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Original

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A new sampling system tailored to experimentally-derived mechanical properties of icy analogs for evolved Enceladus surface plume deposits

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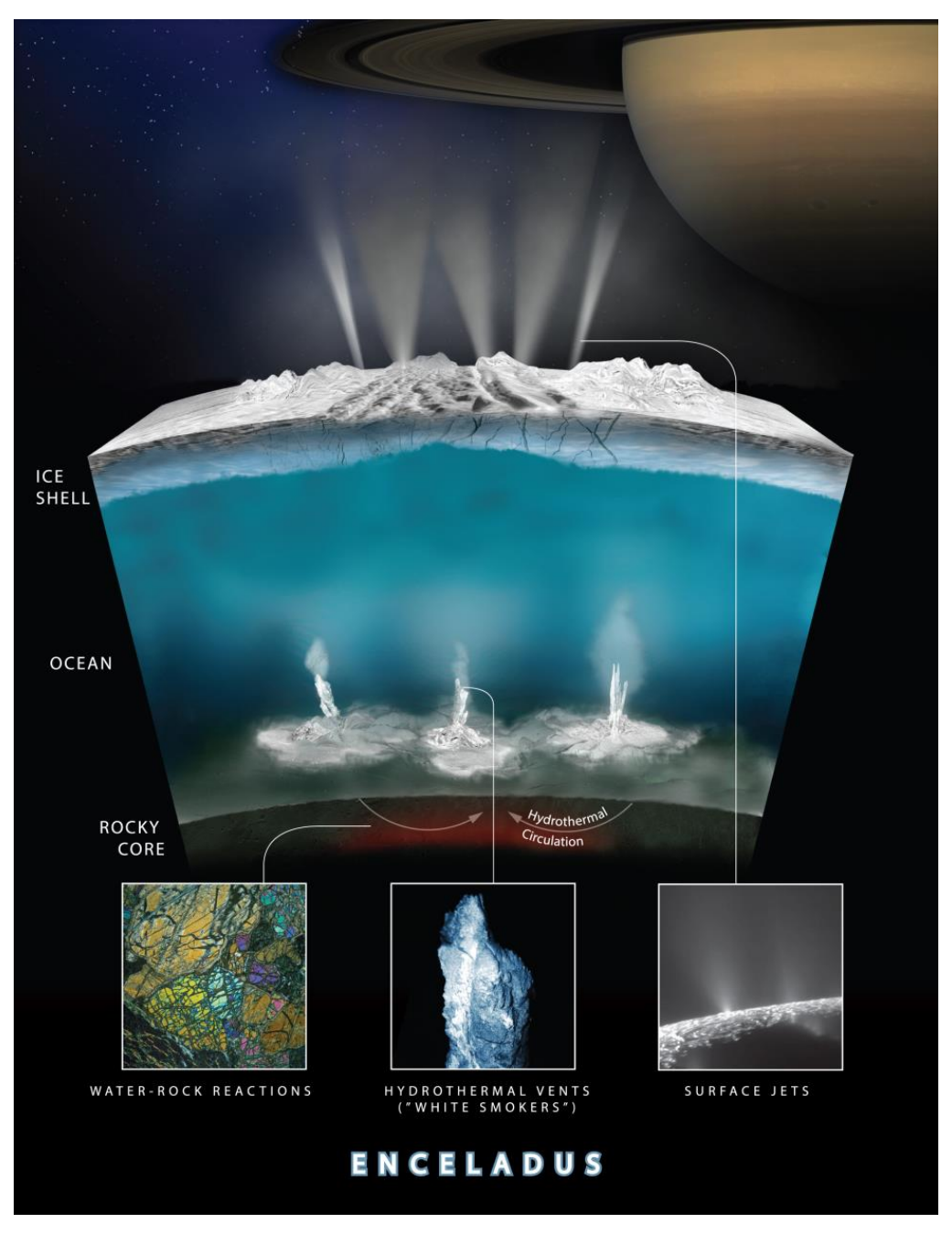
- *Cassini* has shown that Saturn’s moon Enceladus is highly active, with materials emitted from its internal ocean and re-deposited around the surface.

Because of its likely internal hydrothermal activity and plume emissions, Enceladus is amongst the few Ocean Worlds that could harbor life and exhibit fresh traces of it on its surface.



- No *New Frontiers* mission proposals to Enceladus have been selected in the last call.
- However, there is a growing interest to explore Enceladus’ habitability.
- Future landed missions to Enceladus would be best suited at finding traces of life, similarly to the Europa Lander in pre-phase A study.
- Instruments most sensitive to detect traces of recent or extant life will likely require acquisition of surface samples.

We are developing a sampling system for an Enceladus lander mission to acquire and transfer surface samples to in-situ instruments.

- Samples: ten 1cc to 5cc ice samples from top 1 cm
- Material: 40-95% porosity and strength up to 12 MPa unconfined compressive strength (initial requirement)

Understanding the properties of the surface is essential to assess where and how to acquire surface samples. This characterization includes the evolution of water ice under surface conditions: Although plume particles are micron-size, how fast would they evolve after deposition? What is the expected strength of materials after this evolution?

Dual-Rasp Sampling System Development

The novel Dual-Rasp sampling system was developed to meet the unique Enceladus surface sampling needs. Sampling is accomplished with two counter-rotating rasp cutters with teeth that remove material that is thrown up between the cutters and directed by a guide into a sample collection cup (Figure 1). A robotic arm would deploy the tool to the surface. Two versions of sample transfer were developed. A mechanical sample transfer system (Figure 1) has ten sample cups on a carousel attached at the end of the robotic arm. After one 5cc cup is filled, the cup is rotated on the carousel to a volume measurement station where a plunger pushes a lid into the sample cup to measure the sample volume. If there is enough sample, then the tool is docked at the lander deck and the plunger pushes the cup into a science instrument inlet port. Otherwise another sampling attempt could fill the cup further. A pneumatic sample transfer system (Figure 2) uses pneumatics to transfer sample from the collection cup directly to a science instrument inlet port after the tool is docked at the lander deck. A microwave mass flow sensor is being evaluated for sample measurement for this tool version.

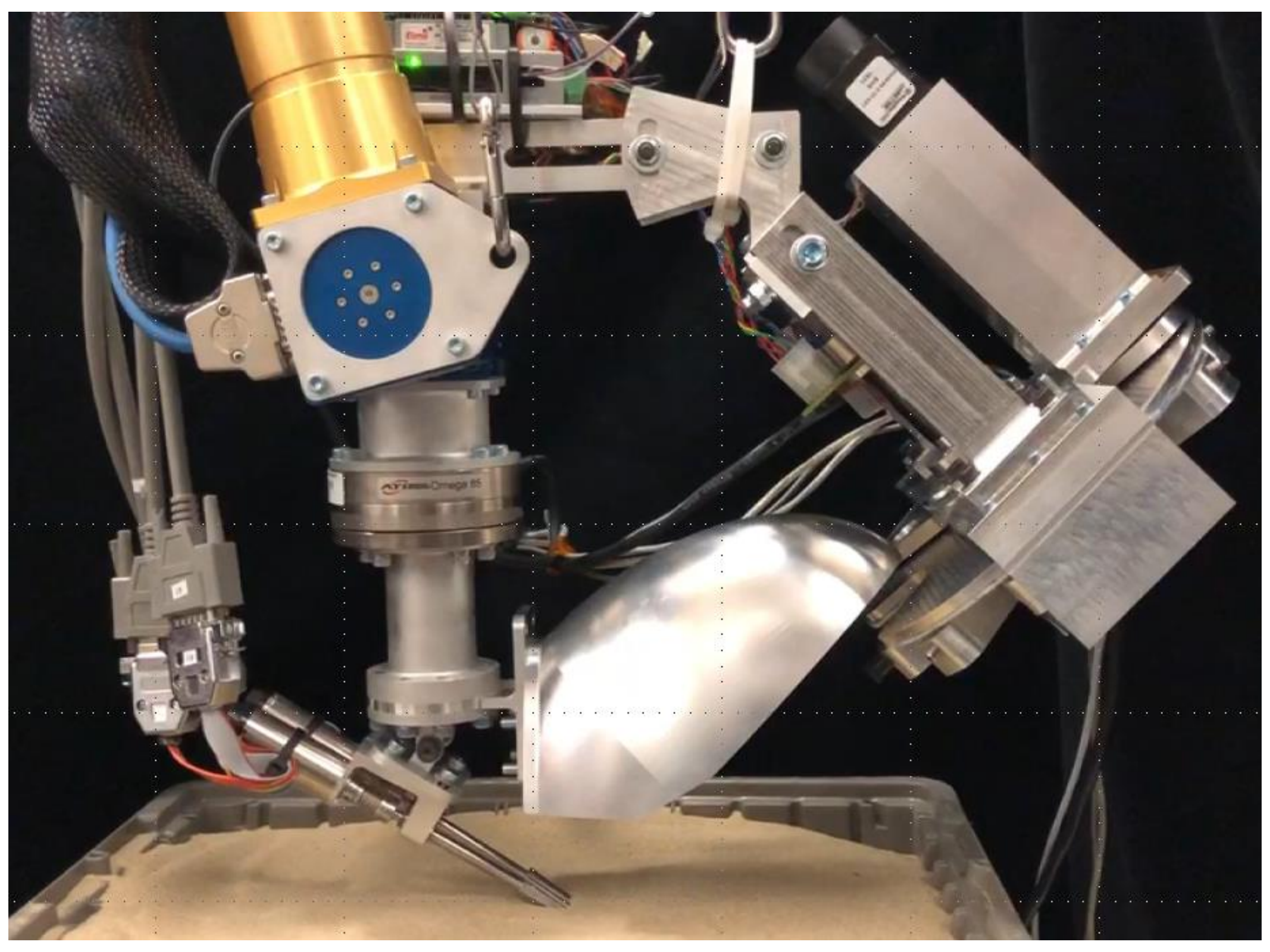


Figure 1. Dual-Rasp with carousel sample transfer

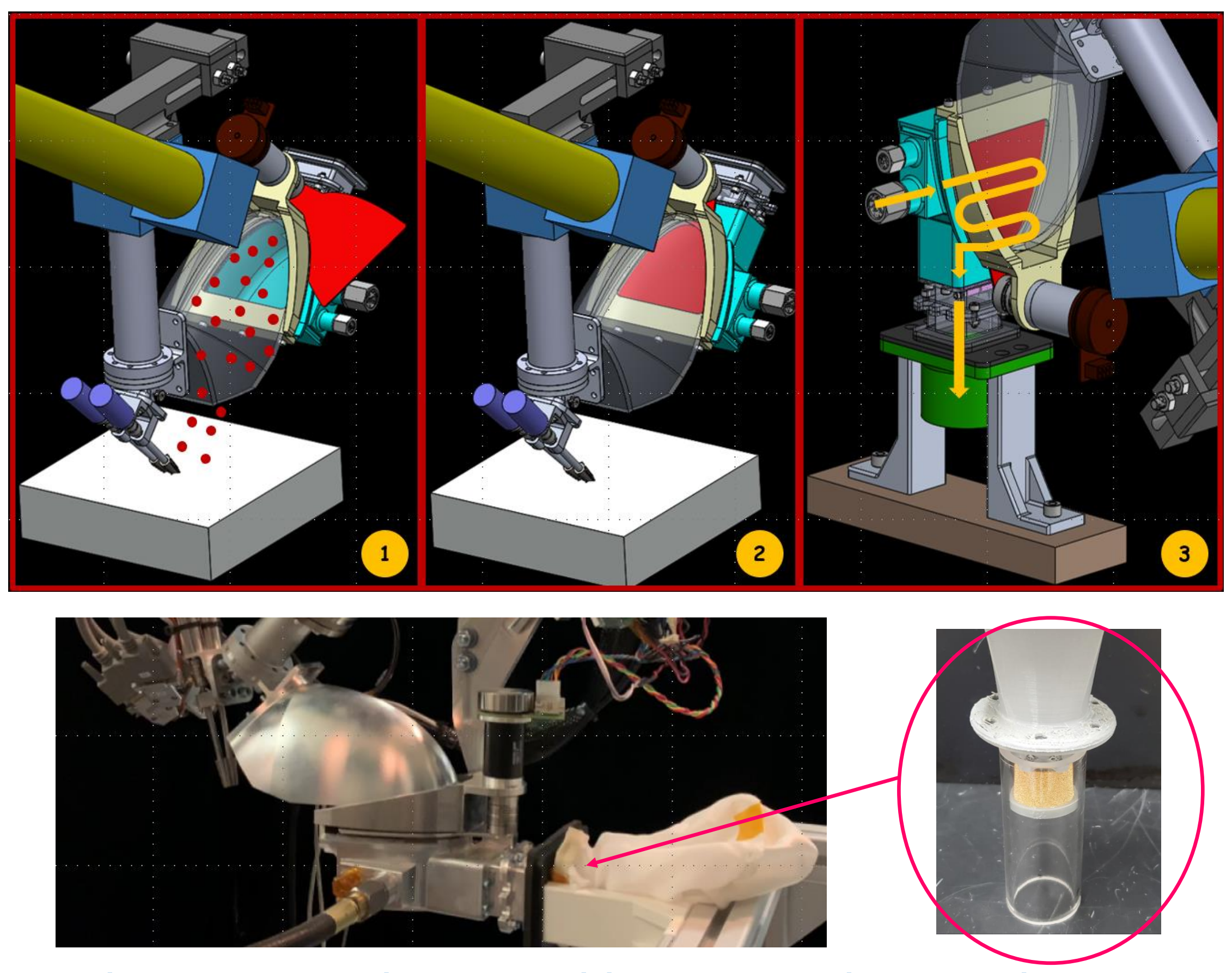


Figure 2. Dual-Rasp with pneumatic sample transfer, concept (top), prototype and science instrument inlet chamber (bottom)

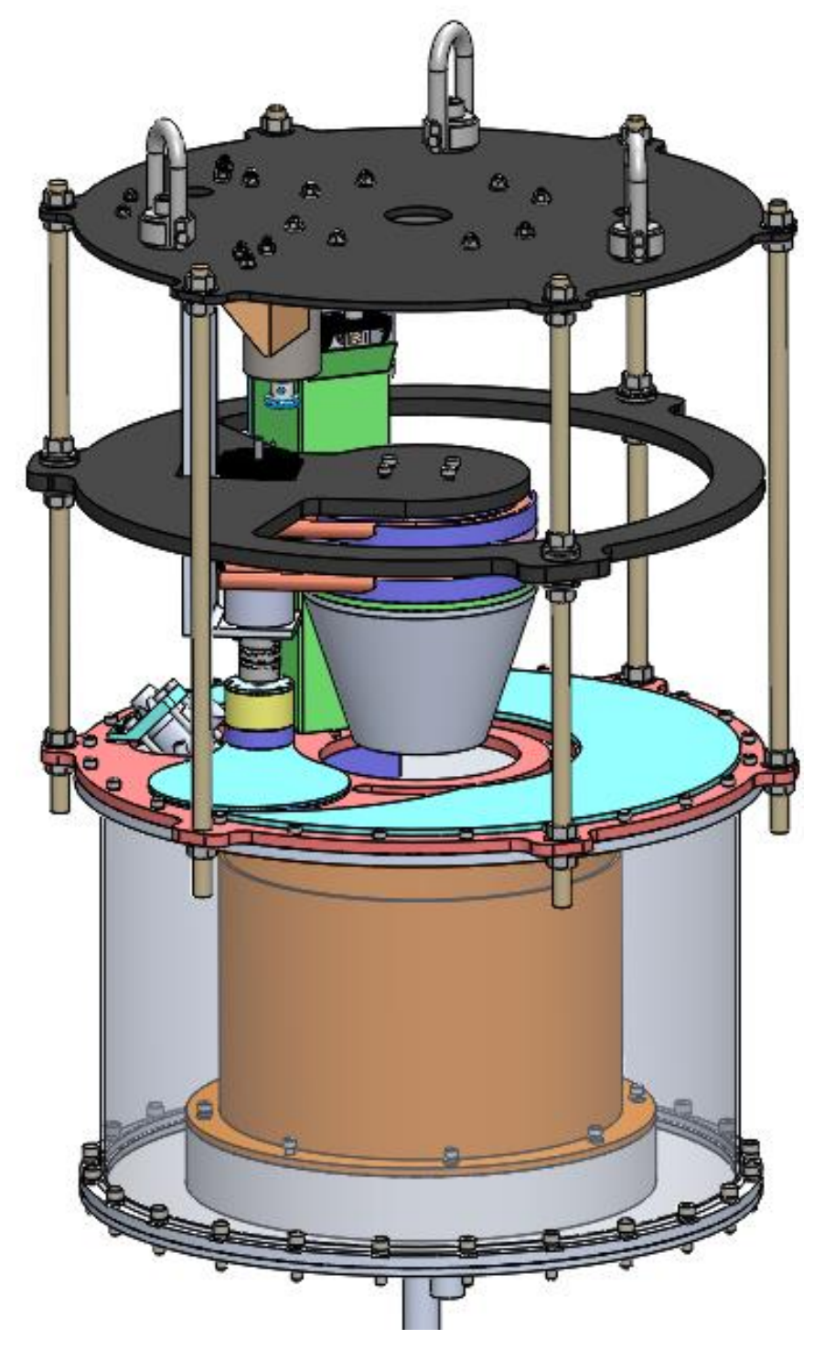


Figure 3. IBoS chamber design

Icy Bodies Simulation (IBoS) Chamber

The IBoS chamber was designed (Figure 3) and fabricated for use in generating and evolving icy body materials including to represent the Enceladus surface. Micron-scale particles will be produced and subject to Enceladus thermal and vacuum conditions and the evolving mechanical properties will be measured.

Ice Sintering Modeling and 1-Bar Experimental Characterization

Ice sintering tests were conducted to determine the potential mechanical properties of the Enceladus surface. Ice samples were prepared by air atomization (spherules with a starting mean grain size 12 microns) and kept at -30ºC, -50ºC, and -80ºC. Penetration resistance data was periodically collected using a custom cone penetrometer apparatus, with a cone of 1 cm diameter and 30º half-opening angle, driven into the samples at 1 cm/s. Sintering of the ice caused growth of the contact regions between grains and mass redistribution, leading to the formation of agglomerate structures and some recrystallization. Combined, these effects resulted in an increase of the penetration resistance of the bulk ice samples, with warmer samples experiencing more modification. Results (Figures 4,5,6) suggest plume deposits remain weak on Enceladus far from the thermal influence of the Tiger Stripes.

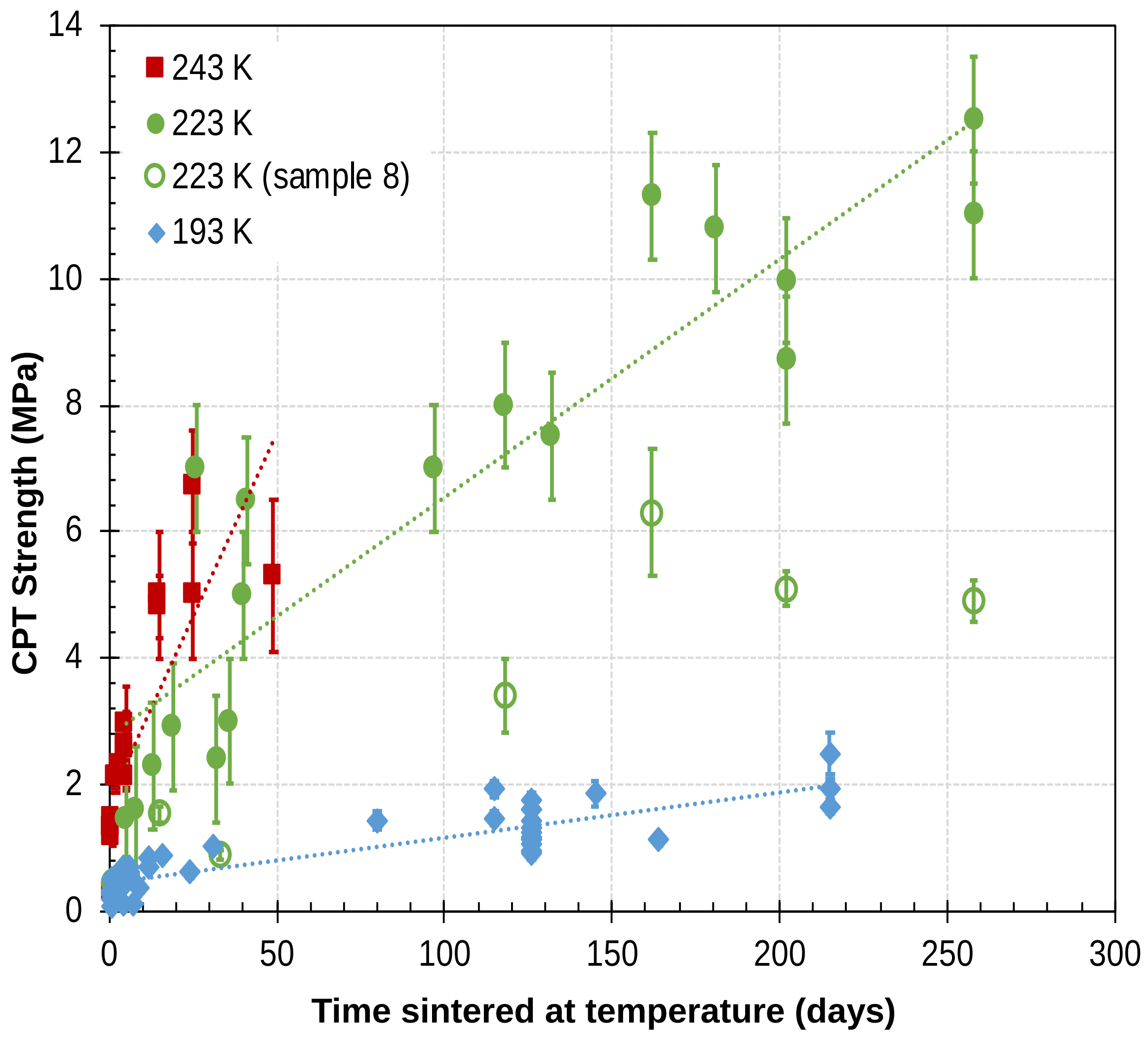


Figure 4. Ice sintering experimental results

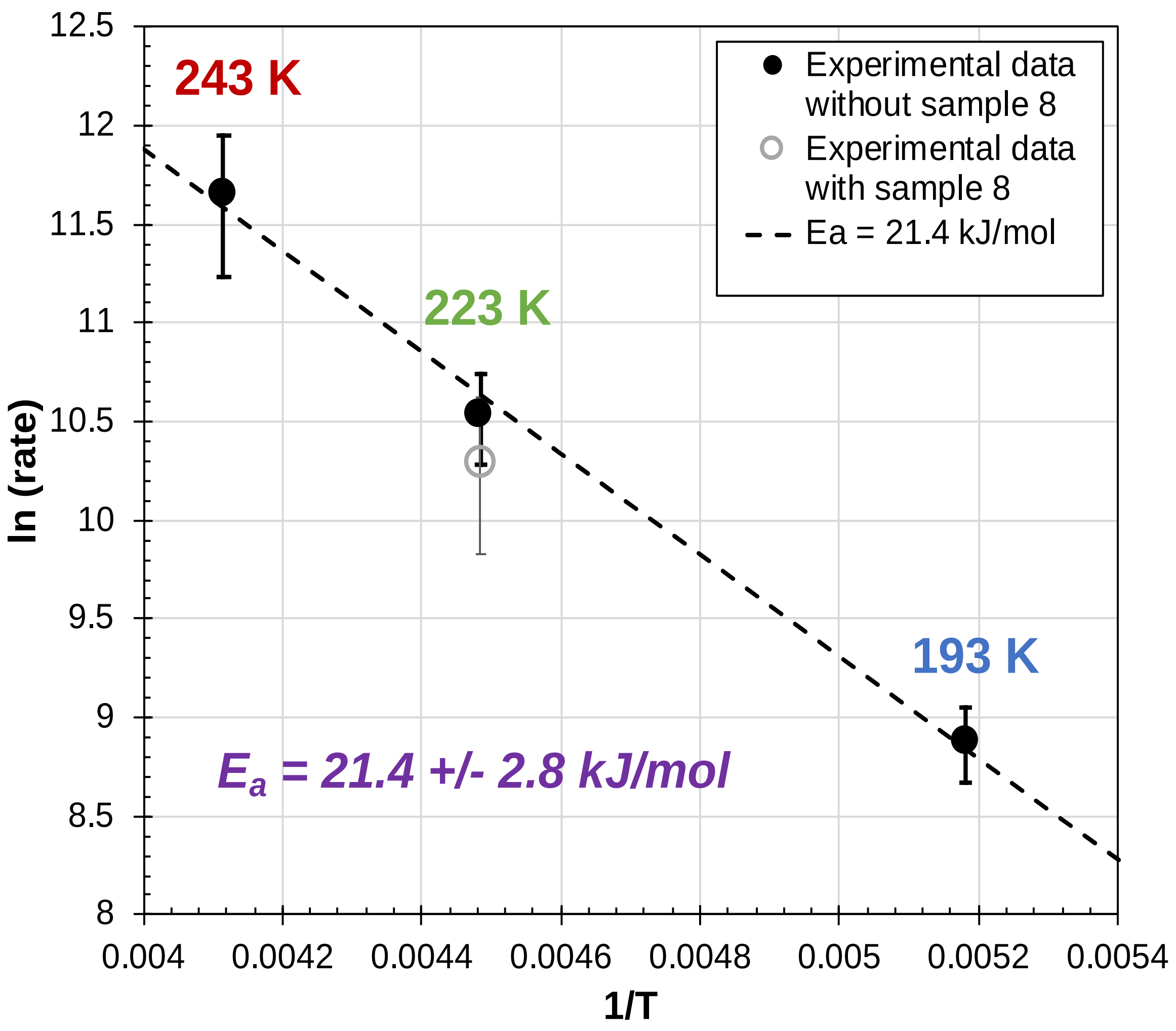


Figure 5. Arrhenius plot of rate of strength increase shows activation energy compatible with vapor diffusion

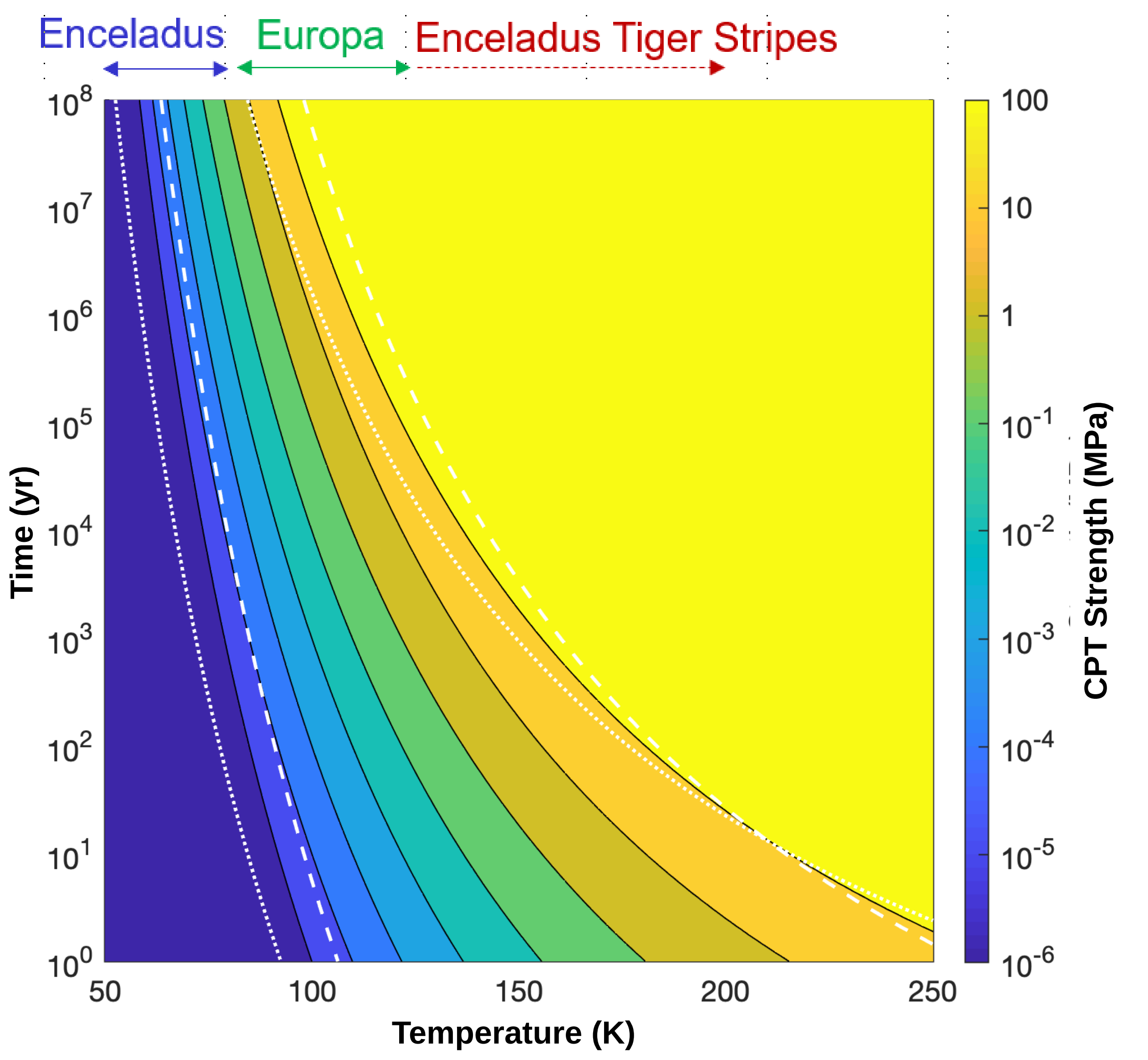


Figure 6. Sintered ice strength evolution model based on 1-bar experimental data

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