STRENGTHENING OF ENCELADUS AND EUROPA ICE PLUME DEPOSIT ANALOGS . Mathieu Choukroun[1], Jamie L. Molaro[2], Eli Phelps[1], Robert Hodyss[1], Eloise Marteau[1], Wassim Dhaouadi[1]. [1]NASA Jet Propulsion Laboratory, California Institute of Technology, Pasadena, CA (Mathieu.Choukroun@jpl.nasa.gov), [2]Planetary Science Institute, Tucson, AZ.

Introduction: *Cassini* data [1,2] unambiguously showed that Enceladus spews materials from its likely habitable internal ocean [3-5] into its environment, and some of these materials are deposited back onto the surface of this Ocean World [6,7]. Similarly, plume activity from the internal ocean has been tentatively detected at Europa [8-10]. This unique setting enables seeking traces of past or extant life at these bodies in ice plume materials deposited around their surface, which would be one of the main goals of the Europa Lander mission concept in development [11]. Mission concepts aiming at the same goal on Enceladus are also being investigated.

The design of surface sampling techniques relies heavily on strength expectations for these materials. However, there is no data to provide constraints on the strength of present-day plume deposits on the surfaces of Enceladus and Europa. We report preliminary results of an experimental investigation of the strength evolution of ice plume deposit analogs at several temperatures, as well as a model that provides a first-order estimate of the strength of evolved ice plume deposits under geologic timescales relevant to Enceladus and Europa.

Sample preparation: Fine-grained (12 microns average grain diameter) porous water ice samples were prepared by direct deposition of an air-atomized pure water mist into liquid nitrogen. The water (deionized, Fischer Scientific) mist was prepared with an atomizing nozzle (Spraying Systems, Inc.) supplied with gaseous nitrogen at 3 bars pressure. The “slush” of ice and liquid nitrogen was poured into plastic containers, forming samples between 1.3 and 2.0 kg each. Once the liquid nitrogen had completely boiled off, the sample containers were capped and sealed, and placed within glove bags in chest freezers held at a constant temperature (-50 °C and -80 °C samples), and in a walk-in freezer (Cincinnati Sub-Zero, Inc.) (-30 °C sample). Three to six samples were prepared then stored for each run. The samples were held in these isothermal conditions over extended periods of time, up to 10 months.

Cone penetration testing (CPT) of strength: The strength of the samples has been measured multiple times over the course of the experiments using a custom-built upright cone penetrometer apparatus. This apparatus uses a linear actuator and potentiometer to drive a custom 1-cm diameter stainless steel cone and rod, pre-cooled in liquid nitrogen, into the samples at 0.1 cm/s. The force exerted by the penetrometer is measured with a 500-lb rated load cell (Transducer Inc.). The cone penetration resistance of the samples is derived from the time-resolved applied force divided by the cross-section of the cone.

Results: Strengthening over time at each temperature resulted in linear trends of strengthening over the duration of the experiments, see Figure 1. The individual temperature-dependent rates of strengthenging were constrained through a linear regression (including error bars on individual data points, and errors on the linear rates of strengthening).

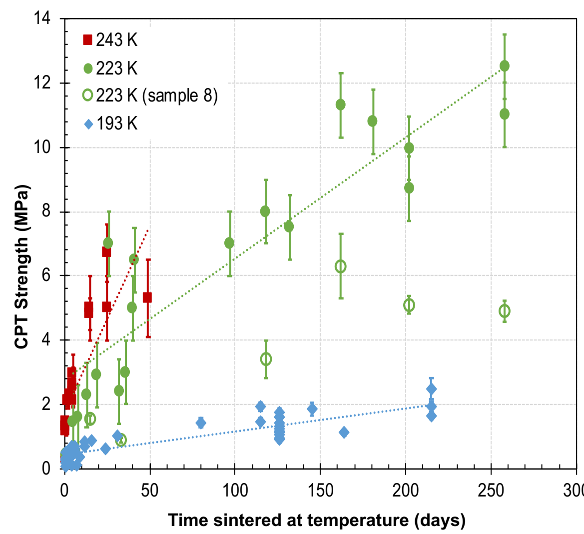

Figure 1. Cone penetration test (CPT) strength data of the icy plume deposit analogs as function of time. At each temperature, a linear evolution in measured strength is observed as function of time. At 223 K, one sample (#8) was found to exhibit a strength evolution at a slower rate, which likely resulted from sample preparation artefacts.

An Arrhenius plot (Figure 2-a) compares the natural logarithm of the rate of strengthening as function of inverse sample temperature. The three datasets clearly follow a line in this representation, whose slope is by definition -Ea/R, where Ea is the activation energy of as function of temperature, and R is the ideal gas constant. A linear regression of the dataset yields an activation energy of 21.4 ± 2.8 kJ/mol, commensurate with that of H_2O vapor diffusion during ice sintering [12].

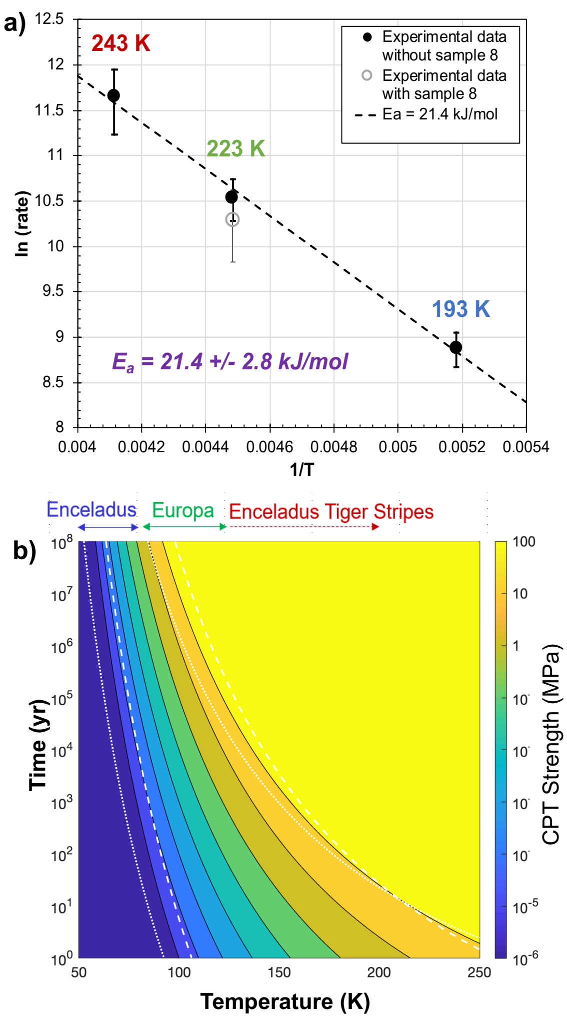

Figure 2. *a)* Arrhenius plot showing the temperature dependence of the measured rate of CPT strength increase over time. *b)* Predicted CPT strength of icy plume deposits as function time and temperature under the surface temperature conditions of Enceladus and Europa. The white dashed and dotted lines show the -2σ and +2 σ expected strength evolutions, respectively.

Figure 2-b presents a modeled prediction of the strength evolution of icy plume deposit materials under Enceladus and Europa surface conditions, assuming a starting negligible strength and an evolution as found in the experiments and extrapolated to lower temperatures relevant to Enceladus and Europa. Under Europa's surface conditions, substantial strengthening (> 1 MPa CPT strength) may be expected for plume deposits of $10^4 - 10^7$ years of age. This suggests that recent plume deposit areas are most likely to provide sampleable materials of astrobiological relevance, which Europa Clipper will seek.

Conversely, under Enceladus' extremely cold surface temperature conditions away from the Tiger Stripes, it appears unlikely that substantial strengthening of plume deposit materials would take place over geologic timescales up to 100 Myr. Near the Tiger Stripes, an interplay between increased rate of strengthening and increased rate of fresh material deposition should be expected. Further analysis is ongoing to disentangle the two effects and assess the strength of recent ice plume deposits on Europa and Enceladus.

Sampling the top ~ 1 cm of icy plume materials of the area around an Enceladus lander appears both achievable and most likely to acquire samples of direct astrobiological relevance.

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