TOPOGRAPHIC PROFILE ANALYSIS AND MORPHOLOGIC CHARACTERIZATION OF EUROPA'S DOUBLE RIDGES. C. E. Coulter[1], S. A. Kattenhorn[1] and P. M. Schenk[2]. [1]Department of Geological Sciences, University of Idaho, PO Box 443022, Moscow, ID 83844-3022, cbader@vandals.uidaho.edu, simkat@uidaho.edu. [2]Lunar and Planetary Institute, Houston, Texas 77058, schenk@lpi.usra.edu.

Introduction: Several models exist to describe the formation of Europa's double ridges (defined as near-linear features with a central trough flanked by two, parallel raised edifices [1,2]); however, questions still linger as to how these ubiquitous features form, and if a self-similar process is at work across all scales of ridges on Europa. The existing ridge formation models invoke cyclical tidal working (with its associated opening and closing of fractures), inducing forced extrusion of materials onto Europa's surface [1], or perhaps frictional heating along crack walls that builds up the ridges [2]. There are also models of incremental ice-wedging within sub-surface cracks [3] and cryovolcanism [4].

We created 229 topographic profiles using combined stereographic (3D) and photoclinometric (PC) images [5,6] for 24 ridge pairs (12 of which display apparent lateral offsets of relatively older crosscut features). These ridges are located in 6 areas in both the leading and trailing hemispheres (corresponding resolutions are given in parentheses): 1) Bright Plains (18 m/pix), 2) Conamara Chaos (180 m/pix), 3) Rhadamanthys Linea (64 m/pix), 4) The Cilix region (110 m/pix), 5) 17EDISSTR01 (northwest of Katreus Linea) (55 m/pix) and 6) Argadnel Regio (~6 m/pix). We hope to use topography as a proxy for ridge formation processes through this thorough analysis.

Measurements: We measured individual ridge height and width, total width (double ridge pair), peak to peak (PTP) distance (across double ridges), and the distance and height to the medial trough for each ridge in a ridge pair. Our measurements for 24 ridge pairs, with associated upper limits of outer slope angles, are shown in Figures 1 and 2. We define the northern or westernmost ridge in a ridge pair as Ridge A and the southern or easternmost ridge in a pair as Ridge B (ridges will be labeled as such from this point forward). Twenty of the Ridge A flanks profiled are in shadow, while only four of the Ridge B flanks profiled are in shadow. Associated errors for slope angles are ±3˚. Lateral and vertical distance errors are conservatively estimated as ± one pixel value for each image.

Ridge Morphologies: In general, double ridge morphologies involve two parallel, raised edifices flanking a central trough [1, 2]. The ridges are near-linear and have relatively smooth outer slopes (with slopes of a few degrees up to about 30° with an average of about 10°). Double ridges may have individual widths of about a hundred meters to about 4 km, with individual ridge heights of a few 10s of meters up to about 400 m. Ridge morphology may also be variable along strike. For example, peak to peak distances may increase or decrease along strike or one ridge in a pair may be consistently taller (as measured from the medial trough or the outer flanks). The lateral or vertical distance from the medial trough to one ridge peak may vary along strike, and sometimes only one ridge is recognizable in a ridge pair (the other may be disturbed by a crosscutting feature or is just not as prominent).

Along strike variability may indicate that changes in ridge morphology may be influenced by background structures (some ridge pairs show background structures trending up onto their outer slopes, as described in [4]). Younger crosscutting features can also affect ridge morphology (i.e., height, PTP distance and/or individual ridge widths) in localized areas.

Discussion: The low outer slopes of ridges and overall low average height to total width ratios (Fig. 1) suggest predominantly time-dependent viscoplastic gravitational collapse. Variability in morphology between ridges may be related to disparate mechanisms driving ridge development (whether extension, compression, or shearing). The formation processes are likely to influence the rate of ridge construction as well as the temperature (and hence rheology) of the icy material involved. We observe a distinct upper limit of 0.58 for the ratio of average ridge height to PTP width (Fig. 2), suggesting that once an active ridge exceeds a certain height, the ridge peaks begin to geomorphically migrate apart in order to maintain a limiting slope of the inner and outer flanks through gravitational collapse (whether viscoplastic or granular flow). However, the smoothness of some outer slopes may indicate that plastic flow or relaxation, not granular flow, dominates the post-formation morphology of ridges. Individual height-to-width ratios of the 24 ridge pairs measured here fall within a wide range, with maxima occurring at 0.52 and 0.53 for Ridge A and Ridge B, respectively. This implies outer slopes of no more than ~28°. This is slightly less than the suggested angle of repose of loose granular ice (~34˚ [7]), also hinting at the possibility of relaxation by viscoplastic flow. Low ratios of average ridge height to peak to peak width may indicate underdeveloped ridge heights, but may also be a sign of dilation across a ridge. Dilation may cause a tectonic increase in the peak to peak distance. Finally, the variability in the ratios of average height to total width along individual ridges indicates that some ridge pairs may have evolved differently along their lengths; an effect partially related to changes in ridge orientation along the observable length and associated variability in ridge kinematics. Future work with this data will include an evaluation of ridge formation by subsurface dike intrusion as well as a displacement ratio analysis [8] (shearing to opening) on ridge pairs that show apparent lateral offset and that have kinematic motion indicators. A displacement ratio analysis combined with the topographic measurements and morphologic characterizations discussed here, will help us to better define ridge formation mechanisms (either dilation, contraction, strike-slip motion, or some combination thereof).

References: [1] Greenberg et al. (1998) Icarus 135, 64-78. [2] Head et al. (1999) JGR 104, No. E10, 24,223-24,236. [3] Melosh & Turtle (2004) LPSC XXXV, Abstract #2029. [4] Head et al. (1998b) LPSC XXX, Abstract #1491. [5] Schenk (2002) Nature 417, 419-421. [6] Schenk & Pappalardo (2004) Geophys. Res. Lett. 31. [7] Kadel et al. (1998) LPSC XXIX, Abstract #1078. [8] Bader & Kattenhorn (2007) LPSC XXXIX, Abstract #2036.

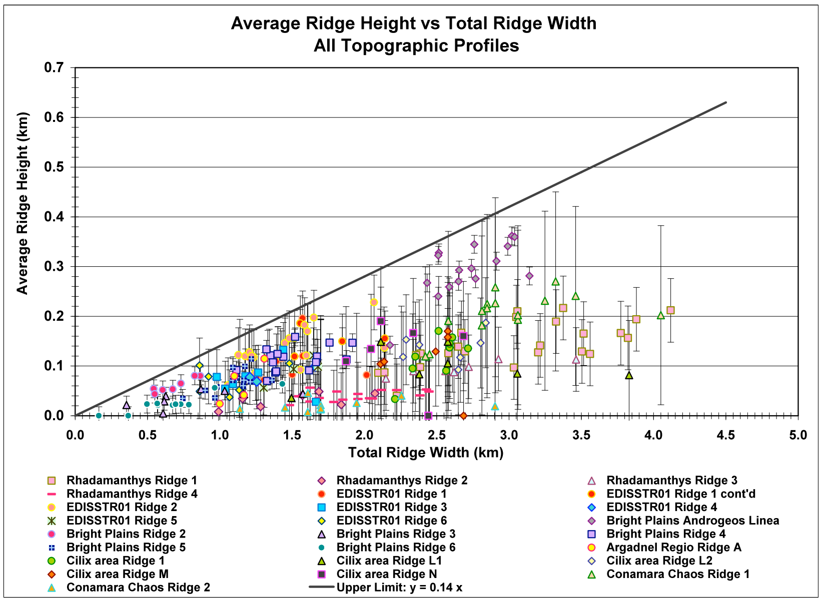

Figure 1. Graph of average ridge heights (A+B/2) vs. total ridge width, with a maximum ratio of 0.14 (height/width), indicating that ridge pairs can be wide and short or wide and tall but not tall and narrow.

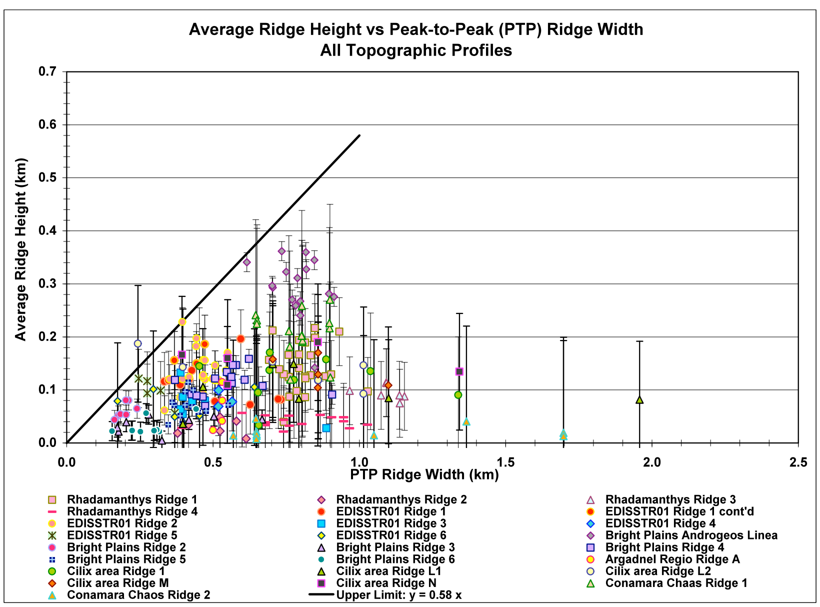

Figure 2. Graph of average ridge height (A+B/2) vs. peak to peak (PTP) distance for 229 ridges. The maximum ratio calculated is 0.58, indicating that ridges may only grow up to a certain height before their peaks must geomorphologically move apart.