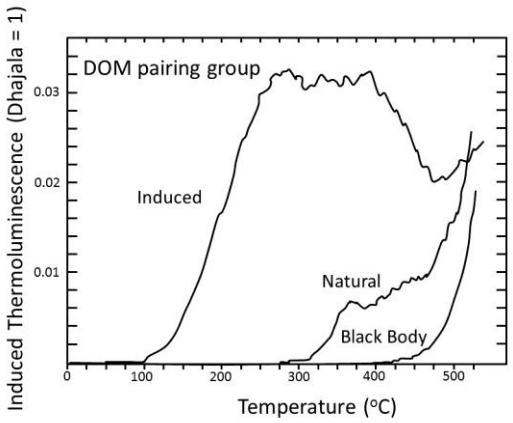

Fig. 1. Representative induced and natural TL glow curves for DOM pairing group and the black body (background) curve.

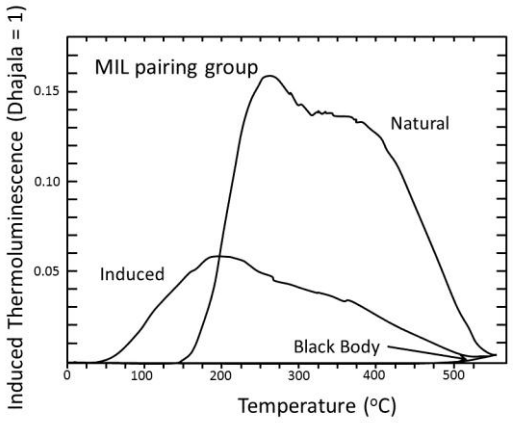

Fig. 2. Representative induced and natural TL glow curves for MIL pairing group and the black body (background) curve.

Induced TL glow curves show three readily resolvable peaks, usually evident as discrete peaks but sometimes as inflections. The data are summarized in Table 1. In both the DOM 08004 and MIL 07531 pairing groups the three peaks appear at approximately 120°C, 210 °C, and 320 °C with TL sensitivities of approximately 0.04, 0.15, and 0.15 (where Dhajala =1).

*Table 1. Induced TL data for two recently recovered CO chondrite pairing groups**

	Peak 1	Peak 2	Peak 3
DOM 08004 group			
Peak T	111±7	203±13	322±14
TL sens	0.031±0.004	0.12±0.02	0.22±0.03
MIL 07531 group			
Peak T	133±9	213±10	310±17
TL sens	0.056±0.008	0.16±0.02	0.10±0.01

**Peak T = peak temperature (°C). TL sens = TL sensitivity (Dhajala = 1). Uncertainties are the mean 1 σ on three replicates for all samples.*

Discussion: Assuming a normal perihelion (~1.0 AU), the MIL group have a terrestrial age of ~100 ka using the calibration curves of ref [6]. The natural TL of the DOM group is too low to be explained by a large terrestrial age and normal orbit suggesting that the meteorite has recently experienced some heating event, most likely close solar passage as a result of a small perihelion. Assuming a perihelion of ~0.8 AU, the terrestrial age would be ~100 ka. Atmospheric heating, which might be a factor if the samples were accidentally taken too close to the fusion crust, is precluded by the agreement between the five paired meteorites in this group.

The existence of three induced TL peaks, at the temperatures observed here, is common to most CO chondrites [4]. These peaks have been attributed to plagioclase in the low-temperature form (120°C), plagioclase in the high-temperature form (210°C), and refractory phases associated with CAI, for example gehlenite (320°C) [7]. There is about 20°C variation in these peak temperatures depending on peak intensity (for a given set of physical parameters, peaks move to higher temperatures as intensity decreases) and peak overlap. For the least metamorphosed (type 3.0-3.1 with red cathdoluminescence due to forsterite) these peaks are less readily resolved due to interference from other phases and the glow curves take on a hummocky appearance (Fig. 3). With increasing metamorphism more feldspar is produced, but for CO and CV chondrites it is in the low-temperature form suggesting that, unlike UOC, even the most metamorphosed members of these class have not seen temperatures greater than ~500°C. Thus the revision to the petrologic grades proposed by ref [8,9] is misleading.

Since it is the 120°C peak that grows with metamorpism, it is this peak that can be used to determine a petrographic grade for these meteorites. A quantitative determination this way enables comparison with other chondrites of this and other classes, keeping in mind that different classes do not need to share the same

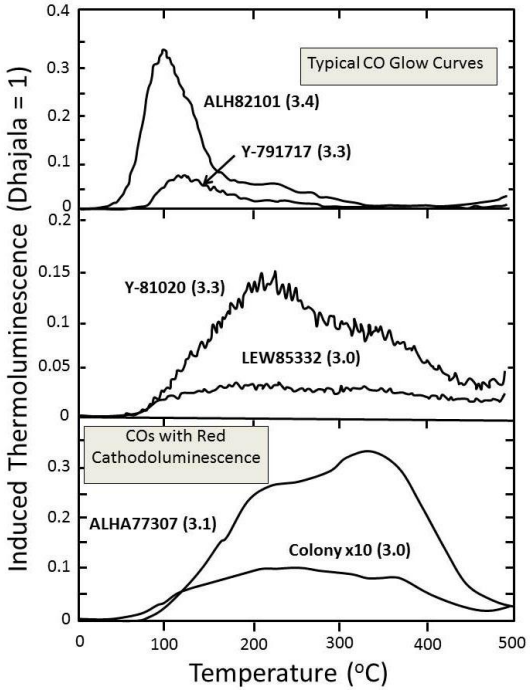

Fig. 3. CO chondrite glow curves of varying petrographic type [4].

time-temperature history during metamorphism. According to the scale defined by ref [4], type 3.2 have TL sensitivities of 0.03-0.054 and type 3.3 have TL seinsitivities of 0.054-0.1 (Dhajala = 1), thus DOM 08004 pairing group is type 3.2 and the MIL 07531 pairing group is type 3.3, but both are the lower end of their type boundaries.

The large number of paired fragments available, especially for MIL 07531, have made it possible to determine the level of internal homogeneity in the meteorites. The scatter in TL sensivitivity, peak temperature, and peak width, is notably small. This is despite these being very low grade meteorites with sometimes poorly resolved TL peaks. Thus the pairing suggested by the JSC processors is confirmed, but more significantly it means that the meteorites are not brecciated, are compositionally and mineralogically homogeneous, and exprienced a uniform metamorphic history, despite being of a very low metamorphic grade. This is an unusual situation for meteorites, especially large meteorites with multiple fragments, which tend to be brecciated even on the centimeter scale.

[1] Antarctic Meteorite Database accessed fall 2012. [2] Huss et al 2006. *MESS II*, 567. [3] Sears et al (2013) *Chem der Erde* (in press). [4] Sears et al 1991. *Proc. NIPR Symp. Antarct. Meteor.* 4, 1745. [5] Hasan et al 1989. *Lunar Planet. Sci.* XX, 383-384. [6] Sears et al 2011. *MAPS* 46, 79. [7] Sears et al. 1995. *Meteoritics* 30, 707. [8] Bonal et al 2006 *GCA* 70, 1849. [9] Bonal et al 2007. *GCA* 71 1605.