HEAT PIPE EFFECTS ON ENCELADUS' SOUTH POLAR TERRAIN AND THE IMPLICATIONS FOR REGIONAL HEATING AND ERUPTION ACTIVITY. S. E. H. Sakimoto[1,2] and T. K. P. Gregg[2], [1]Space Science Institute, 4750 Walnut St # 205, Boulder, CO 80301, susansakimoto@gmail.com, [2]Department of Geology, University at Buffalo, 126 Cooke Hall, Buffalo, NY 14260, tgregg@buffalo.edu.

Introduction: Enceladus has long been suspected to be geologically active. Earth-based telescopic infrared spectra of Enceladus [1] showed nearly pure water ice. Additionally, Enceladus is within and the source for Saturn's diffuse E ring [2,3]. Finally, Voyager observations of its high albedo and of sparsely cratered terrains [4,5] all provided evidence of geologically recent activity. The 2005 Cassini flyby confirmed current and ongoing endogenic activity in the South Polar Terrain (SPT) [6,7] emanating from "Tiger Stripe" fractures. Later flybys generated additional data.

Water vapor and ice grains dominate Enceladus' plume activity. [6-13]. However, molecular hydrogen was also detected in the 2015 Cassini fly-through of the plume, suggesting that the water source hydrothermally reacts with rocks [13], and originates below the icy crust at the rock-water interface. Enceladus' plume varies in intensity with the moon' orbital position, suggesting that a tidal mechanism is driving the activity [14-16], as the cracks cycle through compressive, shear, and tensile stress regimes every orbital period (33 hrs)[15]. While a sub-crustal global ocean layer has been proposed [e.g. 17], a regional ocean is more easily maintained with tidal heating [18,19].

Motivation and Objective: There are numerous models for the origin and attributes of the plumes [e.g. 20-22], and their source cracks [e.g. 23-24]. Here, we instead consider the thermal effects of plume materials passing through the icy layer. Heat pipes are conduits that transfer heat and material from the base of the lithosphere to the surface. In early terrestrial and planetary volcanic regions [25, 26], repeated passage yields localized thermal and structural weakness zones that favor additional eruptions through the same plumbing (or crack) system, leaving more distant crustal areas relatively cold and thick. Thus, the heat-pipe mechanism promotes long-duration resurfacing and a thick cold crust. Understanding this process for Enceladus will yield insights on the SPT thermal evolution, global cooling, and plume material generation and transport.

Observations, Constraints and Approach:

The base of the icy crust is in contact with and therefore in thermal equilibrium with the ocean, and thus at the water-ice melting point (273K) [18]. We assume salt-water filled cracks [24, 27], consistent with Composite Infrared Spectrometer (CIRS) data showing low power thermal output on either side of the vents and high power directly at the vents [24]. Far-field and between-fracture surface temperatures are assumed to be 68K [7, 29]. Within Sulci, the observed maximum temperature is 197K [29]. Prior work on vent constraints suggests that cracks >1m wide and salinities of >20g/kg are necessary to bring water near-surface without freezing [23,24]. We specify flow rates to match modeled vent velocity and flow rate ranges [22,24]. Sulci spacing is 30-40 km, with crust thicknesses of 15-40 km [30]. We use a 2-D model perpendicular to the SPT Tiger Stripes that includes body curvature. We employed the computational fluid dynamics (CFD) finite-element code COMSOL Multiphysics 5.3a. to solve the coupled time-dependent (multi-eruption pulse) thermal and Navier-Stokes.

Results and Discussion: We find that while there is sufficient heat transfer with repeated eruptions to warm immediate crack walls, it does not tend to propagate far enough to ensure significant regional elevated temperatures. The wall warming is likely sufficient to maintain each Sulci locale as thermo-mechanical weak zones that will be preferential paths for subsequent cracking and material ascent. Additionally, it may enable minor shifts of the cracking and ascent paths.

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