Morphological Analysis of Bands in Europa's E-15 Region

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Introduction:

We use stratigraphic relationships as a means to understand the evolution of Europa's ice shell surface over time. Tectonic motion drives changes in surface morphologies, divergence of the plates creates dilational features like bands and ridges, and convergence may cause subduction-like processes.

These subduction processes are referred to as subsumption, as they represent areas where less dense layers of warming ice are subsumed under an overlying plate of ice (see Figure 2). They are visible in the form of subsumption bands, which are asymmetric, with the features on one side being abruptly truncated and not visible on the other side (Kattenhorn and Prockter, 2014).

Collins et al. (2022) make the case for episodic plate tectonics through mobile lid motion in regional patches. Europa does not have distinct quantifiable tectonic plates, rather mobile patches of ice that travel distances of less than a hundred kilometers before coming to a halt.

Linear features have the tendency to overlap and overprint others, and through mapping of bands (>5km width) and narrower linear features such as ridges and freactures, it may be possible to constrain distinct time-steps in plate motion, and linear feature formation at their boundaries. Understanding differences in feature formation over time will provide information toward the evolution of Europa's ice shell.

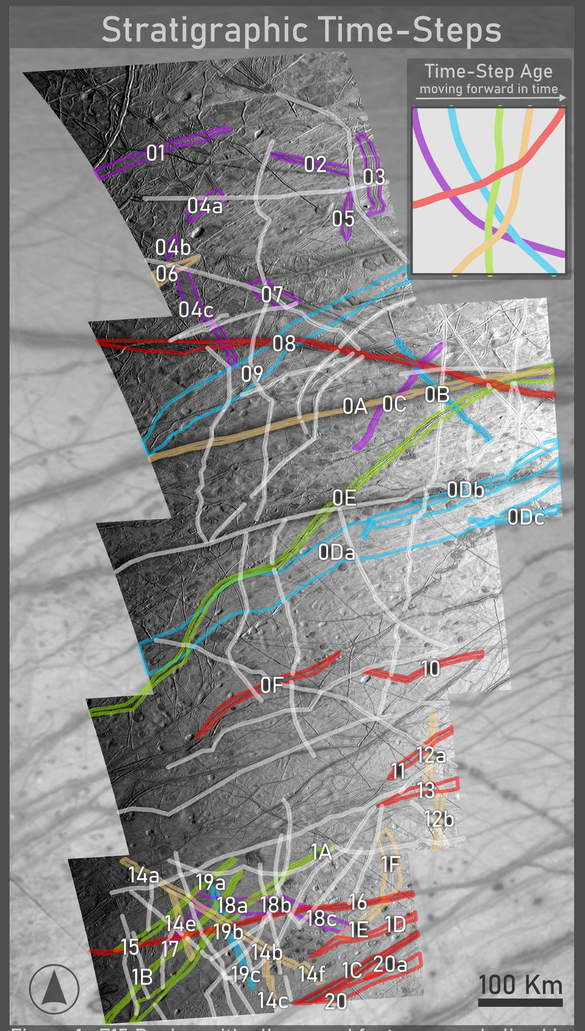

Figure 1: E15 Region with all mapped features symbolized in Time-Steps with supporting features symbolized in white

Methods:

The process of choosing which features of the E15 region to include in mapping started with determining candidacy based of preliminary examination of band width (>5km). This criteria led to a selection of thirty-two features that were digitized following the perimeter of structure rather than extending into the darker albedo material on margins.

The centerlines for bands were derived using a collapse tool then transects were generated along center line; transects were than clipped by band features. Each team member completed this process then compared to judge repeatability of width examination.

Supplemental features such as fractures and double ridges were digitized to aid in determining time-step classification. Through examination if cross cutting relationships the minimum about of time-steps that could be used to represent stratigraphic order is six. However through comparison of team member's ordering, there are a variety of classifications for less connected bands that would satisfy discernible cross cutting relationships.

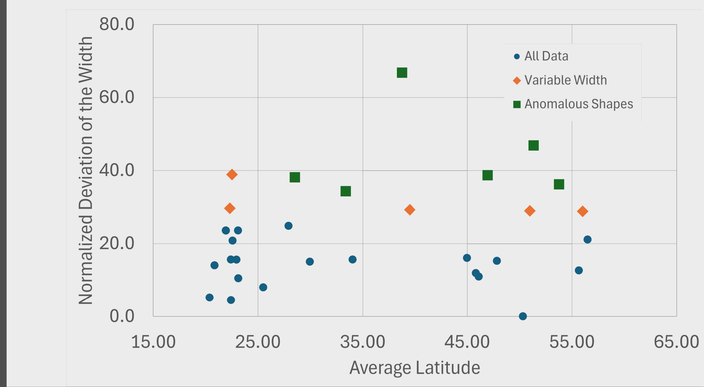

Figure 3: Normalized Deviation of Width vs Average Latitude for each feature. The blue data set represents typical features. Orange diamonds are features that have significantly variable width. Green squares are features with other anomalous shapes.

Feature	Length (km)	Average Width (km)	Normalized Deviation (%)	Morphology	Comment on Shape
02	97.2	6.5	28.8	Lineated	Variable width ◆
04	211.6	13.1	29.0	Lineated	Variable width ◆
05	60.1	9.4	36.2	Smooth	Collapse at margins ■
06	62.6	10.3	46.9	Smooth	Wedge shape ■
08	559.1	7.8	38.7	Ridged	Variable width ◆
0D	555.1	17.5	66.8	Ridged	band splays into 'fingers' on Eastern side ■
0E	713.8	6.9	29.3	Ridge Complex	Variable width ◆
0F	337.3	6.3	34.3	Lineated	Collapse at margins ■
13	98.9	8.8	38.1	Smooth	Wedge shape ■
19	140.4	6.5	29.7	Ridged	Variable width ◆
1A	346.9	7.0	38.9	Ridged	Variable width ◆

Table 1: All features with normalized deviation of width larger than 25%, along with comments on their shapes, and according interpretations.

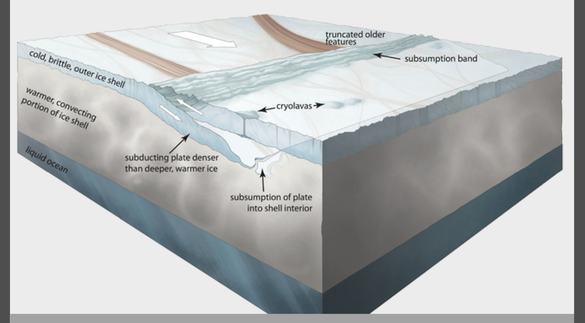

Figure 2: Kattenhorn, Simon A., and Louise M. Prockter. "Evidence for subduction in the ice shell of Europa." Nature Geoscience (2014)

Interpretations and future work:

There are a lot of directions the project could be taken from this point. A full stratigraphy would make it possible to understand temporal relationships between features, and potentially the stresses that formed them. Being able to analyze temporal and spatial trends together might reveal relationships that have not yet been seen. Orientation data for each feature might be useful to understand trends in propagation direction of bands.

To expand the dataset, more regions with high resolution photos could also be mapped. This would be useful especially to understand if the positive correlation between feature length and normalized standard deviation of width is real, or if it is a manifestation of mapping technique. Before doing this, redefining precisely what the classifications for 'ridges' and 'bands' would be necessary. This would also be useful to further investigate feature 09, which has been deemed a 'subsumption band' after Kattenhorn & Prockter, 2014.

Work on identifying morphology was difficult, due to bands frequently not fitting in cleanly within one category or another, but often exhibiting traits of all three classifications (Smooth, Ridged, Lineated) to varying degrees. This opens up an opportunity for alternative classification systems, or alterations to the existing method.

References & Acknowledgements:

1] Collins G. et al. JGR Planets (2022); [2] Daubar,et al. Space science reviews (2024); [3] Greeley et al. JGR (2000); [4] Howell and Pappalardo, GRL (2018); [5] Howell and Pappalardo, Nature Communications (2020); [6] Kattenhorn and Prockter, Nature Geosci. (2014)

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