**THE SUTTER'S MILL CM CHONDRITE AND THE TISSINT SHERGOTTITE: FIRST DATA FROM THE NASA AMES THERMOLUMINESCENCE LABORATORY.** Derek W. G. Sears, Space Science and Astrobiology Division, MS245-3, NASA Ames Research Center, Moffett Field, Mountain View, CA 94035. (Derk.Sears@NASA.gov).

**Introduction:** Studies of the natural TL of meteorites provides information on their recent thermal and radiation history and have application in the study of terrestrial age, orbit, and – in the case of Antarctic meteorites – concentration mechanisms. On the other hand, studies of the induced TL provide unique insights into metamorphic history of meteorites. TL sensitivity (induced TL normalized to the induced TL of the Dhajala H3.8 chondrite) has a dynamic range and precision not matched by any other technique [1]. During the installation of a TL laboratory at NASA Ames Research Center two meteorites with considerable community interest became available for research and these are the subject of the present report. They were Tissint, a martian meteorite that fell in Morrocco in July 2011 and was found three months later [2], and Sutter's Mill, a CM-like regolith breccia that fell in northern California in April 2012 [3].

**Metamorphic History of the Tissint Martian Meteorite:** The background to the TL properties of martan meteorites were described in some detail at last year's LPSC [4]. Two 50 mg chips of Tissint (provided by L. A. Taylor of the University of Tennessee), with very different appearance under the low-powered binocular microscope (one was richer in black glass), were ground, any magnetic material removed with a hand magnet, and their TL measured in the normal way [1]. Here we focus on the induced TL.

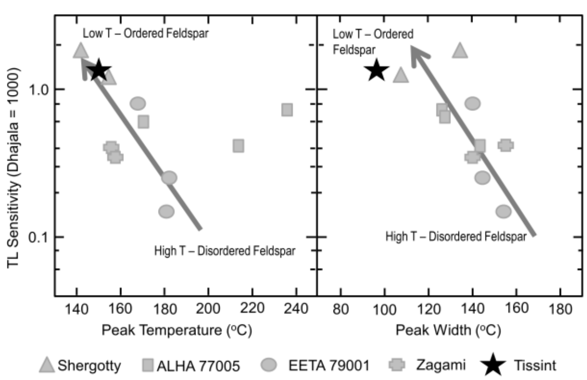


*Fig. 1.. TL sensitivity vs peak temperature (left) and peak width (right) for five martian meteorites including Tissint. Tissint has TL properties suggesting that it cooled more slowly following ejection from Mars than ALHA 77005, EETA 79001, and Zagami, and similar to Shergotty. This would be consistent with a larger ejected mass.*

The two fragments gave almost identical results, the only difference being the presence of high- temperature induced TL in the glass-rich fragment. The TL sensitivities and peak temperatures for the two chips were identical within experimental limits, but the high temperature component precluded measuring peak width in the glass-rich sample. The data are plotted in Fig. 1, along with meteorites for which data currently exist [5]. The TL sensitivitiy, TL peak temperature and TL peah width of Tissint are very similar to those of Shergotty. The TL sensitivity of Tissint, while low in comparison to most meteorites, is at the high end of the range observed for shergottites. Conversely, TL peak temperature and width are at the low end of the range observed for shergottites.

The TL carrier in shergottites is traces of crystalline feldspar in the maskelynite, the low TL sensitivity reflecting the extremely small amounts of crystalline material present. The temperature and width of the TL peak reflect the level of structural disordering in the crystals, disordered feldspar having high peak temperatures and widths (both ~200°C) while ordered feldspars have low peak temperatures and widths (both ~100°C).

Thus as the maskelynite cooled, following its formation by the shock event that liberated the meteorites from Mars, the first feldspar formed was in small amounts and in the high-temperature (disordered) form being above the order-disorder transition temperature. The order-disorder transition temperature (~500°C) corresponds to shock pressures of ~25 GPa [6]. With decreasing temperature, more feldspar formed and the TL sensitivity went up, but as the temperature dropped below the order-disorder temperature the feldspar formed was in the low-temperature (ordered) form.

Thus the shergottites define a trajectory (the arrows in Fig. 1) representing a cooling series with closure setting in at decreasing temperature as they moved along the trajectory. Such differences in closure are most reasonably interpreted as due to different cooling rates and fragment size. Thus for the shergottites currently discussed, Tissint and Shergotty cooled most slowly and therefore were probably the largest fragments ejected from Mars.

**Thermal and Metamorphic History of the Sutter's Mill Meteorite:** Nearly 20 CM chondrites examined as part of the Antarctic Meteorite Natural TL Survey had undetectable TL signals [1]. This is also true of Murchison [7]. It is therefore significant that Sutter's Mill meteorite, which appears to be resemble CM chondrites in many ways, produced weak but detectable TL. The raw TL data (i.e. glow curves, plots of light emitted against laboratory heating temperature) are shown in Fig.2. Our sample is from SM-2, which was found as about a dozen fragments totaling ~4 gram in a parking lot, presumably crushed by a car. Several of the fragments contained fusion crust. In fact, all of the 70 Sutter's Mill meteorites are fully crusted individuals only one is greater than ~30 gram. Thus our sample will have come a few millimeters from the fusion crust.

The natural TL glow curve consists only of a signal at high glow curve temperatures where it is significantly higher than background (black body). There are no obvious peaks, the induced TL consisting of a broad band extending from ~300°C to ~450°C. In contrast to the natural TL, the induced TL starts at ~100°C. It then continues to ~450°C, being broad and somewhat hummocky, suggesting many unresolved peaks.

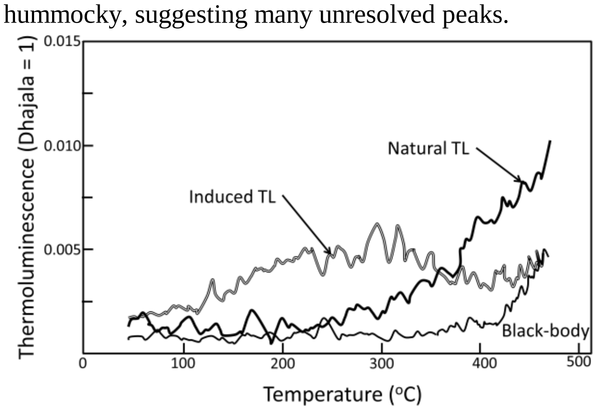


*Fig. 2. Glow curves for the natural and induced TL of the Sutter's Mill meteorite compared with the black body (background) signal.*

The customary way of determining the thermally stable region of the natural glow curve, for dosimetry of pottery dating purposes for instance, is to plot the ratio of the natural to induced TL as a function of glow curve temperature. A leveling off, or a plateau, suggests that the TL signal was stable in this region and may be used for dating. When this is done for Sutter's Mill (Fig. 3) it is clear that the natural TL below 300°C has been removed. Theory and experiment shows that this is the result of heating to ~300°C, and the heating may have been just momentary. This heating event was relatively recent, since in only ~$10^5$ years the meteorite would have recovered from the heating event.

There are several possibilities for the heating event. It may have been during (1) the atmospheric descent, (2) a passage close to the Sun, (3) during a stochastic event such as shock heating event. This shock heating event may have been a collision, or even the event that ejected the meteorite from its parent body.

The smallness of the size of the fragment measured here and the known thermal gradients in meteorites caused by atmospheric heating suggest that the heating event suffered by our sample of Sutter's Mill was passage through the atmosphere. However, the Sutter's Mill meteorite had an orbit with a particularly small perihelion and several other meteorites with a 300°C step in their plateau are thought to have entered the atmosphere on an orbit with a small perihelian. There is nothing in the data to preclude such an explanataion for the Sutter's Mill natural TL data. The third explanation is also a possibility. If we assume that the very short cosmic ray exposure ages for this meteorite (0.05 – 0.1 Ma [3]) reflects the date at which Sutter's Mill was ejected from its parent object, with an associated shock heating, then this event may or may not have been shorter than the natural TL recovery time. Precise measurements of the kinetics of the natural TL of Sutter's Mill are required.

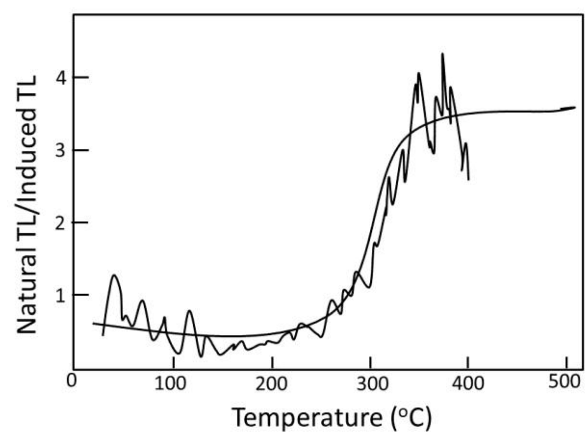


*Fig. 3. Ratio of natural TL to induced TL as a function of glow curve temperature. The step at 300°C indicates that the meteorite has been heated to this temperature sufficiently recently that it has not had time to recover (~$10^5$ years).*

The TL sensitivity of Sutter's Mill is comparable to very low metamorphic grade ordinary, CO, and CV chondrites, say 3.0. As mentioned above, however, the glow curve shape is unique and does not match any other class. This points to a fundamental difference between Sutter's Mill and the normal CM chondrites consistent with a lower degree of aqueous alteration or a metamorphic overprint.

[1] Sears et al. (2013) Chemie d'Erde (in press). [2] Aoudjehane et al. (2012) Science 338, 785. [3] Jenniskens et al. 2012. Science 338, 1583-1587. [4] Sears (2012) LPSC Abs #1853. [5] Hasan et al 1986 GCA 50, 1031. [6] Hartmetz et al 1986 JGR 91, E263. [7] Sedaghatpour and Sears 2009 MAPS 44, 653.