KINEMATIC ANALYSIS OF TRIPLE JUNCTIONS ON EUROPA. G. W. Patterson and J. W. Head, Department of Geological Sciences, Brown University, Providence, RI 02912 (Gerald_Patterson@brown.edu)

Introduction: Reconstructions of preexisting linear features offset by the formation and evolution of ridges and bands on Europa suggests that its surface is locally fractured into rigid plates that have rotated with respect to each other [1-3]. One consequence of this process should be the formation of triple junctions.

A triple junction represents the intersection of three plate boundaries. In a rigid-plate environment, the motions of the plates involved in a triple junction depend on each other. There are 25 possible types of triple junctions [4], but most are unstable and cannot persist through finite rotations of the plates involved [4-6]. If the poles of rotation for each plate in a junction remain fixed over some finite interval of time, however, that junction can be described as stable.

Here, we use instantaneous velocity diagrams to analyze what appear to be three triple junctions on Europa. Two of the junctions are associated with a set of bands in the south-polar region of Europa and the third is associated with a near-equatorial band we have tentatively named Phaidra Linea. Each of these junctions represents the intersection of three extensional bands. The band-band-band configuration is ideal for analysis because the finite motions of each boundary are clearly recorded on the surface. This helps to constrain the kinematics of each junction and allows us to explicitly utilize the assumptions of plate-rigidity and fixed poles of rotation to explore their behavior.

Triple Junctions in Velocity Space: In analyzing the triple junctions we observe on Europa, we utilize the method developed by [5] of examining junctions diagrammatically in instantaneous relative velocity space. The analysis of triple junctions in velocity space has two components. The first component is a velocity circuit consisting of the relative velocity vectors for each boundary associated with the triple junction. For a three-plate system in a rigid environment, the addition of these vectors must form a closed loop. The second component is a constant frame of reference line for each velocity vector that indicates all possible solutions for the velocity of the plate boundary associated with the vector. The orientation of the reference line with respect to the vector it is associated with is dependent on the mode of deformation that vector describes (i.e., extension, compression, or strike-slip). If these reference lines intersect at a point, the triple junction can be stable over a finite time interval.

To constrain the magnitude and direction of the relative velocity vectors for each of the bands associated with a junction, we use the widths of the bands involved and the direction of offset. These components of the vector are determined by the locations of preexisting offset linear features or the intersections of the bounding ridges of a band with the other two bands in the junction. Potential errors in determining the direction and magnitude of the relative velocity vectors are represented by confidence regions surrounding the tips of the vectors. In this study, the radii of these regions are equivalent to the apparent widths of the bounding ridges of each band, since they can obscure the contact between preexisting offset features and the band and it is often not clear whether they are part of the extension process or are remnants of preexisting, strike-slip boundaries.

South Polar Region: The two junctions in this region each represent the intersection of three bands (fig. 1). Cross-cutting relationships of prominent structural features that pre- and post-date the bands that form these junctions suggest they formed coevally. This implies their formation divided the region into four plates (A, B, C, and D in fig. 2) that subsequently rotated with respect to each other.

Within the confidence regions we have established, the relative velocity vectors associated with the junction that consists of bands 1, 2, and 3 form a closed loop in velocity space (Fig. 2a). This implies that, as the bands formed, plates A, B, and C behaved rigidly in the vicinity of the junction. If we use the endmember reference line for the relative velocity vector of band 3 that represents the trend of its axial trough closest to junction, the reference lines of the vectors for bands 1, 2, and 3 intersect at a point. This indicates that the junction could have been stable for a finite time interval. The point at which the lines intersect falls outside of the relative velocity circuit. Such a configuration results in one of the bands receding with respect to the other two [6]. In this case, it would suggest band 1 is receding.

The relative velocity vectors associated with the junction that consists of bands 3, 4, and 5 also form a closed loop in velocity space (fig. 2b). This implies that, as the bands formed, plates B, C, and D behaved rigidly in the vicinity of the junction. The reference lines for the relative velocity vectors of the bands do not intersect at a point for this junction. This indicates that the current configuration of the junction is not stable.

Phaidra Linea. As with the junctions in the south polar region of Europa, this junction represents the intersection of three bands (fig. 3). The cross-cutting relationships with respect to the bands of features that pre- and post-date them suggest that they formed contemporaneously. This implies that the formation of bands 6, 7, and 8 divided the region into three plates that subsequently rotated with respect to each other (E, F, and G in fig. 4).

Within the confidence regions we have established, the relative velocity vectors of the junction that consists of bands 6, 7, and 8 form a closed loop in velocity space (fig. 4). This implies that, as the bands formed, plates E, F, and G behaved rigidly in the vicinity of the junction. The reference lines for the relative velocity vectors of the bands intersect at a point for this junction. This indicates that the junction could have been stable for a finite time interval.

Conclusions: Given the existence of numerous features on the surface of Europa that share morphological characteristics with terrestrial tectonic features [7-9], it is reasonable to assume that many of the techniques used to understand the tectonic history of Earth could be applied to Europa. We have examined three regions on Europa that, based on morphology and cross-cutting relationships, appear to represent the intersection of three tectonic plates. Two of the junctions are associated with a set of bands in the south-polar region of the satellite and the third is associated with the near-equatorial band Phaidra Linea. Each of these junctions represents the intersection of three extensional bands. Analysis of these junctions using instantaneous relative velocity diagrams suggests that rigid-plate behavior for the plates involved is applicable in the vicinity of the junctions.

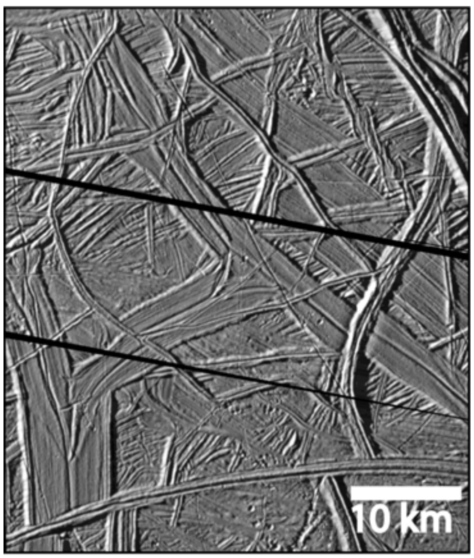

Fig. 1. Galileo image s0466670713 (78°S, 121°) obtained during the E17 encounter of the mission at 500 m/pixel.

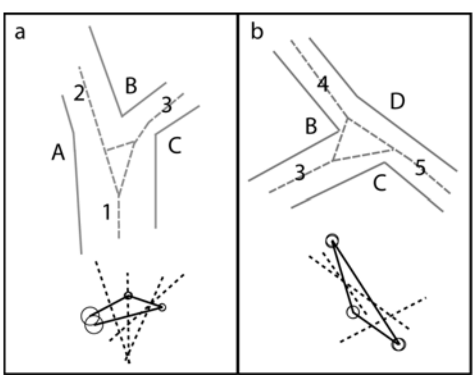

Fig. 2. Idealized representations of the junctions found in the south polar region. Bands are labeled 1-5 and plates A-D in accordance with figure 1b. Relative velocity vectors are shown as solid black lines and reference lines as dashed black lines. Confidence regions (black circles) are also shown and represent random errors in the determination of the magnitude and direction of each relative velocity vector.

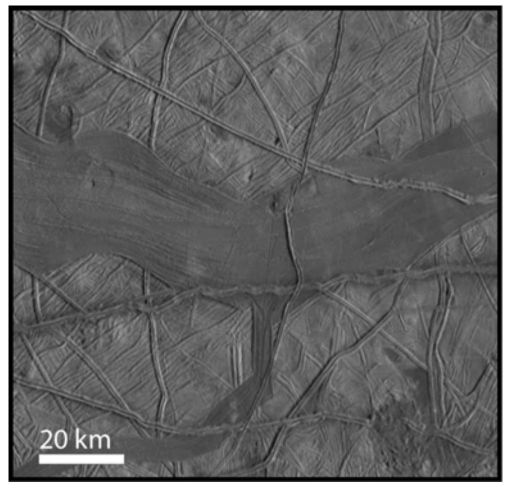

Fig. 3. Galileo image s0420619252 (7°S, 233°) obtained during the E11 encounter of the mission at 220 m/pixel.

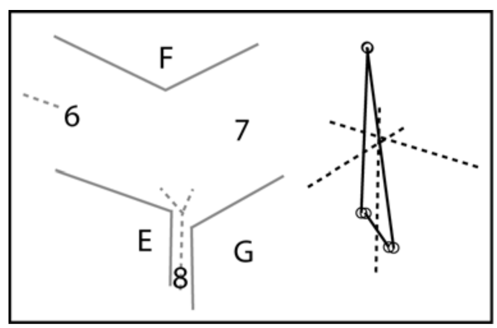

Fig. 4. Idealized representations of the current configuration of the Phaidra junction. Bands are labeled 6-8 and plate E-G. Instantaneous relative velocity diagram is shown with relative velocity vectors as solid black lines and reference lines as dashed black lines. Confidence regions (black circles) are also shown and represent random errors in the determination of the magnitude and direction of each relative velocity vector.

References: [1] Schenk and McKinnon, Icarus 79, 75-100, 1989; [2] Sullivan et al., Nature 391, 371-373, 1998; [3] Tufts et al., Icarus 141, 53-64, 1999; [4] Cronin, Tectonophysics 207, 287-301, 1992; [5] McKenzie and Parker, Nature 224, 125-133, 1969; [6] Patriat and Courtillot, Tectonics 3, 317-332, 1984; [7] Hoppa et al., Icarus 141, 287-298, 1999; [8] Head, LPSC XXX, #1286, 2000; [9] Prockter et al., JGR 107, 10.1029/2000JE001458, 2002.