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Insights into the Formation and Evolution of Europa's Bands from Relationships Involving Morphology, Topography, and Relative Age

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Abstract

Using DEMs produced through a combination of stereo photogrammetry and photoclinometry we have determined the mean elevations of 14 features that can be classified as Europan bands. These bands are spatially and temporally diverse and include features that have been previously used in analyses describing driving mechanisms for the formation of bands [1-3] and support mechanisms for the positive topography associated with such features [4]. With these data, relationships previously discussed involving the morphology, topography, and relative age of bands on Europa have been evaluated. Our results support a driving mechanism involving complete separation of the Europa's crust followed by infill of underlying material. Using the new data, we confirm previous suggestions that the topography of bands is consistent with a formation mechanism that includes a combination of thermal and compositional buoyancy.

1. Europan Bands

1.1 Morphology

With few exceptions (e.g., Agenor Linea), bands on Europa can be generally defined as features with distinct linear to curvilinear margins that can be closed such that the surrounding preexisting surface is reconstructed. Differences in the interior morphology of bands have led to the definition of various sub-categories [2,3,5,6] and two of these categorization schemes have been used to describe driving mechanisms for the formation of these features [2,3]. The "buoyancy" formation mechanism proposed by [1] and expanded upon by [3] results in bands that are elevated with respect to the surrounding terrain, regardless of morphology. The "tidal pumping" formation mechanism proposed by [2] explicitly described a link between the topography and morphology of bands and, for that reason, we adopted their categorization scheme to classify the 14 features used in this analysis (Fig. 1).

1.2 Topography

The mean elevations of the bands range from -56 ± 8 meters below to 147 ± 32 meters above the surrounding terrain, with an average value of 32 ± 7 meters (Fig. 1). Eleven of the bands have positive relief. These data demonstrate the generally high-standing nature of these features with respect to the surrounding terrain, a result that is consistent with previous work based on inferred relative topography and limited available stereo data [2-4]. The range in observed values also indicates that the mean elevations of these bands are not uniform (on a scale of 10s of meters). The implications of variations in the elevations of bands were not explicitly addressed in the buoyancy model for driving band formation [1,3]. However, the tidal pumping model did address potential variations, proposing that a correlation between the topography associated with and the morphological characteristics of bands should exist [2]. The relative ages of features were identified in this model as a complicating factor that would need to be taken into consideration. To determine if the variable elevations of these features could be correlated with morphology and relative age, potential relationships involving these characteristics were examined.

1.3 Relative age

To understand if/how relative age plays a role in the mechanism that drives the formation of bands, it is important to have knowledge of the relative ages with respect to each other of all of the bands

analyzed. In order to determine this information, we considered the orientation of each band with respect to a nonsynchronous stress field. Previous work has demonstrated that nonsynchronous rotation (NSR) of Europa's outer icy shell can plausibly describe the locations and orientations of prominent structural features [7,8]. Using this method, A relative age sequence for the 14 bands was constructed. available superposition relationships were used to constrain the placement of each band within the overall relative age sequence and the need for a continuous progression in orientation was used as an additional constraint. It was also assumed that the youngest features within an observation formed near-contemporaneously with those of the other observations. The sequence that resulted represents the minimum amount of NSR that would be necessary to satisfy those constraints and suggests that at least 440° of NSR would have been necessary for the 14 bands in this analysis to have formed (Fig. 1).

2. Results

The model of [2] proposes that the formation of bands on Europa is driven through a combination of cyclic deformation and secular dilation. They came to this conclusion based on what they observed was a strong correlation between the morphological characteristics of bands (as they defined them) and the topography associated with them. We do not observe this trend in the topography and morphology of the bands we analyzed, even when considering relative age. The model of [3] did not describe a direct relationship between the morphology and topography of bands. Instead they suggested that differences in morphological characteristics were related to the spreading rates of bands and that all such features should generally have positive relief. We find that the relationships between topography and morphology of the bands we analyzed are more consistent with this prediction. Elevation and relative age have also been used to examine potential mechanisms for isostatically supporting bands [4]. We find that the positive relief associated with 11 of the 14 bands we examined most is consistent with the predictions of a combination thermal/compositional support mechanism.

References

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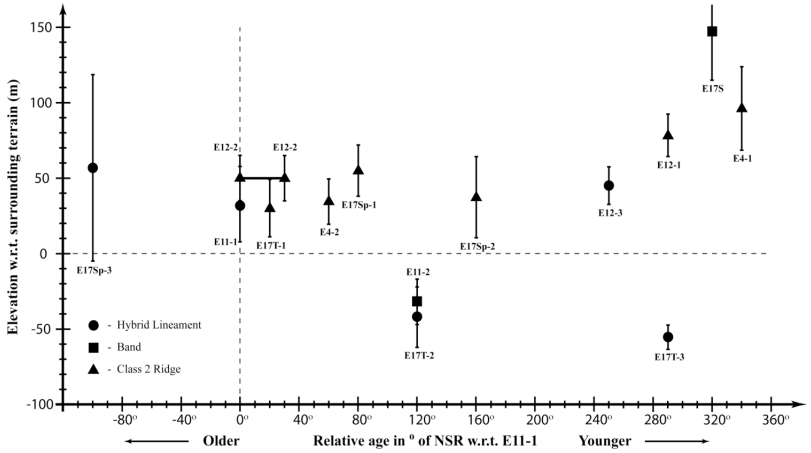

Fig. 1. Plot of band elevation versus relative age. Mean elevations for the 14 bands are labeled based on specific morphological characteristics described in [2]. Vertical bars associated with each band indicate the standard deviation of the mean. E12-2 shows up twice and is connected by a horizontal line to indicate uncertainty in its orientation. Dashed horizontal and vertical lines represent zero meters elevation and zero degrees NSR respectively.