MULTI-STAGE DILATIONAL AND SHEARING HISTORY OF AGENOR LINEA, EUROPA.

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Introduction: Agenor Linea is a ~1500 km long, band-like strike-slip fault [1,2] that experienced at least three evolutionary growth phases marked by three zones of varying albedo, each with a different geological history. Structures within the band material and kinematic indicators are consistent with formation through dilation, dextral strike-slip movement, or combinations thereof, producing a cumulative maximum dextral offset of 28 km and a maximum band thickness of 30 km. We interpret Agenor Linea to have formed in response to the combined effects of long-term nonsynchronous rotation and diurnal tidal flexing. If so, its orientation is optimal for dextral transtension in the current global stress field, consistent with its most recent kinematic behavior.

Internal Structure: Image resolutions only permit detailed structural analysis in the eastern half of the feature. We divide the band into three zones of varying albedo, all with unique geological histories (Fig. 1). The oldest morphological zone is the southern zone, which has the most complex geometry and geological history of the three zones. The northern margin of the southern zone has been destroyed by later tectonic overprinting by the younger morphological zones; however, the southern margin is still exposed and defines the southern boundary of Agenor itself. This boundary is irregular, composed of a mix of linear and arcuate segments that imply an initially complex geometry of progenitor fractures that were dilated to form the southern zone. Linkages between dilating, overlapping fractures resulted in the incorporation of islands of surrounding plains terrain within the band structure (Fig. 2). Shearing of the southern zone, either during or after its initial dilation, resulted in localized zones of both transtension and transpression, dependent on the orientation of the zone margin relative to the shearing direction (which may have been initially sinistral). As a result, the southern zone has a pervasively deformed interior concomitant with geometric bulging in the shape of the southern boundary. We find no evidence of dextral motion along Agenor during the development of the southern zone, in contrast to the findings of [3]. The preserved maximum dilation of Agenor during the period of southern zone development was at least 14 km.

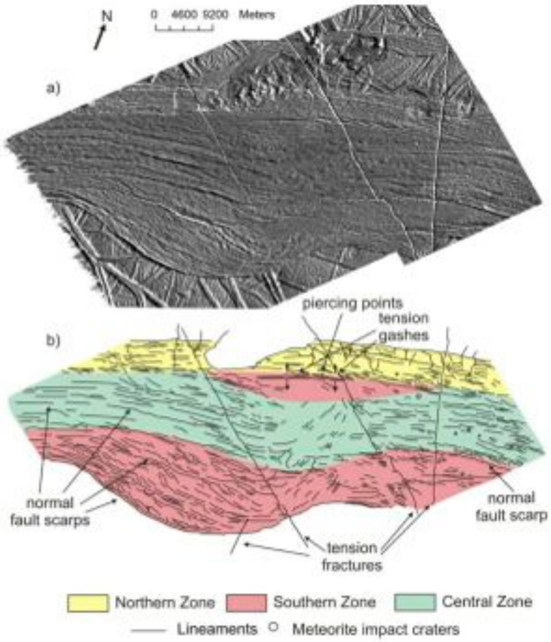

Figure 1: (a) A portion of the western branch (Fig. 2) of Agenor Linea. (b) The northern zone has parallel boundaries and experienced geologically recent dextral transtension. The older central zone was dilational, forming parallel boundaries and interior normal faults. The dilational southern zone (oldest) is crosscut by both the central and northern zones.

The central zone crosscuts the internal fabric of the southern zone, as well as its southern boundary in numerous locations, and is thus relatively younger. The central zone has an intact internal structural fabric, comprised of tilted normal fault blocks (half-graben) oriented parallel to the zone margins, and implying predominantly north-south extension. Unlike the southern zone, the central zone is continuous along the length of Agenor, having localized along the pre-existing weakness provided by the southern zone band, including a kink into a northeast fork near its eastern end (Fig. 2). The 11 km maximum thickness of the central zone decreases steadily from west to east and has a typical opening distribution for a dilational crack in an elastic body.

The northern zone is highest in albedo and is the youngest and most recently reactivated zone. Similar to the relationship between the central and southern zones, the northern zone nucleated along the northern margin of the central zone, and follows parallel to it along most of its length. The northern zone truncates the internal fabric of the central zone in several places and crosscuts its northern boundary in one location, demonstrating the younger age of the northern zone. This is the only zone with both northern and southern margins preserved along its entire length (Fig. 2).

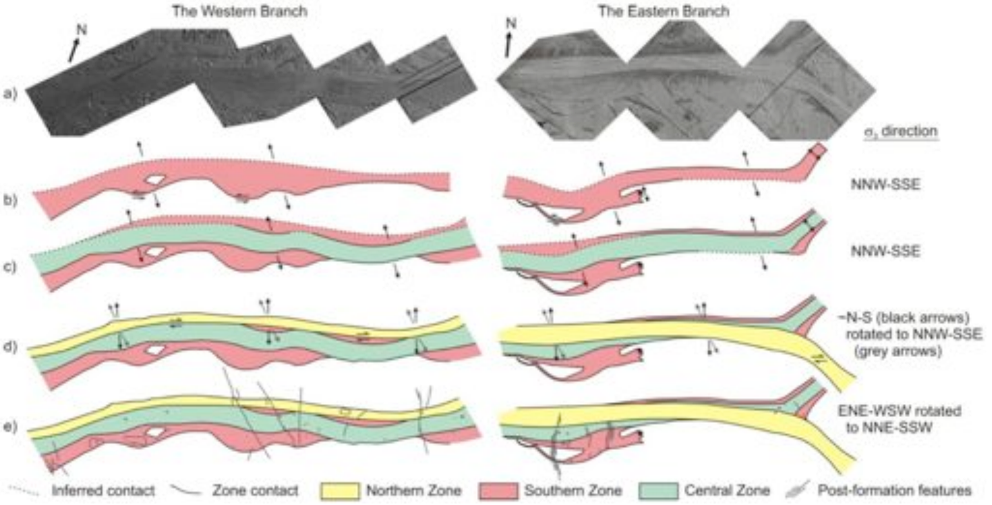

Figure 2: Evolutionary sequence for the formation of Agenor Linea. (a) Western and eastern portions of Agenor. (b) Dilation of arcuate ridges forms the southern zone, potentially with a sinistral shearing component. The zone has a general ENE-WSW orientation and formed by NNW-SSE oriented σ_3 (arrows). (c) Dilation of a relatively straight and continuous fracture formed the central zone, subsequently dissected by normal faulting. (d) N-S extension dilated the northern zone along the northern boundary of the central zone. Continued CW rotation of the stress field induced dextral shearing within the northern zone. (e) Formation of tension fractures and lenticulae across the band.

The northern zone also marks a transition from predominantly north-south extension during the central zone period to dextral transtension during northern zone development, implying a clockwise rotation of the principal extension direction to NE-SW. Transtension resulted in at least 28 km of dextral offset of a crosscut segment of the southern zone, although the offset decreases toward the eastern tip of the fault. In contrast, the total dilation across the northern zone is fairly constant (~5 km) along its length, except in the easternmost (youngest) curved segment of the fault. Hence, the band did not behave as a dilating crack during the majority of the northern zone evolution, experiencing primarily dextral motion and indicating its transition into a band-like strike-slip fault [1].

Right-lateral strike-slip motion during northern zone development resulted in pervasive left-stepping en echelon cracks and tension gashes within the northern zone, particularly along the boundary with the central zone. Some of these cracks also developed along the boundary between the central and southern zones as well as within the southern zone itself. Dextral transtension resulted in the propagation of the SE fork at the eastern end of Agenor, in a zone of tension created near the fault tip. The northern zone cuts across the central and southern zones at the fork point and diverges into the SE fork (Fig. 2).

Ongoing dextral motion resulted in at least two episodes of tailcrack formation at the terminus of the SE branch, with a distinctly cycloidal appearance that indicates rapid growth driven by diurnal tidal stresses [1]. Fault propagation then continued by utilizing these tailcracks, resulting in a distinct geometry of arcuate dilated segments at the eastern end of the fault.

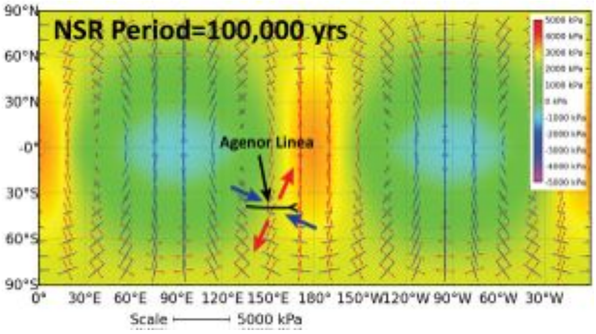

Figure 3: Nonsynchronous rotation (NSR) stress orientations on Europa for an NSR period of 100,000 years. Stresses calculated using SatStressGUI [4]. Tick marks show compressive stresses in blue and extensional stresses in red. Agenor is suitably oriented for dextral transtension.

Discussion: Dextral transtension along the youngest zone of Agenor (northern zone) is consistent with the current stress field in the region related to nonsynchronous rotation (NSR) (Fig. 3), suggesting geological youth. Nonetheless, there is evidence for more recent tension fracturing across Agenor. Many of these fractures are oriented NW-SE, consistent with NE-SW extension during dextral transtension (Fig. 2). In summary, Agenor Linea experienced multiple dilation and shearing events to develop the varying albedo zones that comprise the band-like fault. Its geological youthfulness and optimal orientation for dextral opening raises the possibility that this structure could be active today along portions of its length.

References: [1] Kattenhorn (2004) *Icarus, 172,* 582-602. [2] Kattenhorn & Hurford (2009) *In: Europa,* 199-236. [3] Prockter et al. (2000) *Icarus, 105,* 9483-9488. [4] Kay & Kattenhorn (2010) *41st LPSC* #2046.