ICE SHELL DISAGGREGATION AND MICRO-PLATE MOTION RELATED TO REGIONAL SHEARING IN ARGADNEL REGIO, EUROPA. R. B. Van Auken[1] and S. A. Kattenhorn[2], [1]Department of Geological Sciences, University of Alaska Anchorage, Anchorage, AK 99508 (rbvanauken@alaska.edu), [2]Department of Geological Sciences, University of Alaska Anchorage, Anchorage, AK 99508 (skattenhorn@alaska.edu).

Introduction: Europa, a moon of Jupiter, has an extensively fractured ice shell that overlays a liquid ocean [1] and its uniquely young surface age (~40 - 90 million years old) [2] suggests the ice shell has experienced resurfacing in its relatively recent history [3]. Argadnel Regio on the anti-Jovian side displays a strongly disaggregated surface, containing fractures whose orientations do not align with the orientations expected from global scale stresses, such as diurnal tides, true polar wander, and nonsynchronous rotation [4,5]. In this region the existence of sigmoidal features, which resemble structures observed in terrestrial shear zones experiencing lateral motion, suggests a similar process may be occurring on Europa. Sigmoidal features begin as linear dilational gashes that form at a ~45º angle to the shearing motion. Continued shearing across the zone of deformation causes the dilational gash to rotate and internally shear while the fracture tips continue to propagate at a ~45º angle to the shear zone boundaries, resulting in a sigmoidally shaped fracture [6]. The rotation of icy micro-plates with a range of sizes in Argadnel Regio is suggestive of the process of cataclasis, which occurs on Earth in fault zones experiencing lateral motion as well. Cataclasis is a brittle process that involves shearing in granular rocks, leading to the fracturing, sliding, and rolling of granular fragments, which induces further mechanical breakdown [7]. The characterization of these deformation features through mapping and surface reconstructions constrains the motions of the ice shell in Argadnel Regio and may indicate how this region fits into a larger plate tectonic paradigm for Europa.

Mapping: Images used for regional mapping are from the Voyager 2 and Galileo missions whereas images used for detailed mapping are from the 17th orbit of the Galileo mission (s-clock number s0466664239, s0466664240, and s0466664241). All images were accessed from NASA's Planetary Data System (PDS) and mosaicked in a global Mercator projection relative to the Europa_2000 reference system in ArcGIS Pro 3.0.3.

Regional Mapping (Figure 1). Mapping of prominent band-like features and plate-like boundaries was performed at 1:2,000,000 scale. Two distinct sets of band-like features are oriented NE-SW and NW-SE and circumscribe icy micro-plates in the region that have a circular to blocky geometry. The NE-SW oriented set is band-like, has a sigmoidal shape, and a right-stepping geometry reminiscent of that observed in sigmoidal features in terrestrial left-lateral shear zones.

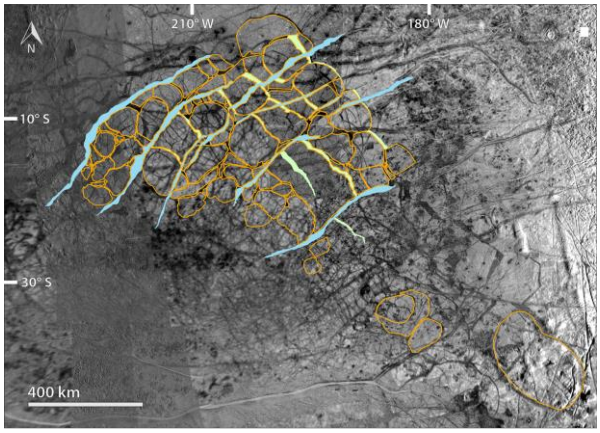

Figure 1. *Regional mapping of Argadnel Regio and regions of Agenor Linea: Candidate plate-like boundaries outlined in orange, candidate right-stepping sigmoidal features in blue, and candidate left-stepping features in green.*

Detailed Mapping (Figure 2). This portion of Argadnel Regio was imaged at a higher resolution of 100 – 200 m/pixel, allowing for more detailed mapping of bands, ridges, troughs, chaos, subdued material, and a portion of a band-like sigmoidal feature at a 1:600,000 scale. Regional plains material consists of high albedo bands and ridges and is crosscut and disaggregated by relatively younger, low albedo bands and ridges. Disruption of surface features by chaos development is minimal in this region; hence, disaggregation of the surface is predominantly related to tectonic activity. Troughs crosscut all features, indicating they are the youngest features.

Sigmoidal features are several kilometers to tens of kilometers in width and hundreds of kilometers in length. They have a lineated and often sinuous internal morphology and features on opposing sides cannot clearly be matched. Although band-like, sigmoidal features do not resemble other band types described on Europa. Subdued material present along the border of the band-like sigmoidal feature has the appearance of embayment of older terrain by material extruded from the sigmoidal feature. Some ridges also display haloes of dark subdued material along their margins.

GPlates Reconstruction: The identification of features and analysis of their crosscutting relationships

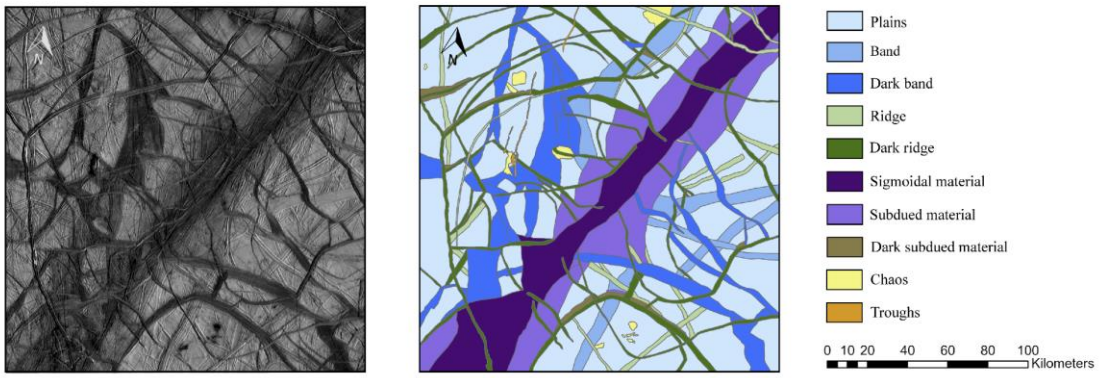

Figure 2. *Detailed mapping of 180km x 180km region of Argadnel Regio that was imaged at higher resolution and crosscutting relationships between features.*

from detailed mapping allowed for determination of the relative ages of the features and development of a timeline of formation of plate boundaries for the SE portion of the high-resolution imaged region. GPlates, an open-source visualization software that projects raster and vector data onto a spherical surface was employed for manipulation of the icy micro-plates in order to determine their relative motions. In the SE portion, reconstructions revealed counterclockwise rotation of micro-plates occurred through dilation, shearing, and fragmentation/comminution around their boundaries (Figure 3). On Earth, fragments in a fault zone experiencing left-lateral shearing also experience counterclockwise rotation during cataclasis, further supporting the likelihood of left-lateral shearing in Argadnel Regio.

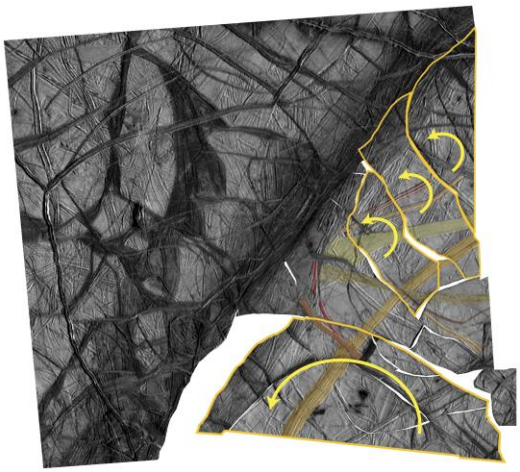

Figure 3. *GPlates reconstruction shows counterclockwise rotations are needed to move the microplates into their current positions.*

Discussion: Argadnel Regio contains two distinct sets of band-like features characterized by a NW-SE orientation and a NE-SW orientation which create a crosshatch pattern that disaggregates the surface into circular to blocky icy micro-plates. NW-SE fractures of unknown origin are overlain by inferred later right-stepping NE-SW sigmoidal features from the hypothesized left-lateral shearing event. Further reconstructions of the NW portion of the high-resolution imaged area in Argadnel Regio will help to constrain the motion of the icy micro-plates in the region and specifically inform our understanding of the deformation history of the sigmoidal feature. Considering the crosscutting relationships and motions on opposing sides of the sigmoidal feature will elucidate whether it opened and/or sheared in stages and will verify whether this sequence of deformation was before, after, or concurrent with the formation of the NW-SE oriented fracture set. Characterization of the direction and geologic timeline of the motions of micro-plates within the ice shell may demonstrate that there is regional lateral shearing occurring in Argadnel Regio and possibly the surrounding area. This would be consistent with the existence of differential motion within a mobile lid and further bolster evidence for a plate tectonic paradigm on Europa.

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