AN ANALYSIS OF PLATE MOTIONS ON EUROPA ASSOCIATED WITH THE FORMATION OF ASTYPALAEA AND LIBYA LINEAE.

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Introduction: The surface of Europa is heavily dissected by tectonic features that may act as the boundaries of icy lithospheric plates. Analyses of plate motions on Europa have provided insight into the formation and evolution of specific feature types and provided a means of testing processes and assumptions based on terrestrial plate tectonics [e.g., 1-4]. The scale of plates observed on Europa is generally on the order of 10^4-10^5 km^2, or less than ~0.3% of the satellite's surface area. This presents a significant challenge to reconstructing plate motions in regions with complex geologic and cross-cutting relationships (i.e., much of Europa's surface). In this study, we use an open source visualization tool and an inverse modeling code to reconstruct the history of plate motions for a portion of Europa's surface containing Astypalaea and Libya Lineae (Fig. 1) in order to search for evidence of convergence/subsumption.

Background: Astypalaea and Libya Lineae are located in the southern antijovian region of Europa and are both classified as dilational bands. In general, the margins of dilational bands can be readily reconstructed, indicating that their interiors were emplaced via separation of the satellite's lithosphere [5]. Astypalaea Linea, observed at resolutions as high as ~40 m/pixel, has morphological characteristics that suggest it consists of several N-S trending ridge segments that are aligned in a right-stepping, NNE/SSW-trending *en echelon* pattern [6]. The ridge segments define the boundaries of several rhomboidal pull-apart features (e.g., Cyclades Macula) and the orientations of parallel lineations within these pull-aparts suggest that Astypalaea opened at a highly oblique angle. Libya Linea, observed at resolutions as high as ~200 m/pixel, shares morphological characteristics with Astypalaea Linea, suggesting a similar formation history.

Methods: Geologic mapping of Astypalaea and Libya Lineae was used to define the boundaries of six plates in the region (Fig. 1). Geologic indicators for the direction of opening of the bands and observed cross-cutting relationships of features that are cut by, intersect (defining plate boundaries), or overlap the lineae provide information on the magnitude and relative timing of plate motions that were necessary to accommodate the formation of the bands. Visualizing and validating those plate motions was accomplished using the open source software GPlates (www.gplates.org) [7] and an inverse modeling code for determining poles of rotation (and their associated errors) [3].

GPlates utilizes georeferenced spacecraft image da ta to allow a user to map plate boundaries as polygon fragments in a spherical projection and to interactively reposition those fragments to line up offset features [8]. The software can provide a pole of rotation that

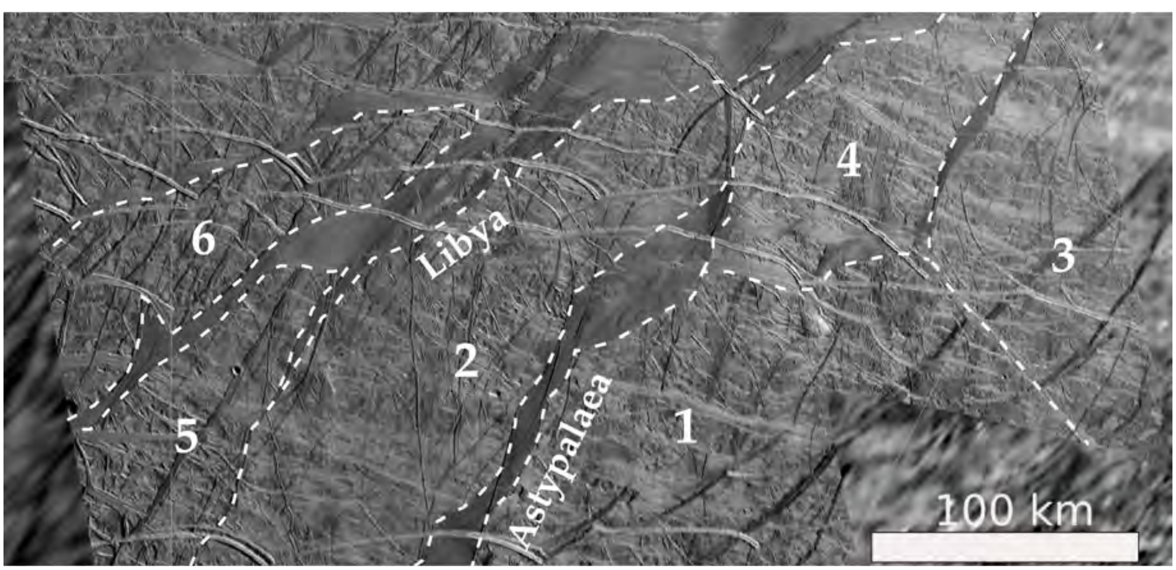

Figure 1. Portion of Galileo E17 REGMAP mosaic (at ~200 m/pixel) that includes Astypalaea and Libya Lineae. Plate boundaries defined, in part, by the lineae are outlined with dashed lines and labeled 1-6.

describes the motion of one plate with respect to another but does not provide any quantitative information on the quality-of-fit for the rotation.

The inverse modeling technique [3] uses the displacement azimuths of offset features separated by a plate boundary to determine a least-squares best-fit Euler pole of rotation for a two-plate system. It employs an iterative grid-search method to test a wide range of possible rotations, providing a means of assessing confidence in the location of a pole. The technique is difficult to apply to multi-plate systems but, in combination with GPlates, can provide a powerful means of validating complex plate motions.

For this study, the plates in the Astypalaea/Libya region are repositioned in GPlates to realign offset features along the plate boundaries and poles of rotation associated with those motions are recorded. The locations of offset features associated with a subset of plate boundaries are also used by the inverse modeling code to determine best-fit rotation poles, with associated errors. The results are used to refine the collection of rotations necessary to reconstruct the history of plate motion in the region.

Results: Preliminary results suggest a reconstruction of the region that closes Astypalaea Linea and partially closes Libya Linea is possible, given constraints provided by the geology and cross-cutting relationships in the region and by inverse modeling of a subset of boundaries within the collection of plates (Fig. 2). These constraints indicate an initial stage of concurrent dilation and right-lateral shear associated with the formation of Astypalaea Linea and an unnamed smooth band along the boundary between plates 3 and 4. This is followed by a later stage of right-lateral shear associated with the formation of the stratigraphically younger Libya Linea. Limited amounts of convergence are required to accommodate plate motions during each stage of formation (Fig. 2b,c). The reconstuction is broadly consistent with previous work in the region, which includes the suggestion of some convergence associated with the formation of Astypalaea Linea [5,9]. Additional work to refine the reconstruction of Libya Linea and search for evidence of subsumption on scales similar to what has been observed at Falga Regio [4] is ongoing.

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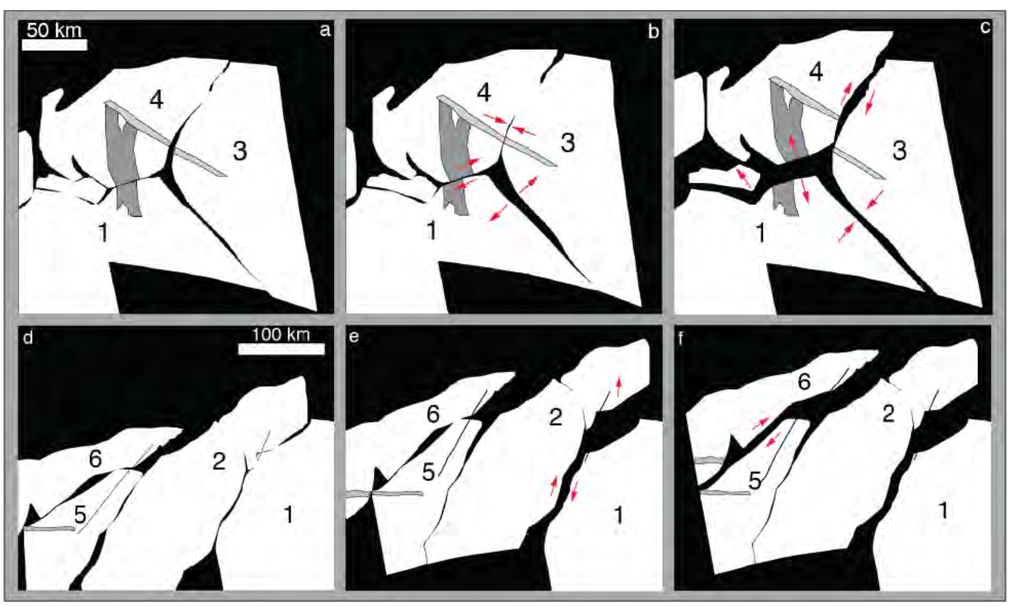

Figure 2. Two-stages of plate motions in east (a-c) and west (d-f) portions of the Astypalaea/Libya region, inferred from GPlates reconstruction. (a) area east of Astypalaea post-reconstruction. (b) Stage 1: initial opening of along plates 1 and 3; convergence along plates 3 and 4. (c) Stage 2: opening between plates 1 and 4; convergence along plates 1 and 3 – leads to present-day plate configuration. (d) plates including Astypalaea and a western portion of Libya Linea post-reconstruction. (e) Stage 1: concurrent right-lateral shear and dilation along plates 1 and 2 (Astypalaea) . Stage 2: (f) right-lateral shear along plates 5 and 6 (Libya) – leads to present-day plate configuration.