CONVERGENT BOUNDARIES ON EUROPA: A NUMERICAL APPROACH TO EULER POLE ANALYSIS AND ITS IMPLICATIONS FOR PLATE RESCONSTRUCTION. G. W. Patterson[1], J. W. Head[1], and R. T. Pappalardo[2], [1]Department of Geological Sciences, Brown University, Providence, RI, 02912 (Gerald_Patterson@brown.edu), [2]Laboratory for Atmospheric and Space Physics, University of Colorado, Boulder, CO 80309.

Introduction: Europa's surface is highly fractured and broken into plates that have rotated with respect to one another. The effect of these rotations can be seen as regions of extension, strike-slip motion, and possibly compression [1-5]. Various authors have tried to reconstruct several of these regions in an effort to gain a better understanding of the tectonic history of the icy satellite [4-8]. This analysis will focus on using numerical methods of determining an Euler pole to test quantitatively the validity of reconstructions that previously suggested that a set of lineaments in the Castalia Macula region had undergone compression [4,5] (Fig. 1).

Background: The region of interest for this analysis is from 10° to –11° latitude, and 218° to 232° longitude (Fig. 1) with the prominent dark spot Castalia Macula located near its center. A set of lineaments (marked by white dashed lines in Fig. 1) trends approximately N-S through the region, with one of the lineaments turning toward the east and then south as it is traced from west to east. Numerous features crosscut and are displaced by these lineaments, and strike-slip displacement with a right-lateral sense of motion is suggested by the offsets of these preexisting structures. The crosscutting relationships of these features also suggest that the lineaments are contemporaneous in age.

Previous attempts to reconstruct these lineaments have suggested that a component of compression is necessary in order to achieve a 'best-fit' reconstruction [4,5]. Patterson and Pappalardo [4] suggested a reconstruction which indicated that oblique compression had occurred along the lineaments. The majority of this compression could be found in the lower half of the lineament set shown in Fig. 1, with smaller regions of compression found along the upper portion of the lineament set and possibly along a band that truncates the set of lineaments in the southern portion of the image. Sarid et al. [5] show a reconstruction in which the lineaments could be realigned with essentially strike-slip motion only along the lineaments and all compression concentrated in a band at the southern extent of the ridges (which they termed muscle-tissue terrain). They suggested that the morphology of this terrain might be characteristic of regions of convergence.

Discussion: Both previous analyses of this region employed a 'cut-and-paste' method, in which the determined plates in an image are manually separated and reoriented in an effort to reconstruct preexisting features. An Euler pole of rotation for the reconstruction shown was not determined in either case. Defining a pole of rotation is an essential step in determining the validity of a reconstruction when the size of the region in question is such that the curvature of the satellite is relevant. The extent of these lineaments (~800 km over ~21° of latitude and ~14° of longitude) suggests that such is the case for this area.

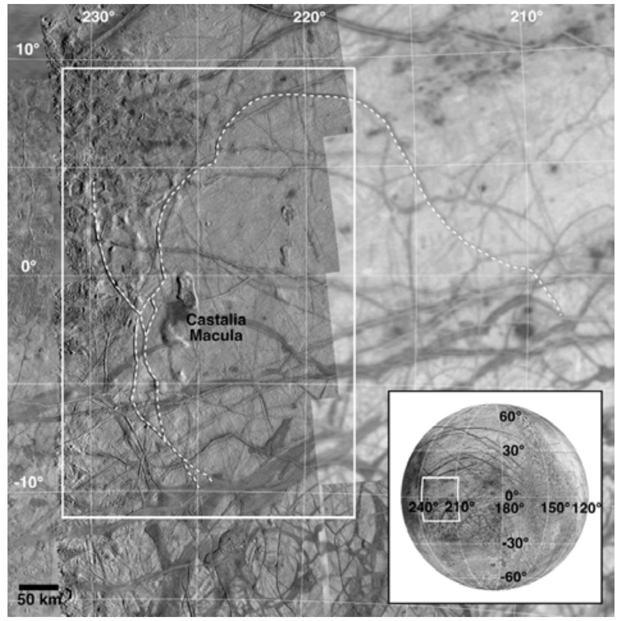

Fig. 1. Mosaic of Galileo and Voyager images of the Castalia Macula region taken from the USGS controlled photomosaic map of Europa (I-2757). The resolution of the mosaic ranges from <500 m/pix to ~2 km/pix. The white box indicates the region used in the following reconstruction (Fig. 2) and the dashed white lines indicate the set of lineaments considered in performing the reconstruction.

Terrestrial methods of determining a pole of rotation for a region in which rigid plate motion has occurred typically take a forward approach, in which the trend of strike-slip faults and/or spreading velocities of ridges at the boundary of a plate are used to trace the location of the pole of rotation for divergent and transform boundaries [9]. These methods are applicable to Europa and have been used to determine poles of rotation for some features [7,8]. The kinematics of convergent boundaries, on the other hand, makes determination of a pole of rotation difficult when using a forward approach.

Here we will take advantage of an inverse method of locating the Euler pole for a rotated plate [10] to determine if a unique pole of rotation exists about which the offset of features across one of the lineaments described above can be reconstructed. This approach uses an iterative grid-search technique to locate the pole of rotation for the plate; therefore, it can be used to test all possible combinations of location and rotation within the grid resolution limits imposed. This technique is mathematically robust but is limited in that it cannot consider interactions involving more than two plates.

Considering the latter limitation of the technique described above, as well as the contemporaneous age of the set of lineaments, we chose to apply the inverse method to the eastern-most lineament (Fig. 2). Twenty-seven offset features spanning the entire length of the lineament were used in this analysis. The main criterion for choosing these features was clarity of the precise location of each feature across the plate boundary.

Results: Application of the inverse model to this lineament in the Castalia Macula region indicates an Euler pole exists at 11º lat. and 253º lon. with –0.43º rotation. The offset of preexisting features across the lineament can be realigned using this pole to within an average of 235m/pixel (or approximately one pixel in the image) and the reconstruction can be seen in Fig. 2. The search grid used to obtain this result was a 1ºx1º lat/lon grid (covering 90º of latitude and 360º of longitude) which tested rotations from -1º to 1º in 0.01º increments. Coarser grids testing wider ranges of rotation were also employed to ensure that the pole indicated is a unique solution.

The ridge along the region where the majority of compression occurs in this reconstruction has a morphology that differs from that of typical double ridges described in the literature [11]. Instead of a set of bounding ridges with a V-shaped axial trough, it is characterized by a flat-appearing hummocky region bound on either side by ridges. This may be a morphology that is associated with compression.

The reconstruction shown in Fig. 2 further indicates that the band which truncates the southern extent of the ridge, termed muscle-tissue terrain by [5], appears to play a relatively minor role (if any) in accommodating the inferred compression. This contradicts the suggestion of [5] that muscle-tissue terrain is characteristic of convergence. It should also be noted that it is not clear whether that feature is contemporaneous with or younger than the lineament set; therefore, it is difficult to determine the actual nature of the terrain.

Conclusions: Determination of an Euler pole for a lineament in the Castalia Macula region using inverse modeling suggests the existence of a convergent boundary marked by a prominent ridge. The convergence is not associated with the muscle-tissue morphology previously suggested as characteristic of convergence zones [5]. Instead, we have demonstrated that at least some ridges are sites of convergence and that a distinctive morphology indicative of compression along these ridges may exist.

The amount of compression inferred in this region is minor in comparison to the net extension seen across the surface of Europa, and regions of similar scope, morphological character, and geological relationships have yet to be found with available Galileo images. Increased image resolution and global comprehensive coverage by future missions will allow for greater opportunity to locate features with similar morphologies. However, the paucity of such sites in the available image data indicates that there may be numerous other ways in which Europa's icy surface compensates extension.

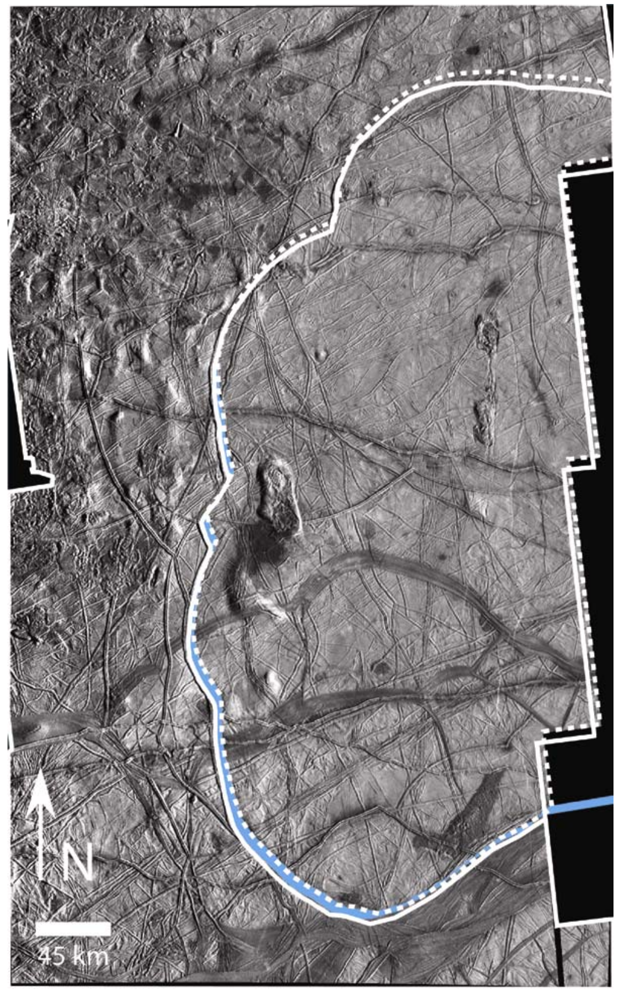

Fig. 2. Reconstruction of Castalia Macula region (E17REGMAP01 mosaic centered at ~0° lat and 227° lon) using an Euler pole at 11° lat., 253º lon and a rotation of –0.43º. Image resolution is 220 m/pix. Solid white line indicates position of the plate before reconstruction and dashed white line indicates position after.

References:

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