PLATE MOTIONS ON EUROPA FROM CASTALIA MACULA TO FALGA REGIO. Geoffrey C. Collins[1], Benjamin B. Cutler[1], J. Pablo Brenes Coto[1], Louise M. Prockter[2], G. Wesley Patterson[2], Simon A. Kattenhorn[3], Alyssa R. Rhoden[4], and Catherine M. Cooper[5]. [1]Wheaton College, Norton, MA; [2]Johns Hopkins University Applied Physics Laboratory, Laurel, MD; [3]ConocoPhillips Company, Houston, TX; [4]Arizona State University, Tempe, AZ; [5]Washington State University, Pullman, WA.

Introduction: Offsets of stratigraphically older features on Europa's surface by younger tectonic features are commonly observed. Previous studies reconstructing features in the Castalia Macula region [1], the Phaidra Linea region [2], and in Northern Falga Regio [3] have all reported observations of past plate-like motions in Europa's icy lithosphere. Quantifying the direction, age, and magnitude of plate motion is important for constraining geophysical models of Europa's ice shell. Plate motions on Europa also have astrobiological importance, since subsumed surface material could drive the flow of nutrients to Europa's subsurface ocean.

In this study, we use GPlates software [4] to reconstruct plate motions in the regions of Europa's surface examined by the previous studies [1-3], and extend the areas of these studies to link them together into a broader regional context on the trailing-antijovian hemisphere. This area is well-covered by several *Galileo* imaging datasets at ~200 m/px resolution (Fig.1).

Methods: GPlates is freely available software [4] (www.gplates.org) that allows us to import georeferenced spacecraft imaging data, map plate boundaries as polygon features, use those polygons as a "cookie cutter" to clip out image fragments, and then interactively move the image fragments to line up features within a spherical projection. During an interactive plate fitting session, the software calculates the rotation poles necessary to describe the motion on a sphere from the original plate positions to their currently observed positions.

GPlates also allows us to animate the plate motions to show the paths taken during plate motion. Since two plates can't physically pass through one another, the animations serve as a reality check to constrain possible motions. Plates can also be given different poles of motion for different time periods, allowing multi-stage reconstructions.

We prepared a mosaic of Galileo images (Fig. 1) in ISIS3 and imported it into GPlates. Starting in Castalia Macula and Northern Falga, and working outward, we searched for groups of older features that had been truncated by younger tectonic features in order to find possible plate boundaries. We subdivided the surface along recent tectonic features until we arrived at a set of polygonal areas (plates) which had an internally coherent set of older features, but which did not line up with adjacent areas.

After linking the image mosaic to the plate boundaries in GPlates, we interactively rotated the plates to align the truncated older features. During the interactive reconstruction, GPlates populated a database of Euler poles to describe the past motions.

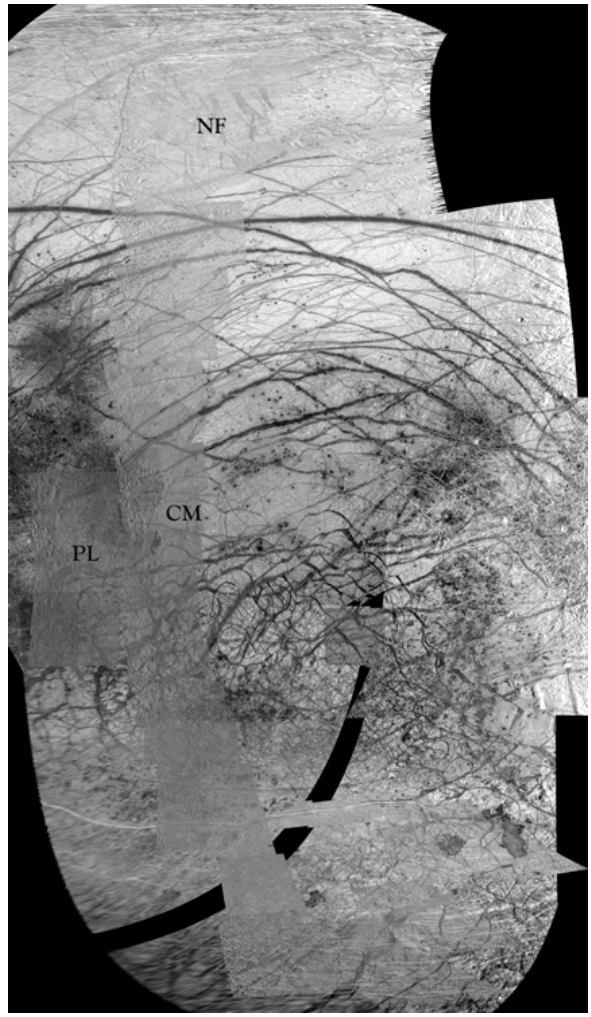

Figure 1. The high-resolution image mosaic used for this study spans from 110°E to 180°E and includes the areas in previous studies of plate motion: Northern Falga Regio (NF), Castalia Macula (CM), and Phaidra Linea (PL).

Comparison to previous studies: The Castalia Macula and Phaidra Linea regions were previously studied [1-2] using software to match piercing points across spreading bands, using a statistical best fit to find rotation poles. Although this method was well-quantified, it was difficult to deal with large numbers of plates, and the goodness of fit method did not prevent plate overlap during the rotations.

When we incorporated the reported rotation poles from [1] and [2] into GPlates, we found that while the

older features were close to matching, the shapes of the boundaries did not fit together neatly. Some pairs of plates showed several km of overlap in their "past" state, which is impossible since the features in the overlap regions are not themselves deformed.

Our reconstruction of the same area (Fig. 2) required breaking some of the plates into smaller, independent pieces along minor recent tectonic features. Small motions between these plates changed the shape of the boundary and allowed an almost perfect fit. While the new rotation poles for these plates are not very similar to the previously reported poles (Table 1), there is likely to be significant uncertainty in the pole positions. We are currently in the process of quantifying this error margin.

We also discovered evidence for multi-stage plate motions in the Phaidra Linea region, based on crosscutting lineaments in the interiors of the spreading bands. We have linked the plate motions in Phaidra to the motions around Castalia Macula, and we are developing a new two-stage plate motion history for this region.

Plate motion in Northern Falga was previously reconstructed on a flat plane by manipulating image fragments [3]. With the correct map projection, this method can work on a small area, but it becomes increasingly inaccurate with larger plates and larger motions.

Our reconstruction of Northern Falga is still in progress, but the preliminary version shows the same large rotation of the southwesternmost plate that led *Kattenhorn and Prockter* [3] to claim ~100 km of surface material had been subsumed during plate motion. The strength of their reconstruction will be tested by our examination of motions to the south of the subsumption band, in an area covered by another high-resolution mosaic not in their paper, but which is included in our larger mosaic. It is interesting to note that their subsumption band can be traced outside of the high-resolution coverage into the global imaging dataset, where it can be seen curving southward toward the vicinity of Manannan crater. An arm of this lineament seen in the global coverage is visible again in higher resolution imaging of the Phaidra Linea area. It is long-range connections like this that will help us to test the self-consistency of the Europa plate tectonic hypothesis.

References: [1] Patterson et al., *Journal of Structural Geology*, 28, 2237-2258, 2006; [2] Patterson & Ernst, *LPSC XLII*, #2102, 2011; [3] Kattenhorn & Prockter, *Nature Geoscience*, doi:10.1038/NGEO2245, 2014; [4] Williams et al., *GSA Today*, doi:1130/GSATG139A.1, 2012.

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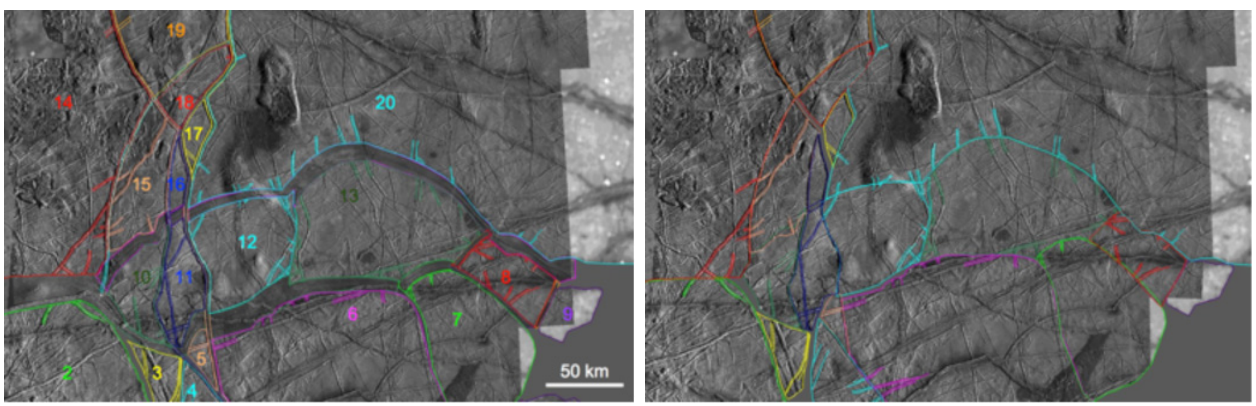

Figure 2. The area to the south of Castalia Macula is a complex mosaic of spreading plate-like regions. The image on the left shows the region in its current state, and the image on the right shows the region after back-rotations are applied to place the plates in their (presumed) original positions. The previous study of this region [2] broke this area into 5 plates, but to fit all of the features older than the spreading bands, we needed up to 20 plates to achieve a satisfactory fit.

Table 1. Comparison of rotation poles in this study (right) to the previous reconstruction of the region south of Castalia (left, [2]). The ID numbers

Plate ID in previous study[2]	Rotation pole lon. [2] (converted)	Rotation pole lat. [2]	Rotation magnitude	Plate ID shown in fig. 1	Rotation pole lon.	Rotation pole lat.	Rotation magnitude
1	(fixed)			14	(fixed)		
2	323°E	0°	0.67°	10 through 12	321°E to 325°E	0° to -3°	2.1° to 3.4°
3	103°E	-12°	0.99°	13	349°E	-14°	1.1°
4	37°E	10°	0.57°	8	334°E	-6°	2.3°
5	317°E	5°	5.8°	2 through 7	*(multiple, scattered – plate was subdivided)*		