A POLISHING TECHNIQUE FOR TARDA AND FUTURE SIMILARLY DIFFICULT SAMPLES

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Introduction: Tarda is an aqueously altered ungrouped carbonaceous chondrite (C2-ung) that fell in Morocco on August 25th, 2020 [1,2]. This meteorite is dominated (~80%) by a smectite- and serpentine-rich matrix that contains chondrules, chondrule fragments and minor magnetite, dolomite, and Fe-sulfides [1,2]. Compositionally and isotopically, [1-5] found that Tarda is most similar to the C2-ung meteorite Tagish Lake, suggesting a genetic link. Tarda, therefore, may be the only meteorite to share a parent body with Tagish Lake, or represent a sample from a new chemical reservoir that rarely gets delivered to Earth's surface. The unique composition of Tarda additionally serves as excellent analogue material for return samples from carbon-rich asteroids, such as Ryugu [6] and Bennu [7].

With rare and significant samples such as Tarda, sound sample preparation methods are paramount to ensure that the meteorite remains as minimally disturbed as possible. However, when attempting to polish a thick section of Tarda, it was found to rapidly slake in contact with common polar polishing liquids. This phenomenon requires deviation from typical carbonaceous chondrite sample preparation methods [e.g. 8]. This abstract will describe a sample preparation method for polished mounts of Tarda.

Sample Preparation: This study uses a 2.1g Tarda sample loaned from the Royal Ontario Museum (ROM) in Toronto, Canada (catalogued as ROMESM60117). To prepare the sample for analyses, it was embedded in epoxy, cut, and finely polished.

Epoxy embedding: The Tarda sample was placed in a 1-inch epoxy mold. Struers EpoFix™ resin and hardener [9] were mixed following the manufacturer's instructions. The mixture was poured over Tarda into the mold and set to cure for 24 hours in a fume hood under vacuum to remove bubbles. It was then removed from the mold and cut to produce two flat surfaces.

Cutting: The epoxy puck containing Tarda was cut in half parallel to the epoxy surface over one hour with a dry and clean diamond wire saw to minimize contamination and material lost. Suspended particles were vacuumed to minimize the dust resettling on the surface of Tarda.

Polishing: Tarda cannot be exposed to any alcohol, water, or other polar polishing liquids during the polishing phase, as rapid slaking will occur within the sample. This study was initially unaware of the extreme delicacy of the sample and attempted to use isopropyl alcohol to rinse the sample between polishing iterations to remove stray particles. Upon inspection of the first polish and rinsing iteration, the smectite within the sample rapidly and significantly swelled, and subsequently dried and flaked off, severely disrupting original textures in both sections (Fig. 1).

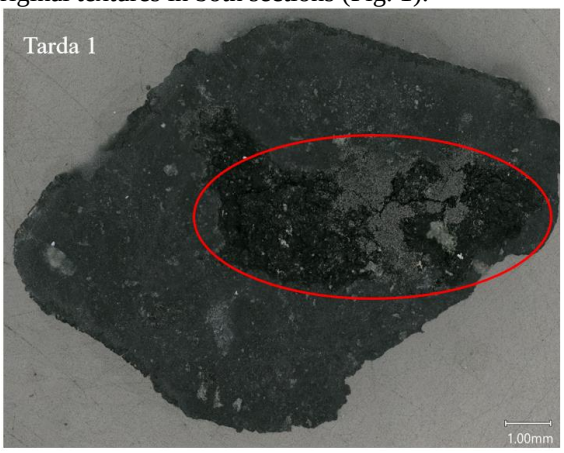

Fig. 1: Reflected-light composite photograph for one of the two Tarda sample halves. Red circle denotes most significant zone of alteration, expressed as a large cavity with interior features resembling desiccation cracks.

To prevent further damage to Tarda, an experiment was conducted on montmorrilonite. Three small and similar montmorillonite chips were provided by the ROM to test their reactivity with three common polishing lubricants and cleansers: isopropyl alcohol, ethylene glycol, and ethanol. Each montmorillonite chip was embedded in epoxy replicating the procedure used for Tarda. Using 120 grit sandpaper, the epoxy surface was sanded down for each until the surface of the montmorillonite was exposed. Approximately 10-15 mL of isopropyl alcohol, ethanol or ethylene-glycol were poured on each surface and allowed to rest for ~3 minutes (Fig. 2A). After each experiment, all three polishing cleansers caused the montmorillonite to significantly react and swell to large proportions displayed by Fig. 2.

Since the montmorillonite interacted with all polar polishing cleansers, a non-polar polishing cleanser was required. A more successful polishing recipe was developed to address this issue. The recipe incorporates steps to better consolidate the sample (if required), and

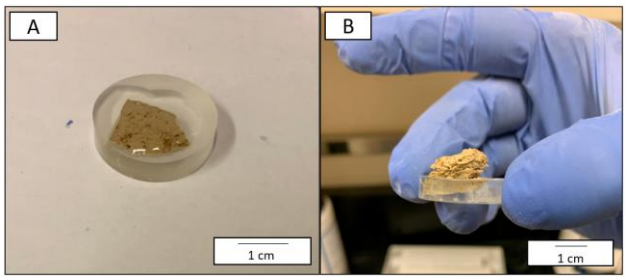

Fig. 2: Montmorillonite sample being exposed to ~10 mL of ethylene glycol for 3 minutes before and after it expanded (panel A and B respectively).

only uses mineral oil and toluene (which has a lower polarity) during the polishing process. After embedding the sample in epoxy and cutting, the polishing recipe is as follows:

1. Dry polish sample to 1200 grit: Using a series of silicon-carbide and corundum sandpaper sheets, Tarda was carefully polished dry from 120 to 1200 grit over the course of six steps (120, 200, 400, 600, 800, 1200 grit). The Tarda sample was polished in small (~10 cm diameter) circles using moderate pressure for 3-5 minutes for each iteration. After each sanding iteration, a dry Kimwipe™ [10] was used to gently wipe debris from the surface.
2. Improve cohesion (optional): At 1200 grit, the surface of Tarda was reimpregnated with Struers EpoFix™ epoxy. Tarda was placed back into the 1-inch epoxy mold, face up. The mixture was poured over its surface. It was set to cure in a fume hood under vacuum for 24 hours, to allow bubbles to escape from pore/cavity space.
3. Repolish dry to 1200 grit: After curing, the epoxy-impregnated surface of Tarda was re-exposed by coarsely polishing down the epoxy surface until dust began to appear. Step 1 was then repeated to achieve a dry polish to 1200 grit. Once at 1200 grit, Tarda was placed in a fume hood and, wearing appropriate protective gear, toluene was used to rinse the surface.
4. Precision polish: An automatic polisher (Buehler Metasev™ 250) was used to polish Tarda. A Struers 300 mm diameter DP-Floc polishing pad [11] was attached to the polisher and charged with mineral oil and 0.5-micron diamond powder to get a slurry consistency. Both samples of Tarda were loaded into the automatic polisher, pressing down on the polishing pad with ~1 pound of pressure. The pad was then spun at 200 rpm for 1 minute.
5. Sample cleaning: The sample was quickly removed and taken to a fume hood where it was submerged face up in a small container of toluene to dissolve the mineral oil. Several changes of toluene were required for complete removal of the mineral oil. If polishing residue remained on the surface once dry, a Kimwipe™ [10] dipped in toluene was used to gently wipe the residue away. The Tarda sample is now suitable for future analyses, such as microprobe analyses (Fig 3).

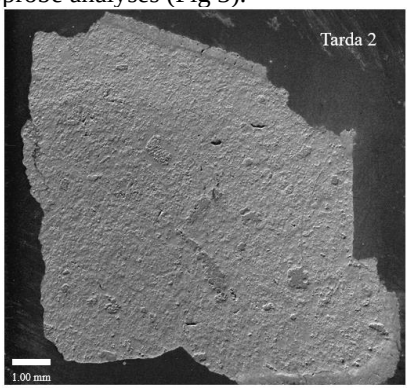

Fig. 3: Secondary electron image of Tarda (sample 2). Mild topography is still present showing olivine risen above the softer phyllosilicate matrix.

Discussion: To date, Tarda is the only carbonaceous chondrite sample that displays such extreme sensitivity to polar polishing lubricants and cleansers. This sensitivity may imply subtle differences in swelling-phyllosilicate matrix proportions, exchangeable cation species within smectite [12], and/or smectite interlayer fault differences [12], but further study is required.

Conclusion: Tarda samples a new chemical reservoir that shows similarities to Tagish Lake and is uniquely situated to provide a deeper understanding of parent body chemistry, evolution, and processes. It is imperative to employ sound sample preparation techniques to preserve as much material from these rare samples as possible. The technique employed in this abstract can be used to prepare future similarly difficult samples, possibly including the largely unknown and ultra-pristine samples returned and returning from carbon-rich asteroids Ryugu and Bennu.

References:[1] King, A. J. et al. (2021) *LPSC LII*, Abstract #1909. [2] Garvie, L. A. J. and Trif, L. (2021) *LPSC LII*, Abstract #2446. [3] Marrocchi, Y. et al. (2021) *ApJL 913*, L9. [4] Dey, S. and Zolensky, M. (2021) *LPSC LII*, Abstract #2517. [5] Shrader, D. L. et al. (2022) *LPSC LIII*, Abstract #1157. [6] Yokoyama, T. et al. (2022) *Science, 392*, 1-17. [7] Lauretta, D.S. et al. (2021) *LPSC LII*, Abstract #2097. [8] Harrington, R. and Righter, K. (2013). *LPSC XLIV*, Abstract #2206. [9] EpoFix™ Kit, Struers Inc., Catalog #40200029. [10] Kimwipes™, KimTech Inc., Product code #34120. [11] DP-FLOC, 300mm. Struers Inc., Catalog #40500230. [12] Suquet, H. et al. (1975). *Clays and Clay Minerals, 23*, 1-9.