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Episodic mobile lid activity in Europa's ice shell

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Abstract

Blocks of Europa's surface have moved laterally by tens of kilometers in a plate-tectonic-like system, representing mobile lid behavior in Europa's ice shell. We will present a set of plate reconstructions across the antijovian hemisphere of Europa. These reconstructions show that, unlike the continuous, global system of plate tectonics on the Earth, Europa's mobile lid activity appears to be confined to certain regions that are active at different times.

1. Introduction

Plate tectonics describes how a planet's lithosphere is divided into multiple rigid blocks (plates) that move independently, accommodating deformation in narrow zones around the edges of the plates. Earth is the only planetary body known to operate under a plate tectonic system, but reconstructions of surface features on Europa indicate that it also experiences plate-tectonic-like behavior [1]. The discovery of plate tectonics on Europa would have important implications for both comparative planetology and for astrobiology, as subsumed surface material could be an important source of oxidants for Europa's subsurface ocean.

In this study, we examined five regions in the antijovian hemisphere of Europa (Fig. 1).

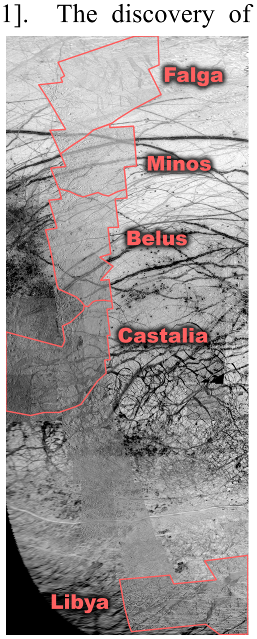

Figure 1: *Location of study areas. Image spans from 70°N to 70°S and 115° to 175°E.*

In each region, we identified potential plate boundaries, mapped the crosscutting sequence of boundary offsets, and performed a sequential reconstruction of plate motions.

2. Example of method: Falga region

We adopt a similar method to Kattenhorn and Prockter [1], with the important addition of performing all reconstructions within a spherical geometry. Below, we step through the method by which one of our regions was reconstructed.

The first step is to identify potential plate boundaries. This is done by finding offset features, and tracing the structures that accommodate the offsets to find isolated plates of preexisting terrain that behaved rigidly. Then crosscutting relationships among the boundaries (Fig. 2) determine the sequence of motion.

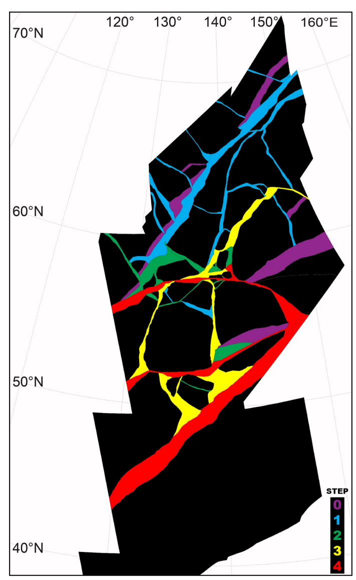

Figure 2: *In the Falga region, identified plates are shown in black, and the plate boundaries are shown in age order from purple (oldest) to red (youngest). Steps refer to the reconstruction sequence (Fig. 3).*

The plates are then shifted along the boundaries using the derived time sequence to reconstruct the original surface (Fig. 3). Reconstruction of original features is performed interactively using GPlates software [2]. The reconstruction shown below improves on the reconstruction in [1] by recognizing several additional plates, which led to aligning more of the preexisting features. See the caption below for details of the results of this reconstruction.

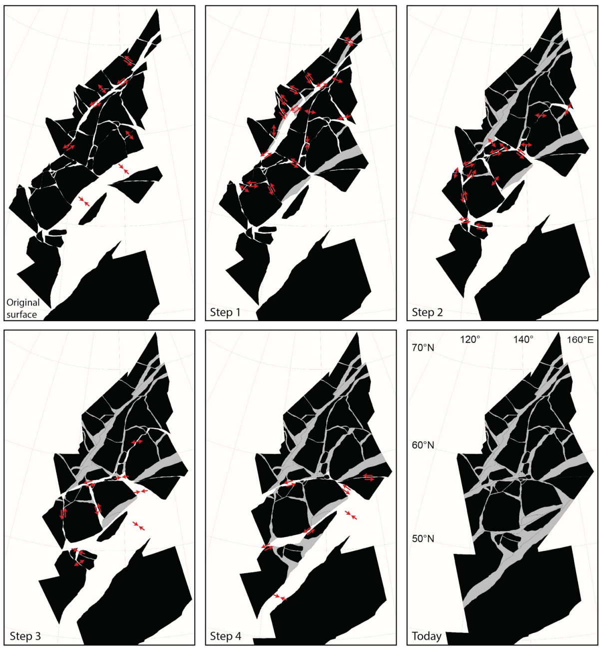

Figure 3: *Steps in the Falga reconstruction: red arrows show relative motions necessary to get to the next step, grey areas show inactive plate boundaries. The original surface preserves several old features that span several plates. Early left lateral shear in the north opens a releasing bend in step 1, while convergence in the south brings plates together. Further left lateral shear in steps 1 and 2 begins to break the surface apart. Activity shifts to the south in steps 3 and 4, as clockwise rotation of plates and closing of a band along the southern boundary completes the sequence of movement to today.*

3. Results from other regions

To the south of Falga, the Minos region exhibits many small offsets, but the offsets are inconsistent and decrease along the length of potential plate boundary structures, and the structures do not link to form coherent plates. We believe the Minos region is behaving non-rigidly.

The Belus region exhibits a system of plates, including locations where several km of material has been subsumed in convergence zones. The Castalia region is dominated by N-S spreading with minor amounts of strike-slip and convergence. All of the plate activity in the Castalia region appears to post-date all of the plate activity in the Belus region. Plate motions in the Libya region are dominated by spreading and right-lateral shear.

4. Conclusion

Even though the plate-like motions on Europa strongly resemble plate tectonics on the Earth, the results of our reconstructions point out several ways in which the mobile lid activity on Europa is different. First of all, the plate motions appear to be regionally confined and the timing of plate motions is not globally uniform. None of the identified plate boundaries lie at the top of their local crosscutting sequence of structures, indicating that plate motions are not active today. Thus, mobile lid behavior on Europa appears to be episodic and regional, which has interesting implications for the convective system that may be driving the motions. Our modeling of the convective system within Europa's ice shell indicates that Europa could dominantly lie in a stagnant lid regime, with temporary excursions into a mobile lid regime. In contrast to oceanic plates on the Earth, we do not see material that emerged from a spreading zone travel across into a convergent zone. Plate motions appear to be limited to tens of km of motion, up to ~ 100 km, before the system shuts down and plate motions stop.

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References

[1] Kattenhorn and Prockter, Nature Geoscience, 2014.

[2] Williams et al., GSA Today, 2012.