IMPLICATIONS OF CYCLOID HISTORY IN THE NORTHERN TRAILING HEMISPHERE OF EUROPA. Julie M. Groenleer[1] and Simon A. Kattenhorn[2], Department of Geological Sciences, University of Idaho, Moscow, ID 83844-3022. ([1]groe7937@uidaho.edu, [2]simkat@uidaho.edu)

Introduction: The surface of Europa consists of an intensely fractured ice shell that is floating on a subsurface ocean of liquid water [1]. Compelling evidence for a floating ice shell comes from the presence of arcuate tensile cracks (or cycloids) [2]. Cycloids consist of curved segments linked together at cusps (Fig. 1). Individual cycloid chains of 100s – 1000s km in length are observed at a variety of orientations in nearly every imaged region of Europa.

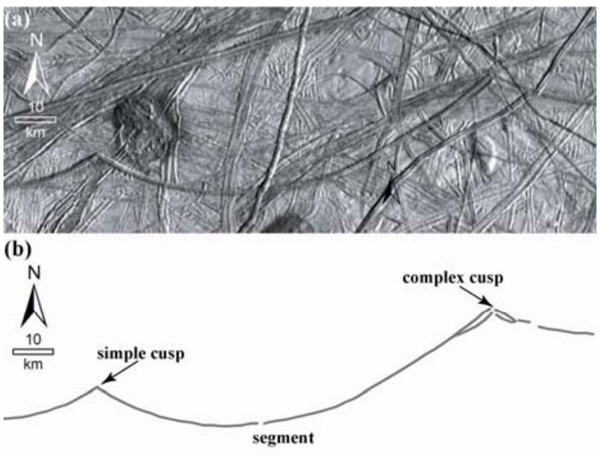

Fig. 1. (a) Image of a cycloid in the E15RegMap01 area. (b) Trace of the cycloid with cusp and segment labels. The different cusp types (simple and complex) are also indicated.

Crack growth is strongly controlled by rotating diurnal stresses in the ice shell that result from oscillating tidal bulges in the subsurface ocean [2, 3, 4]. However, the long-term stress component due to nonsynchronous rotation (NSR) of the ice shell also likely affects the overall distribution and patterns of cycloidal features observed on the surface [5]. While geologic mapping has revealed cycloids are geologically recent, relative age sequences documenting multiple episodes of cycloid formation are needed to study changes in cycloid characteristics (i.e., orientation, morphology) over time. Using age sequences determined through cross-cutting relationships, and conventional means of interpreting NSR based on a consistent rotation of fracture orientations through time, we have estimated the amount of NSR that occurred purely since the onset of cycloid development in the E15RegMap01 area.

Cycloids in the E15RegMap01 Area: The E15RegMap01 mosaic (Fig. 2a), located in the northern trailing hemisphere, spans latitudes 19 to 62°N and longitudes 212 to 234°W. Twenty-two cycloids have been identified in the mosaic [4], 14 of which (Fig. 2b) could be fitted into a relative age sequence based on cross-cutting relationships of both cycloids and other lineaments. The remaining 8 cycloids had an insufficient number of cross-cutting features to fit them into the age sequence.

In the northern hemisphere, the diurnal stress field rotates in a counterclockwise sense. This allows cycloid chain growth directions to be predicted based on the direction cusps point [2]. As indicated in Fig. 2b, there are two predominant cycloid growth directions in the E15RegMap01 area: ~ N-S oriented cycloid chains that grow from N to S and ENE-WSW oriented cycloid chains that grow from ENE to WSW.

Cycloids are, in general, some of the youngest features in the E15RegMap01 area. However, each of the 22 cycloids identified is cross-cut at least once by younger features. These younger features include other lineaments (cycloids, ridges, troughs, or bands) and, to a lesser extent, chaos, pits, or craters. The oldest cycloids studied are predominantly cut by non-cycloidal features but the youngest cycloids are predominantly cut by other cycloids and are only occasionally cut by non-cycloidal features. Therefore, the onset of cycloid development in this area does not indicate the end of the formation of non-cycloidal fractures.

Most cycloid segments are defined by double ridges but there are a few band and trough cycloids observed in the mosaic. All of the 14 cycloid chains fitted into the age sequence have predominantly double ridge morphologies. Cycloid cusps are either simple (one splay) or complex (multiple splays) (Fig. 1b). Neither segment nor cusp morphologies appear to show a preferential pattern through time.

Nonsynchronous Rotation Implications: Cycloid chain orientations have rotated in a clockwise sense through time which is consistent with previous NSR studies in the northern hemisphere (e.g., [6, 7, 8]). Relative age sequences determined through cross-cutting relationships of 14 cycloid chains in the E15RegMap01 area have been used to estimate the amount of NSR that occurred between the formation of the oldest and youngest cycloids studied. Based purely on average cycloid chain orientations, there has been at least 600° of NSR during cycloid development in this area (Fig. 3).

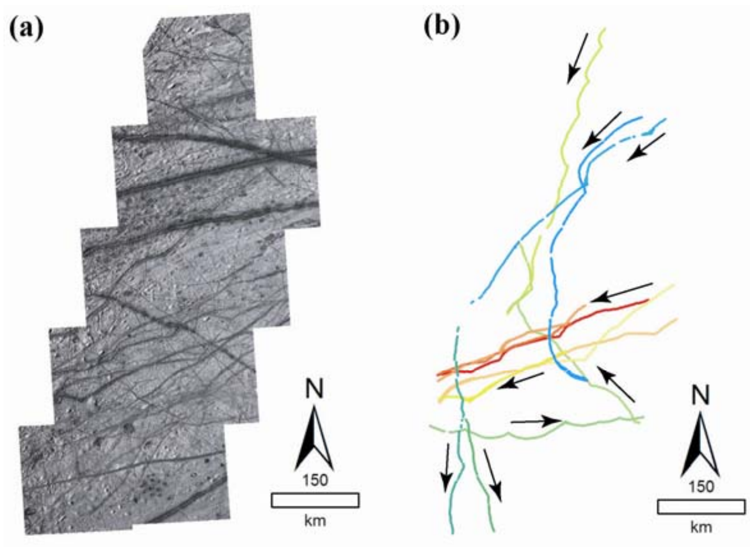

Fig. 2. (a) E15RegMap01 image mosaic. (b) Traces of the 14 cycloid chains fitted into the age sequence. The colors grade from darkest blue (oldest cycloid) to red (youngest cycloid) and the arrows indicate growth direction.

Previous NSR studies based on detailed fracture maps of the leading hemisphere [7] and the Bright Plains region [8] reported NSR amounts of 360-720° and 720-900° respectively. The minimum of 600° of NSR found in this study is based purely on average cycloid chain orientations. If the orientations of other non-cycloidal lineaments that cross-cut the 14 cycloids studied are taken into account, the minimum amount of NSR would be much greater. Therefore, this study suggests that the amount of NSR may be significantly higher than previously reported.

Fig. 3 shows the amount of NSR that has occurred between time steps in cycloid formation. Older time steps tend to have larger amounts of NSR between each other than younger time steps. Therefore, the amount of NSR between periods of cycloid growth is temporally variable and there are potentially long time intervals between episodes of cycloid formation. An average of 8.4 cycloids grow per NSR period based on the minimum of 600° of NSR that occurred during the development of the 14 cycloids studied.

Two previous studies have constrained 1 NSR period to be between 12,000 [9] and 240,000 [3] years. Using those estimates and our 600° minimum amount of NSR and assuming a consistent rotation of fracture orientations through time, the minimum duration of cycloid development in this region has been constrained to between 20,000 and 400,000 years. However, recent work [10] suggests NSR does not occur at a constant rate through time due to thickening of the ice shell. This implies that the constraint on the minimum duration of cycloid development may not be representative of the actual duration.

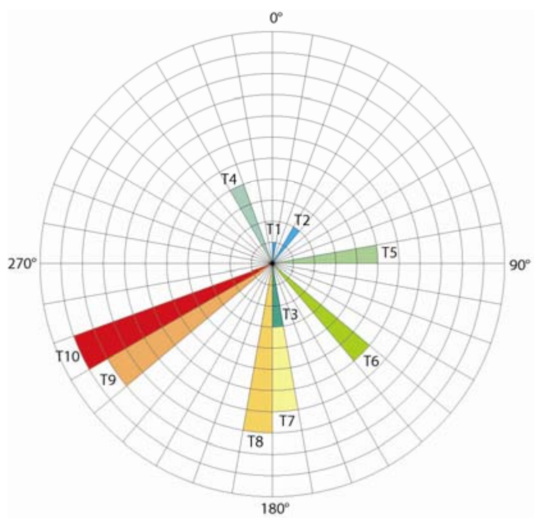

Fig. 3. Rose diagram showing average cycloid chain orientations through time. Each ring represents a time step in the age sequence with the first ring being the oldest. Colors also represent time steps with blue being older and red being younger (as in Fig. 2b).

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