REGIONAL SCALE TECTONIC FEATURES AT ARGADNEL REGIO AND AGENOR LINEA, EUROPA: PLATE TECTONIC EVIDENCE OR GLOBAL TIDAL FORCING? C. E. Detelich¹ and S. A. Kattenhorn¹, ¹Department of Geological Sciences, University of Alaska Anchorage, Anchorage AK 99508 (cedetelich@alaska.edu, skattenhorn@alaska.edu).

Introduction: Europa, Jupiter’s fourth largest moon, has an anomalously young surface age (~90 Myr) [1,2] and has experienced intense tectonic deformation due to global-scale stresses related to tidal distortion of the ice shell [3-5]. Several tectonic feature types and distributions, however, do not align with predicted global scale stresses [6-11]. Some have suggested icy plate tectonics as a potential mechanism that would not only add an additional stress component to Europa, but would also reset Europa’s surface age via subsumption [11-15]. Evidence of broad-scale lateral shearing (plate movement) is necessary to support the plate tectonic hypothesis, but this evidence has been elusive. Previous work [16] has looked at Agenor Linea and Argadnel Regio as potential sites of broad-scale lateral shearing. Agenor Linea appears to have experienced several kilometers of right-lateral shearing resembling deformation along a transform plate boundary [10]. Argadnel has a broadscale tectonic fabric defined by sigmoidal band-like features that resemble a terrestrial shear zone [17] in addition to motion involving small, icy plates [18,19]. Detailed mapping in these regions is necessary to determine if the deformation styles can be placed into a broader context of lateral motions of the ice shell. To test whether some aspects of deformation may or may not be consistent with global scale stress models and how stresses change over time, we mapped, in unprecedented detail, three sites surrounding and containing Agenor Linea and Argadnel Regio (Fig. 1).

Mapping:
Castalia Macula Site (Fig. 1a). This region, which is the northernmost and farthest of our three sites from Argadnel Regio and Agenor Linea, was chosen to represent a “baseline deformation” that has not been as significantly disrupted by potential shearing across Argadnel and Agenor. The oldest features in this region are sets of single ridges oriented 130°-180°. These ridges are overlain by an orthogonal set of single ridges oriented 050°-060° that are not only much longer than the oldest set of ridges, but are almost double in quantity. Ridge complexes, with dominant orientations of 060°-065°, ~115°, and ~175° are younger than these background ridges, but still one of the oldest features in this site. The youngest features in this region are double ridges and dilational bands, some of which have formed by dilating pre-existing cycloids. While cycloids are thought to be among the youngest features on Europa, they appear to have formed throughout the geologic history of this mapping site, contrary to the outcome of previous studies [20]. The most recent features are troughs and chaos/lenticulae, the latter of which envelop ~26% of the site’s surface area.

South of Argadnel Regio Site (Fig. 1b). This site, includes an E-W oriented linear boundary across which the deformation style appears to abruptly change. This boundary is represented by a band-like feature with non-matching opposing margins and which lacks relatively older crosscut features that would typically be matched when reconstructing dilational bands. South of this band, smaller, sigmoidally shaped bands resemble artifacts of E-W oriented shearing potentially related to shearing by Agenor Linea or the band like feature discussed above. The tectonic features in this region consist mainly of orthogonally intersecting sets of single ridges. There is a distinct lack of bands, cycloids, double ridges, ridge complexes, and chaos that were evident in the “Castalia Macula” site. The ridges in this site are dominantly oriented 060°-070° and 110°-120°. This is a shift from the 050°-060° oriented ridges in the “Castalia Macula” site and the relative frequency of ridges in the two dominant orientations is about equal. Chaos/lenticulae envelops ~24% of the site’s surface area.

Agenor Linea Site (Fig. 1c). This site contains the major strike-slip feature Agenor Linea and includes tectonized terrain extending 210 km to the north and 260 km south of this transform-like boundary. To the north and southwest of Agenor, there is extensive chaos and double ridges. To the southeast of Agenor, there are orthogonally intersecting sets of single ridges similar to those in the “South of Argadnel Regio” site and the background ridges in the “Castalia Macula” site. Again, there is an absence of the cycloids, double ridges, ridge complexes, and dilational bands that were present in the “Castalia Macula” site, with the exception of Agenor itself, which has likely experienced up to 30 km of dilation along with right-lateral strike slip motion [10]. The ridges in this site are dominantly oriented 030°-040° and 120°-140°. Chaos/lenticulae envelops 43% of the surface area to the north of Agenor and 21% of the surface area south of Agenor.

Discussion: Across all three study sites, an underlying tectonic fabric of patterns of fractures with preferred orientations suggests a consistent stress field has been responsible for the creation of Europa’s oldest fractures. More recently, shearing related features appear to overprint the underlying tectonic fabric. While the stress field may be the result of global-scale stresses...
such as nonsynchronous rotation, true polar wander, obliquity, and/or ice shell thickening, the recent patterns of fractures, such as the sigmoidal bands of Argadnel Regio, are also possible with plate-like motion. This change in deformation style spatially and temporally may suggest a shift in Europa’s stress field. To gain a more concrete understanding of how stress fields on Europa change, a comparison of global tidal stress models with mapped features is necessary to test how the stress field has changed over time and whether or not fractures can be reconciled with solely global-scale stresses or whether plate tectonics may also need to be invoked. In planned ongoing work, we will be relating the observations from both the broad scale map of [16] and the highly detailed maps of this study to test this hypothesis.

Conclusions: Detailed mapping of Europa has revealed systematic sets of fractures that each indicate a regionally consistent stress field at the time of formation, potentially related to global tidal stresses. However, more recent fracturing on Europa is more consistent with broad-scale lateral shearing, a key piece of evidence necessary for proving the existence of plate tectonics. This change in deformation style with time indicates that Europa’s stress regime has changed over time. Using global-tidal stress models to see how the stress field has changed is necessary to test the hypothesis of whether fractures on Europa are solely related to changing global scale stresses or whether another source of stress, i.e. plate tectonics, needs to be invoked to explain observed patterns of fracturing on Europa.

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Fig. 1: Locations of detailed mapping (globe) to search for evidence of broad-scale lateral shearing. All images are from Galileo observations 17ESREGMAP01 and 17ESNERTRM01; a) Castalia Macula: north of Argadnel Regio, small troughs, ridges, ridge complexes, cycloids, and bands dominate deformation; b) South of Argadnel Regio: this location is characterized by orthogonally intersecting ridges and troughs between Argadnel Regio and Agenor Linea. This deformation style is juxtaposed next to Argadnel Regio, a region of intense deformation. This juxtaposition is separated by a strikingly linear –E-W oriented boundary (dashed line); c) Agenor Linea: This region is most notably characterized by Agenor Linea, a large, young band-like strike slip fault [10]. To the north of Agenor, an abundance of chaos terrain dominates. To the south of Agenor, chaos continues but is superimposed on top of several sets of double ridges, background ridges and troughs.