RECONSTRUCTING THE HISTORY OF PLATE MOTIONS INVOLVED WITH THE FORMATION OF LIBYA LINEA, ASTYPALAEA LINEA, AND CYCLADES MACULA, EUROPA. Charlene E. Detelich[1], G. Wesley Patterson[1], and Geoffrey C. Collins[2], [1]The Johns Hopkins University Applied Physics Laboratory, Laurel, MD (charlie.detelich@jhuapl.edu), [2]Wheaton College, Norton, MA.

Introduction: Europa, an icy moon of Jupiter, has an anomalously young surface age (~40-90 My) and is covered in tectonic features [1-2]. Previous research has shown that these tectonic features break the surface into plates that rotate with respect to one another [3-9]. The successive episodes of feature formation and associated plate motions create a highly complex geologic history. Here, we examine the cross-cutting relationships involving a collection of features that include Astypalaea Linea, Libya Linea, and Cyclades Macula to characterize and reconstruct their geologic history. We then use these relationships along with an open source visualization tool, GPlates, to reconstruct the history of plate motions in this region of Europa's southern anti-jovian hemisphere. Preliminary results of this effort suggest a multi-stage formation history for Libya, Astypalaea, and Cyclades resulting from plate rotations and translations driven by combinations of dilation, transtension, and (potentially) convergence.

Background: Libya and Astypalaea Linea are located in the southern anti-jovian region of Europa and are both classified as pull-apart or smooth bands [10, 11]. In general, the margins of smooth bands can be reconstructed by matching previously continuous features on either side of the bands, similar to terrestrial mid ocean ridges [3 and 12]. Libya Linea trends SW-NE and consists of highly complex intertwining bands with internal lineations whose orientations are not consistent. While Libya's internal morphology varies spatially, its northeastern segments share characteristics with Astypalaea Linea, suggesting a shared/similar formation history. Astypalaea Linea, which also broadly trends SW-NE, consists of several N-S trending ridge segments that are aligned in a right-stepping, NNE-SSW-trending en échelon pattern [13]. The ridge segments define the boundaries of several rhomboidal pull-apart features, including Cyclades Macula [12]. Cyclades Macula is a low albedo, rhomboidal, pull-apart feature, notable by its scale and for an anomalous set of isolated tectonic structures with vertical relief that have en échelon geometries located within the feature. In addition, apparently coeval tectonic features are observed that cross into Cyclades, orthogonally intersecting the pull apart feature's boundaries and ending within Cyclades's interior [10-12].

Methods: To characterize the geologic history of the region that encompasses Astypalaea Linea, Libya Linea, and Cyclades Macula, we examined cross-cutting relationships among ~70 tectonic features and established a stratigraphic framework (Figure 1). This was accomplished using an image mosaic built from data acquired during the Galileo mission's E17 encounter. These data have resolutions ranging from ~40 m/pix to ~200 m/pix and are illuminated from the northeast. The stratigraphic framework we developed was then used to define ~300 plates in the region. Cross-cutting and offset features associated with the boundaries of the plates were identified and are being used to reconstruct the geologic history of this prominent and complex area of Europa's anti-jovian, southern hemisphere. This is being accomplished with the open source software package GPlates (www.gplates.org) [14]. GPlates utilizes georeferenced spacecraft image data to allow a user to map plate boundaries in a spherical projection and create polygonal fragments that can be interactively reconstructed [15]. The software calculates Euler poles of rotation that describe the motions of each plate and can create visual time-ordered, multi-stage reconstructions.

Results: The youngest tectonic features that we used for our reconstructions are E-W oriented double ridges along which small amounts of offset is observed. Overall, the youngest tectonic features appear to be concentrated in the northwest and northeast of Libya Linea. However, the eventual opening of Libya Linea, Astypalaea Linea, and Cyclades Macula complicate the stratigraphic framework. These features all appear to be connected with one another at various points in time. The opening of smaller tectonic features located between present day Libya, Astypalaea, and Cyclades heavily influence the opening of these major tectonic features and are key to creating as accurate a reconstruction as possible. To the south of Libya, Astypalaea, and Cyclades, there is a distinct lack of reconstructable tectonic features. However, to the east of Libya, Astypalaea, and Cyclades, there is an older band that marks the connection of at least three plates and has varying morphologies across its length. Older still are several E-W oriented bands with diffuse boundaries and high albedos. The oldest bands in the entire study region are a set of two N-S oriented bands with prominent parallel internal lineations (Figure 1).

A preliminary GPlates reconstruction of the region indicates several distinct stages of plate motion associated with the formation Libya Linea, Astypalaea Linea, and Cyclades Macula. An initial stage of smaller-scale clockwise plate rotations in the region is followed by a stage of larger-scale plate translations that correspond with the opening of Libya Linea via right-lateral, NE-SW trending transtension. This stage also leads to the dilation of Cyclades Macula and Astypalaea Linea along N-S trending, right-stepping en échelon fractures. A second stage of pure N-S dilation of Astypalaea and Cyclades drove another stage of clockwise rotation. This opening stage also drives additional NW-SE dilation of the eastern half of Libya Linea. A final stage of counterclockwise plate rotations led to another opening phase for Libya Linea, leaving it in the state we observe today. The missing image data to the north of the central part of Libya Linea makes our current interpretation of this last stage uncertain, as it hinges on a few poorly-observed features that cannot be traced very far beyond Libya.

While our current reconstruction succeeds in describing the full deformation history of Astypalaea Linea and Cyclades Macula, a full reconstruction of Libya Linea was not achieved resulting in several thousand square kilometers of "missing" surface material. This suggests there is an additional stage in the reconstruction of this region that has not been captured or that a significant amount of convergence may have occurred early in the formation of this prominent pull-apart band. The latter explanation is supported by a lack of reconstructable offset features along much of Libya Linea.

Conclusions: We have developed a stratigraphic framework of tectonic features within and surrounding Libya Linea, Astypalaea Linea, and Cyclades Macula. Through this framework, we have identified distinct stages of plate motions that contribute to the formation of these features. Astypalaea Linea and Cyclades Macula have opened in as few as two stages. However, these stages are intertwined with the multiple opening stages of Libya Linea, as all three tectonic features appear to be linked. Locally, the geomorphology of Libya Linea, and crosscutting relationships, indicate it has opened in at least four stages along slightly different opening paths, causing complex disaggregation. We continue to work on reconstructing the multiphase band Libya Linea and surrounding regions with an aim to fully understand the sequence of motions that have created this region of Europa.

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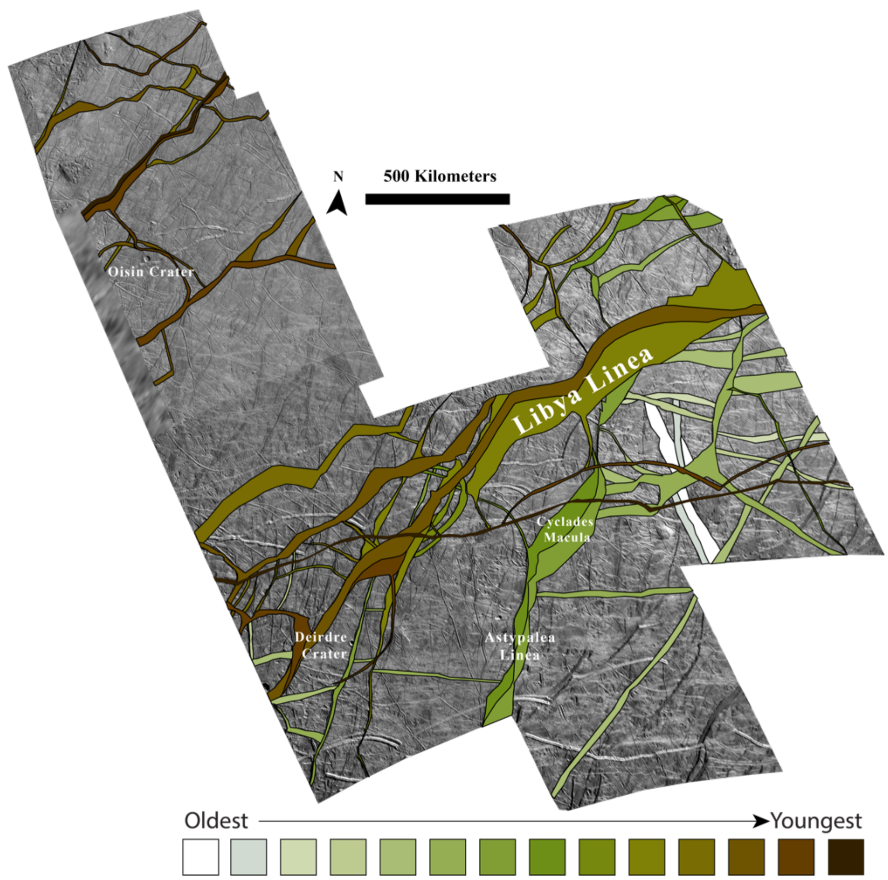

Figure 1: Geologic map of bands within and surrounding Libya Linea and Astypalaea Linea showing relative ages of mapped band-like features. Darker colored bands are younger while lighter colored bands are older. Basemap is part of Galileo E17 REGMAP mosaic in orthographic projection centered at 60.21°S, 163.53°E. Resolution ranges from 40-200 m/pix and illumination is from the northeast.