NEW CROP CIRCLES FOUND ON EUROPA [BUT NOT GANYMEDE]! TRUE POLAR WANDER CONSPIRACY CONFIRMED!

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Introduction: The tectonic histories of both Europa and Ganymede are exceedingly complex [1], complicated by multiple overlapping deformational events and fragmentary global mapping. Schenk et al. [2] proposed that enigmatic topographic features across Europa are evidence of true polar wander (TPW), first proposed by Ojakangas and Stevenson [3]. Significant questions remain regarding the timing and extent of TPW deformation. Further examination of Europa reveals additional features potentially linked to TPW on Europa, some of which can be dated. Further, we make a detailed search of Ganymede for any evidence of TPW on that satellite (and briefly consider Ceres).

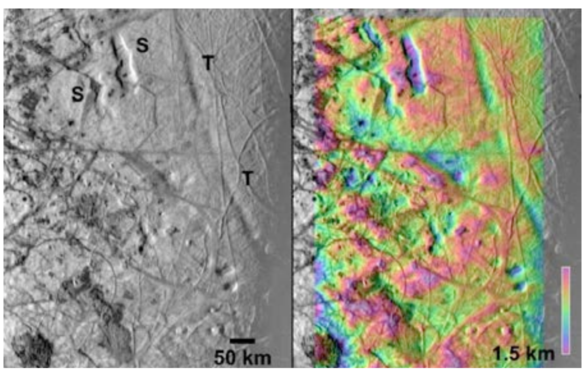

Figure 1. Image (left) and topographic map (right) of troughs (T) and depressions (S) on Europa.

The crop circles of Europa: Two incomplete sets of concentric arcuate trough-like depressions are roughly 25-40 km across and 500 or more km long have been previously identified on Europa [2], as well as a number of smaller associated, or secondary, basins ~40 to 100 km long (Fig. 1). The main troughs are ~500 m deep, while the subsidiary depressions are 1 to 1.5 km deep, and are the deepest known features on Europa. These features form two antipodal 'circles' with centers at 120°W, 10°N (Leading Circle) and 300°W, 10°S (Trailing Circle).

A key finding is that this pattern is offset 10° north and south of the Equator and oriented ~40° to it, a pattern that cannot be replicated with nominal nonsynchronous or tidal deformation stresses. A good match was found for this pattern to stresses associated with 80° of true polar wander (TPW) (and a modest amount of isotropic extension) [2]. The trough locations correspond with the locations where deviatoric extensional stresses are maximum.

Additional features have now been identified as potentially associated with TPW. These include simple fissure-like fractures 3-4 km wide and 25 to 130 km long and 100 to 250 meters deep (though resolution limits allow for slightly deeper depths). These fractures form in parallel sets arranged in en-echelon fashion stretching for 400-500 km (or more, given the many gaps in mapping coverage). In some locations, the fractures appear to have a raised rim.

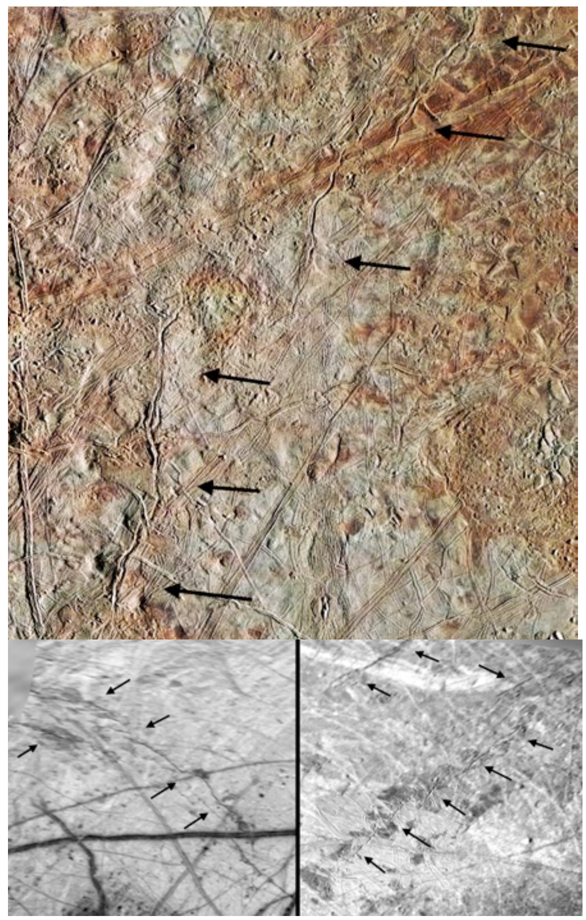

Figure 2. Images from global map of Europa showing en-echelon fractures at 3 locations. (top) Cross-cutting fractures along 240°W, 0°N. (bottom left) Diagonal fractures at 260°W, 60°N. (bottom right) Diagonal fractures at 350°W, 50°N. Scenes are ~450 km across.

The best examples of these features are the set of large fissures extending generally N-S near the Equator along longitude 242°W and within the E11

REGMAP 225-m resolution mapping coverage near Manannan crater (Fig. 2, top). Additional major sets occur near 50°N, 350°W (and seen in a single 250-m-resolution image) and 60°N, 260°W (Fig. 2, bottom). The highest resolution we have on these features is a short segment across smooth band Libya Linea (a 42-m-resolution 2-frame mosaic), which is cut by a prominent 200-to-250-m deep V-shaped fracture. Several smaller subsidiary fractures and surface undulations also run parallel to the main crack.

All identified en-echelon fractures are concentric to and occur 350 to 500 km from the arcuate troughs that define the inner ring of the putative TPW pattern. Fewer clear-cut examples of en-echelon fractures are mappable around the Leading Circle, but detection appears to require 1-km-resolution or better, and much of this region is covered by 1.5-km mapping or worse. We must await new mapping to determine the full extent of these features.

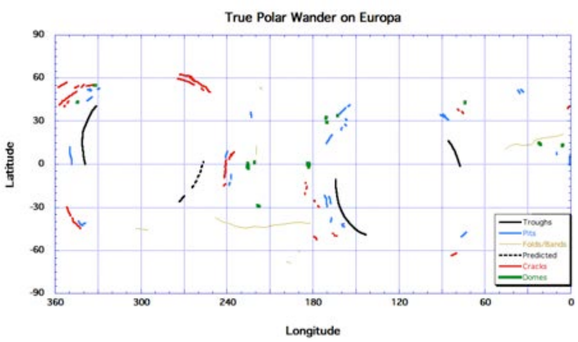

Figure 3. Location of TPW features on Europa. Circular troughs (black), depressions (blue), fractures (red) and putative associated features (thin tan) on Europa (including the long bright bands Agenor and Corick Linea). Dashed line represents mirror "image" of troughs in leading hemisphere transposed onto trailing hemisphere.

The TPW deformation pattern on Europa is thus more complex than the original features reported. The pattern forms 3 concentric features (Fig. 3): the inner arcuate trough, and the middle irregular depression zone and outer fracture belt (with some overlap). En-echelon fractures are usually associated with shear, and in the modeled stress field of [2] the observed fractures occur in the projected shear stress zones for TPW. Breaks and irregularities in the pattern may be related to ice shell variations.

TPW may also explain a number of unusual features. Most of Europa's 500-10,000 meter high polygonal plateaus are found within 700 km of the arcuate troughs (but not interior to them) (Fig. 3). Europa also has a number of narrow graben-like fractures several hundred km long and <2 km across. Some of these are concentric to the troughs. Most areas of rugged topography on Europa, including Moytura Regio, appear within this concentric zone. The few fold-like structures that have been identified on the surface [4] also appear to be oriented in such a way as to be concentric to the trough patterns. Even Agenor and Corick Linae appear radial to the pattern, though this may be coincidence. Global mapping coverage is sufficiently incomplete as to make a definitive match of these features to TPW (as opposed to other stress fields) uncertain.

The en-echelon fractures provide an important clue to the age of the TPW events on Europa. The topographic depressions identified previously are remarkable in that they are not associated with any crosscutting deformation. The longevity of such relief on a warm ice shell is likely short but the age of formation is uncertain. The en-echelon fractures, however, crosscut most known features, indicating that TPW occurred geologically recently.

We also searched for evidence of residual topographic bulges associated with the expected thickening of the ice shell at the paleo-pole locations [3,4]. Unfortunately the stereo coverage of Europa is very poor in these locations and do not have sufficient resolution to reliably detect such features.

The non-circles of Ganymede: Extensive search of the entire Voyager and Galileo image library, including all terminator image sequences and all high resolution images reveals no trace of any of the features currently associated with TPW on Europa. No arcuate troughs, no irregular depressions, no raised plateaus, no crosscutting en-echelon fractures. This may be consistent with a thicker ice shell on Ganymede. A thicker ice shell (and lithosphere) will not deform as easily, and will resist polar wander in the first place [3]; a thinner icy shell, more plausible in Ganymede's past, may have undergone polar wander [5], but the resultant stresses will be lower by a factor of 3 compared with those on Europa [6] and may not have created such a distinctive tectonic signature. We are engaged in a global search for other manifestations of TPW on Ganymede and will report on our findings.

We note that TPW is plausible on Ceres, possibly leading to fracturing (though a bulge will relax), but requires a global ocean presently or in the past.

References: [1] Collins G. C. et al. (2010) in *Planetary Tectonics* (Watters T. R. and Schultz R. A., eds.), CUP, 264–350. [2] Schenk P. et al. (2008) *Nature, 453,* 368–371. [3] Ojakangas G. W. and Stevenson D. J. (1989) *Icarus*, *81*, 242–270. [4] Nimmo F. et al. (2007) *Icarus*, *191*, 183–192. [5] McKinnon W. B. et al. (2014) *45th LPSC*, Abstract #1869. [6] Leith A. C. and McKinnon W. B. (1996) *Icarus*, *120*, 387–398.