ASSESSING THE RELATIONSHIP BETWEEN FAULT MORPHOLOGY AND SHEAR HEATING ON EUROPA. N. P. Hammond[1], G. C. Collins[2], J. C. Goodman[2], C. Walker[3], C. Chivers[3], C. McCarthy[4], and M. Zaman[4], Providence College, 1 Cunningham Square, Providence RI (nhammond@providence.edu), [2]Wheaton College, Massachusetts, [3]Woods Hole Oceanographic Institute, [4]Lamont-Doherty Earth Observatory of Columbia University.

Limerick:

Shear heating's an interesting theory
But how can we test such a query?
When fault slip is quicker
do ridges grow thicker?
The answers are making us leery

Introduction: Shear heating is one of several hypotheses for double ridge formation on Europa [1-4]. As faults slide, frictional heating warms up the ice and pushes the surface upward via-thermal expansion. If faults slip fast enough some near-surface frictional melting could be generated [1-4]. Frictional melts that reach the surface could generate plumes or cryovolcanic flows, and melts that sink through the ice shell could deliver near-surface oxidants to the subsurface ocean [5]. Thus, shear heating could play a profound role in shaping both the habitability and geologic evolution of Europa.

Shear heating, however, could be insignificant if fault slip rates are insufficiently slow, and a challenge in testing the shear heating hypothesis is that fault slip rates are poorly constrained. However, it is possible to estimate the magnitude of cyclic-slip caused by diurnal tides acting on faults. According to the model in [6], Europa's faults may slide back-and-forth by 0.01 – 1 meter per orbit. The diurnal tide causes the magnitude of cyclic-slip to vary strongly with fault location and orientation. It is therefore possible to compare fault slip rates driven by the diurnal tide to linea morphology. We can then ask: are faster moving faults more likely to have a double ridge morphology? A strong correlation between predicted shear heating rates and linea morphology would support the hypothesis that shear heating helps to build ridges.

To test this correlation, we calculated the cyclic-slip rate and resulting shear heating rates on 47 stratigraphically recent linea over four regions on Europa in order to ascertain the relationship between fault slip rate and linea morphology. The most stratigraphically recent features were chosen in order to increase our confidence that they are primarily responding to the diurnal stress state in today's ice shell orientation, (hopefully) not affected by nonsynchronous rotation (NSR) or true polar wander.

Model: We use a fault mechanics model to calculate the magnitude of cyclic-slip along faults in response to the diurnal tide. We calculate the local diurnal stress field and determine the resolved shear and normal stresses acting on the fault based on the fault orientation [7,8]. For each fault, the depth of frictional failure is then determined based on a Mohr-Coulomb failure criterion. Once the depth of the fault is known, we use an elastic-half space model to determine the cyclic displacement between fault walls [9]. The magnitude of the displacement depends on the depth of the fault, the shear stress magnitude and the shear modulus of the fault zone. Cyclic-slip rates are then used to calculate the frictional heating rates along the fault as,

$$F_{fric} = v_{slip}\sigma_n\mu$$

where v_{slip} is the slip velocity, μ is the coefficient of friction of ice and σ_n is the normal stress along the fault including overburden. We use a temperature dependent coefficient of friction for ice based on recent laboratory experiments [10,11].

Previously we found that cyclic-slip magnitudes of up to 1 meter per orbit were possible if the fault zone is weak and the coefficient of friction of ice is low [6]. Additional long-term driving stresses acting on the fault, such as those from NSR [12], may increase the frictional failure depth and allow faults to slide farther. Obliquity tides may also alter the diurnal tidal stress field. [13] found than an obliquity 1-degree could best explain the distribution of observed strike-slip faults on Europa. So far we have focused on estimating slip driven purely by the diurnal tide, but will explore more stress fields in future work.

Example Results: Figure 1 shows recent linea we have mapped in the Acacallis Linea region. All the linea included are either younger than the local chaos terrain or just older than the chaos (the only thing they are crosscut by is chaos). We therefore assume these are the stratigraphically most recent linea, making their current coordinates and tidal stress states least affected by potential ice shell rotations. Analysis of this area reveals that linea predicted to have strong heating have a double-ridge like morphology, and most of the linea that are predicted to be weakly heated seem to have a simple trough-like morphology. We also examined an area to the north near Rhadamanthys Linea (near 25°N, 135°E) and found a strong correlation there between heating rate and morphology.

However, initial examinations of the most recent features in the vicinity of Conamara Chaos (near 10°N, 85°E) failed to find any correlation between heating rate and morphology. Initial examination of recent lineae in the high-resolution Galileo images near the north pole also found no correlation. We note that strong interactions between recent fractures and chaos areas were observed in both of these regions.

Discussion: While the region shown in figure 1 and another region show an intriguing correlation between strongly heated faults and ridge development, two other regions we have mapped have shown no such correlation. It remains too soon to draw any firm conclusions from our analysis, as more areas of Europa, more possible stress fields, additional feedback interactions and greater physical parameter space must be explored. We believe, however, that our method of estimating the fault slip rate and comparing our predictions to observed morphology will be a novel test of the shear-heating hypotheses.

References:

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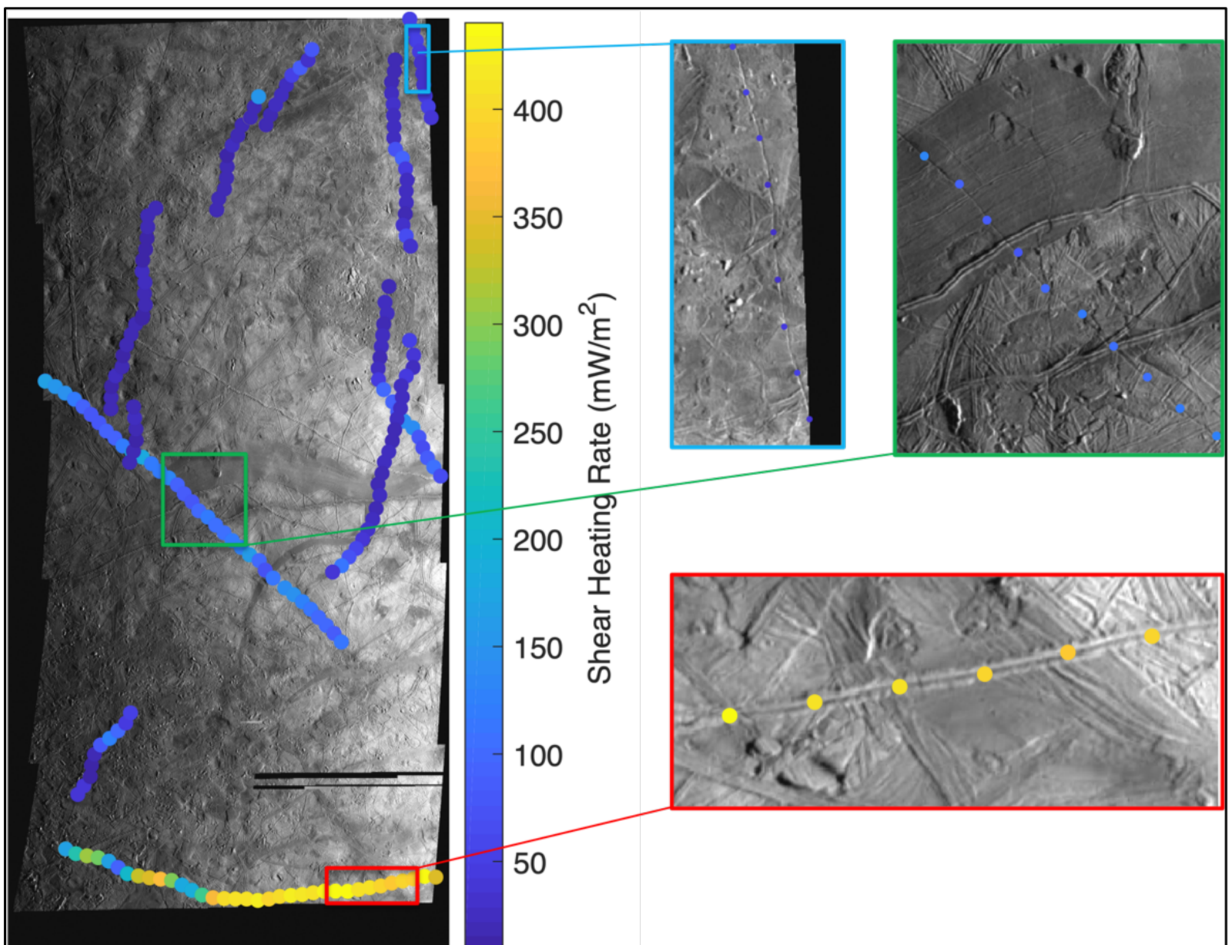

Figure 1: Stratigraphically recent linea on Europa mapped using a Galileo image mosaic covering ~21 S to 9 N, 115 E to 129 E. Colored points represent 10 km long segments where shear heating rates were calculated. Close up boxes reveal that the morphology of strongly heated linea have double ridge morphology and several weakly heated linea have trough-like morphology