THE EVIL TWIN OF AGENOR: MORE EVIDENCE FOR TECTONIC CONVERGENCE ON EUROPA.

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Background: Voyager images of Europa showed evidence of both strike-slip displacement and dilation along cracks [1]. Galileo images confirmed that dilation has been common and widely distributed. Large crustal plates have separated, with the space between them filled by new surface material creating *dilational bands*. Similarly, new surface has also been created along strike-slip faults, where curves in the faults have resulted in pull-apart zones [2,3], similar in appearance to the dilational bands. Terrestrial style convergence features have not been identified, raising the question: How and where has crust been removed to compensate for the new surface area that has been created?

In principle, surface area could be reduced by corrugation-like folding, an idea based on examples of such folding that have been observed [4]. However, it is not clear whether that process could be quantitatively significant in reducing surface area. Alternatively, or in addition, surface contraction may be taken up within Europan chaotic terrain, especially if that terrain represents thermal perforation of the crust [5,6]. Patches of chaos cover about half the surface [7], so they could accommodate considerable surface contraction, but there is no compelling indication that they have played a major role.

Increasing evidence is emerging that crustal surface is removed along several *convergence bands*, all with morphological similarities. From surface reconstructions of strike-slip displacement, Sarid et al. [3] identified two examples of linear surface features that appeared to have accommodated surface convergence. At these locations, band-like structures have an appearance distinctly different from dilational bands. The latter have parallel boundaries of identical shape, with intervening material covered by fine grooves parallel to the edges, and the pre-dilation configuration can be reconstructed by removing the intervening material and fitting together the adjacent crustal plates. In contrast, the convergence bands have curved boundaries that do not fit together. Bands with the general appearance of the convergence bands found in [3] are fairly common on Europa.

Further support for the hypothesis that such bands generally represent convergence comes from consideration of 1400 km long Agenor Linea. As a long, bright, wide band, Agenor (including the nearby, associated, similar Katreus Linea) is unique on the relatively heavily imaged anti-jovian hemisphere. The proximity of the Wedges region, where considerable surface dilation has been a source of new surface, is consistent with Agenor being a site of corresponding surface removal by convergence [1]. Furthermore, unlike dilational bands, Agenor has resisted efforts at reconstruction. At a convergence site, by definition, the adjacent terrain from the neighboring plates is missing. Hence the inability to match the crust on opposite sides of Agenor could be explained by convergence. Moreover, Agenor's appearance at higher resolution is similar to the morphology of the convergence zones found by [3]. Unlike those other cases, Agenor is bright compared with surrounding terrain, but albedo is not necessarily a distinguishing characteristic of convergence [3]. These several pieces of evidence collectively point to Agenor being a convergence feature, but they do not prove it. However, a very similar feature diametrically opposite Agenor on the globe of Europa can be reconstructed to show convergence.

Agenor's twin: This linear feature (Fig. 1) runs E-W just north of the equator on the sub-Jovian hemisphere (from about 5°W to 45°W) where imaging has been limited. Aside from global-scale (low-resolution) color images, and a few very-high-resolution images of isolated locales, the best broad coverage was obtained during Galileo's 25th orbit as a mosaic of a dozen images at about 1 km/pixel. A number of important features have been identified on this image sequence that show similarity to the anti-jovian hemisphere [8], including considerable chaotic terrain, and crack patterns similar to those 180° away. Specifically, tightly curved cracks that form circular or boxy patterns, similar to those in the anti-jovian Wedges region, are common [9], although unlike at the Wedges little dilation is evident.

With such a similar appearance, Agenor's twin became another candidate convergence feature. Unlike the other convergence candidates, at Agenor's twin the plates bordering the convergence have (fortuitously) prominent markings that allow reconstruction, even though substantial crustal surface has been eliminated at the interface. The reconstruction is shown in Fig. 2. The reconstruction is largely defined by the thick dark lineaments that cross Agenor's twin and that also cross one another on the island in the middle. The reconstruction is corroborated by several other alignments of less prominent crossing lineaments. Going back in time, a gap of 25 km opens, showing that this much surface has been removed. Thus, over the length of this feature (>1200 km) a total of 30,000 km^2 of previous surface appears to have been eliminated, a significant component of the surface-area budget.

Discussion: Agenor's Twin provides the first direct reconstruction of a convergence band on Europa, as well as strong supporting evidence that Agenor and, more generally, the type of morphology noted in [3] represent convergence.

In terms of topography and structure, the morphology of these convergence bands is fairly subtle and subdued. This result contrasts with types of features found where thick crustal material converges on terrestrial planets. On solid planets, plates pass above and below one another (as in subduction or thrust faulting) or they pile up together, as in continental collisions (e.g., building of the Himalayas). On Europa, the lack of structure at convergence sites suggests that there was not much solid material involved, consistent with a crustal structure of fairly thin ice over liquid water [e.g. 10].

The locations of Agenor and its twin nearly diametrically opposite one another on the globe may be simply coincidence. On the other hand, tidal processes have played a major role in governing Europan tectonics [e.g. 10] and tidal stresses are symmetrical on opposite sides of the planet. It is possible that tides played a role in determining the character and locations of these convergence features in ways that are not yet understood. The Wedges region, whose dilation provided the first hint that Agenor might be a convergence feature, does have a counterpart near Agenor's twin, likely due to tides [9]. However, in the sub-jovian region, there has been less dilation along these cracks than in the anti-jovian Wedges, so there is less evidence of as much regional need for surface removal by convergence.

Detailed understanding of the surface area budget in the sub-jovian hemisphere is hampered by the lack of moderate-to-high resolution imaging. On the other hand, even with better imaging, as on the anti-jovian side, unraveling in detail the history of this dynamic, rapidly changing surface is challenging. We do know that new surface area has been continually created at widely distributed sites of crustal dilation. Now, with identification of specific examples of convergence bands and of the characteristics that identify them, we can move toward better understanding of the global surface-area budget.

References: [1] Schenk P. and McKinnon W.B. (1989) *Icarus 79*, 75. [2] Tufts B.R. et al. (1999) *Icarus 141*, 53. [3] Sarid A.R. et al. (2002) *Icarus 158*, 24. [4] Prockter L.M. (2001) *LPS XXXII*, Abstract #1452. [5] Greenberg R. et al. (1999) *Icarus 141*, 263. [6] O'Brien D.P. et al., *Icarus 156*, 152 (2002). [7] Riley J. et al. (2000) *JGR.-Planets 105*, E9, 22599. [8] Hoppa G.V. et al. (2000) *LPS XXXI*, Abstract #1380. [9] Bart G. et al. (2003) *LPS XXXIV* Abstract (this conference). [10] Greenberg, R. and Geissler P. (2002) *Meteoritics and Planetary Science 37*, 1685.

Fig. 1: Agenor's twin. Scale: 800 km between arrows; N left.

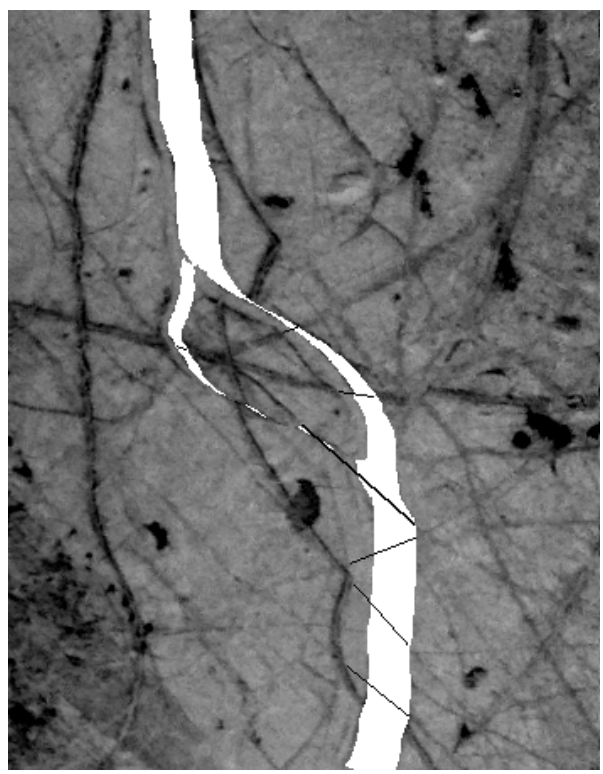

Fig. 2: Reconstruction of evil twin is 25 km wider.