IDENTIFYING CONTRACTION AND EXPANSION ALONG DOUBLE RIDGES AND BANDS ON EUROPA WITH STRIKE-SLIP DISPLACEMENTS. C. Culha[1], A. G. Hayes[2], M. Manga[1], A. Thomas[3], [1]University of California, Berkeley, Department of Earth and Planetary Science, (307 McCone, Berkeley, CA 94720-4767, c.culha4@berkeley.edu), [2] Cornell University, [3]Stanford University.

Introduction: Stresses from diurnal tides and possibly from non-synchronous rotation cause Europa's surface to expand during high tide and contract during low tide. These stresses may be sufficient to create cracks [1] that ultimately lead to the development of the various lineaments preserved on the surface.

A variety of models have been proposed to create lineaments, including diapirism [2], volumetric expansion to make bands [3], folding of ductile ice [4] shearing to make ridges [5], opening-mode fractures [6], and shearing of opening mode fractures [7]. Each of these predicts different lineament-normal displacements. Our objective is to quantify such displacements, and their variation along strike and with tectonic feature.

Method: kinematics We exploit cross-cutting relationships to map both strike-slip and normal displacements. Faults were mapped using images collected by the Galileo SSI spacecraft. In particular, we measure the relationship between the main lineament and the older lineaments it crosses. Variation in the offset of crossing lineaments allows derivation of both the magnitude and direction of along-strike and normal displacement of the main lineament. On geometric grounds we expect

$$O_{T_i} = O_S + \delta\cos(\theta_i) \qquad (1.1)$$

where O_{T_i} is the total (measured) offset, O_S is the strike-slip offset, θ_i is the incidence angle of the crossing feature, and δ is the lineament-normal expansion or contraction component. The strike-slip segment is positive if the lineament is a right-lateral strike-slip fault and negative if it is left-lateral. The component of the normal displacement (δ) is positive if the lineament has expanded and negative if it has contracted.

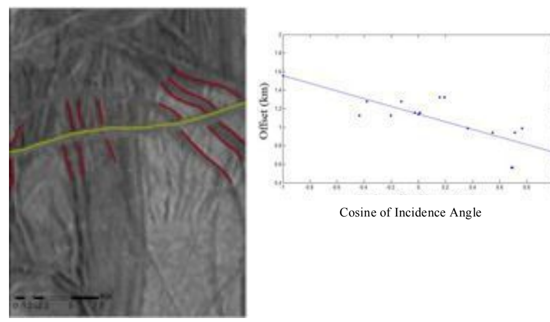
Total amount of expansion for *n* features is given by:

$$E = \delta\sin(\theta) \qquad (1.2)$$

where $\sin(\theta)$ is the average of $\sin(\theta_i)$ for all incidence angles. Positive E is expansion and negative E is contraction. Coulter performed a similar analysis to identify the slip and feature-normal displacement for ridges, though not bands [8]. Our analysis differs in the approach to fit models to the data and hence the displacements that are best resolved.

Results: We have mapped 8 lineament systems (some are displayed in Figure 1) and have observed a correlation between lineament morphology and strike-slip/normal displacement. Bands typically record divergence while double ridges preserve convergence. There is no observed variation in strike-slip displacement with distance along the lineament, implying that cumulative strike-slip displacement is not a key variable.

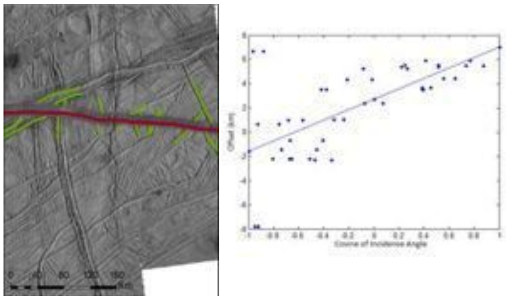
Double ridges. Double ridges show right or left lateral strike-slip with convergence.



Lineament 1. *Lineament offset at latitude 12°S and longitude 143°E. The main lineament (in yellow) is a double ridge lineament with* $\delta = -0.41 \pm 0.12$ *km,* $O_S = 1.14 \pm 0.05$ *km, and* $E = -0.36 \pm 0.11$*km. Each older lineament is displayed twice, because the angles on each side of the lineament are not necessarily equal.*

Lineament 1 is a right-lateral double ridge. It shows contraction, $E = -0.36 \pm 0.11$ km.

Bands: Bands also express both right and left lateral motion and involve a component of expansion. Ridge Bands show expansion and strike-slip as well, suggesting a similar formation mechanism to normal bands. It is recognized that normal bands are formed by expansion and strike-slip faults [1][2][3][4][7]. Our results confirm this. If a similar mechanism formed both morphologic classes, one may represent an older or faster forming unit.



***Lineament 2**. Lineament offset at latitude 9°S and longitude 140°E. The main lineament (in red) is a band lineament with* $\delta = 4.30 \pm 0.78 km$, $O_S = 2.70 \pm 0.45 km$, *and* $E = 3.40 \pm 0.62 km$.

As an example, lineament 2 is a cycloid that later experienced dilation. The center of the lineament appears as a double ridge, but it only intersects 2 lineaments, so it is still a good example of a band. There is evidence that the lineament is expanding, $E = 3.40 \pm 0.62$ km. The main difference between ridges and bands, in addition to showing convergence vs. divergence, is that the magnitude of normal displacement, $|E|$, is much larger for bands than for ridges.

Hoppa *et al.* (1999, 2000) noted that lineaments above 35°N are left lateral and those below are right lateral [9]. Our results are consistent with these findings.

Discussion: Our measurements indicate that what ever process created double ridge lineaments led to net contraction. It is not clear that any of the proposed mechanisms for making ridges produces contraction. Mechanisms involving eruption [10], diapirism [2], folding [4], or tidal pumping of water to the surface [11] should also produce extension; the shear-heating model [5] does not predict lineament normal displacement. Coulter [8] did not find that double ridge features have the same kinematics, with some displaying extension, others contraction.

Ridge bands visually appear as multiple double ridge lineament lined up parallel to each other, but the results show that the feature is expanding (whereas double ridge features appear to be contracting). Lineament 2, ridge bands, and other mapped bands have large strike-slip offsets, supporting the notion [12] that shearing plays a role in forming ridges within bands. Mapping multiples of each type of band will reveal which parameters form each type of band. Mapping additional lineament systems will help to elucidate additional correlations between morphology and geometry, leading to a detailed description of lineament formation mechanisms.

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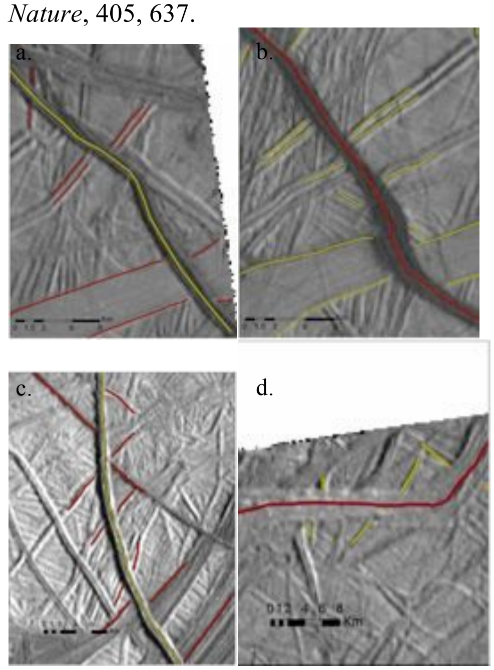

***Figure 1.** Lineaments on the left (in yellow) are double ridge lineament and those on the right (in red) are bands. a) and b) are ~12°S and ~143°E. c) is ~15°S and ~140°E. d) ~48°S and ~148°E.*