

DETAILED FRACTURE HISTORY OF THE BRIGHT PLAINS REGION, EUROPA: IMPLICATIONS FROM NONSYNCHRONOUS ROTATION MODELS. S. A. Kattenhorn, Department of Geological Sciences, University of Idaho, Moscow ID 83844-3022 (simkat@uidaho.edu).

Introduction: The complex fracture history of the Bright Plains region of Europa's trailing hemisphere (~15N/273W) has been unraveled using detailed fracture maps created from *Galileo* SSI images obtained during the E6 orbit. Features identified include double ridges, complex ridges, smooth bands, and surface fractures, each of which formed in multiple fracturing episodes. The fracture evolutionary sequence reveals a consistent clockwise rotation of fracture orientations through time and hence an ongoing clockwise rotation of the principal stresses in the stress fields responsible for each fracturing episode. This behavior is consistent with nonsynchronous rotation (NSR) models for the northern hemisphere of Europa. The amount of rotation of the stress field implies at least 720° (and perhaps >900°) of NSR of Europa's decoupled outer crust with respect to the moon's interior.

Fracture Mapping of the Bright Plains: Detailed fracture mapping was carried out using images of the Bright Plains, in the Conamara Chaos region of Europa's trailing hemisphere. The mapped region is immediately north of the intersection point of Agave Linea and Asterius Linea and covers an area approximately 60 km long and 33 km wide. High resolution *Galileo* SSI images (down to 20m/pixel) enabled fine details of fracture lineament relationships to be unraveled. Most lineaments are either "mode I" fractures (tensile fractures and intrusive dikes) or normal faults. Such structures developed perpendicular to regional maximum principal tensile stresses where the driving stress was of sufficient magnitude to break Europa's ice crust. The fracture lineaments thus provide direct evidence of the history of principal stress orientations and driving stress magnitudes in the Bright Plains.

Geologic Features: A number of lineament types were differentiated [e.g., 1], with several different aged fracture episodes for each class of feature. Each fracture episode is shown in the geologic map in Figure 1. The fracture types are described below.

Ridged Plains. These are the oldest portions of the surface, comprised of a dense network of ridges upon which younger fracture lineaments are superimposed.

Smooth Bands (SB). These are generally linear bands (2-13 km wide) of smooth, featureless material internally dissected by normal faults. Smooth bands probably represent crustal spreading where icy material was intruded from below to form new crust. Five separate episodes of smooth band development can be identified, typically with an east-west orientation.

Double Ridges (DR). This is the most common class of fracture lineament in the Bright Plains. Double ridges are essentially ice dikes that constructed flanking ridges to either side of the central fracture due to extrusion of icy material. At least five separate episodes of double ridge development can be identified.

Complex Ridges (CR). The two episodes of complex ridge development represent repeated intrusion of adjacent parallel dikes/double ridges within linear bands having similar dimensions to smooth bands [cf., 2, 3].

Medial-trough Ridges (MTR). These features may be similar to double ridges but have wider flanking ridges of featureless material to either side of a central fracture, thus resembling smooth bands [cf., 1, 2].

Proto-ridges (PR). Transitional features between surface fractures and double ridges. They generally have poorly developed flanking ridges and represent the youngest intrusive features in the Bright Plains area.

Surface fractures. These are the youngest lineaments at the surface and do not extend through the entire crust. Individual fractures are <12 km in length. At least five separate fracture set orientations can be discerned, although relative ages are difficult to gauge.

Faults. Both strike-slip and normal faults are common in the Bright Plains. Strike-slip faulting occurs along pre-existing lineaments such as double ridges. Ancient transform faults define sudden terminations of complex ridges. Normal faults are generally restricted to smooth bands, and are sometimes reactivated with a strike-slip component of motion.

Fracture Sequence: Cross-cutting relationships were used to identify a fracturing sequence (Figure 2). The history of fracturing is generally unambiguous, with uncertainties where similar aged features do not cross-cut directly. Smooth bands, double ridges and complex ridges formed throughout the fracture sequence in a range of orientations. Successively younger fractures are consistently oriented in a more clockwise sense compared to older fractures. This pattern of fracture development provides strong support for NSR models in order to explain the repeated episodes of fracturing of the crust in the Bright Plains.

Nonsynchronous Rotation Models: Tensile stresses can be induced by diurnal tidal flexing of Europa's crust in response to the variable gravitational pull of Jupiter during Europa's elliptical orbit [4, 5]. However, the range of fracture orientations in the

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Bright Plains is inconsistent with the stress field that currently exists at this longitudinal position (red box in Figure 2). A plausible explanation for these observations is rotation of a decoupled crust with respect to Europa's interior in response to the spin rate being slightly faster than synchronous [4]. The resultant NSR stress field is superimposed on the diurnal stress field (Figure 2). NSR causes the global stress pattern to migrate relatively westwards across the European surface through time, resulting in a progressive rotation of fracture lineaments during the fracture sequence (clockwise in the northern hemisphere and counter-clockwise in the southern hemisphere). Successively older fracture sets can thus be placed into a time sequence of older stress states that existed when the Bright Plains region was positioned at successively more westerly longitudes. This technique is demonstrated in Figure 2. Clockwise rotation of principal stress axes in the Bright Plains region implies a minimum of two complete nonsynchronous rotations (720°) of Europa's crust during the visible fracture history. If recent surface fracturing is also attributable to NSR

effects, an additional 180° of rotation is required to account for the current state of stress at this longitude, totaling 900° of NSR. This implies that the most recent surface fracturing occurred when the Bright Plains was located 70° west of its current longitude (green box in Figure 2). For a suggested minimum NSR period of >12,000 years [6], the most recent surface fractures must have formed >2,300 years ago, assuming NSR models are applicable. NSR model assumptions thus imply intermittent fracture development throughout the fracture history of the Bright Plains with intervening time intervals of perhaps several thousands of years between fracturing events.

References:

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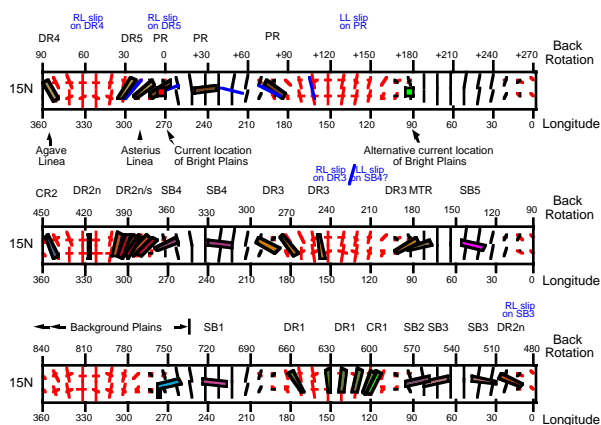
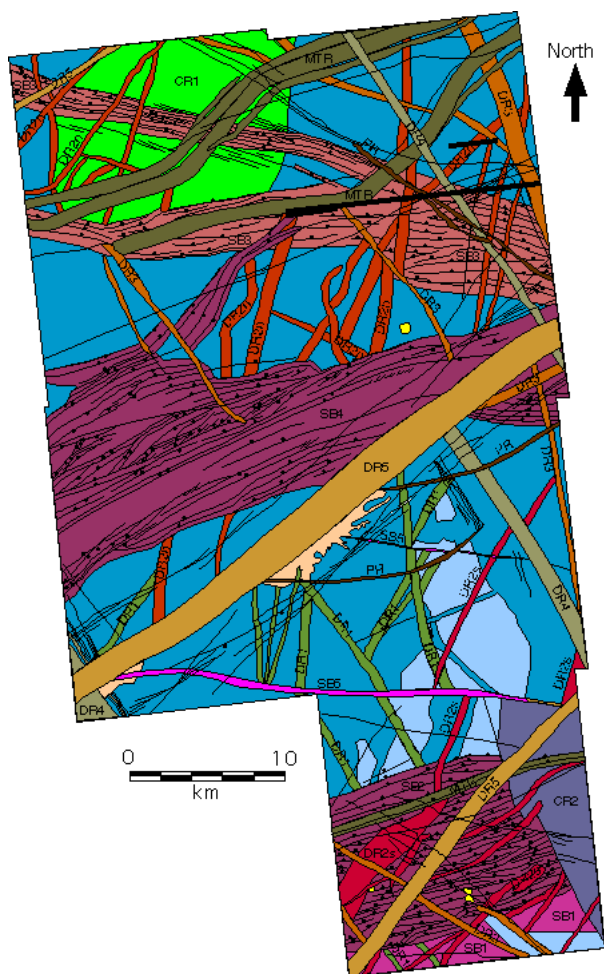


Figure 1 (left): Geologic map of the Bright Plains region. Different lineament type labels are defined in the text. For multiple fracturing episodes of any lineament type, lowest numbers represent oldest fracture episodes. Ridged plains are in blue.

Figure 2 (above): Fracturing sequence in the Bright Plains region. Principal stress orientations due to combined diurnal and NSR stress fields are shown by black ticks (tension) and red ticks (compression). Fracturing episodes are superimposed on this stress field moving backwards in time (westwards). If Bright Plains is at the location of the red box, at least 720° of back rotation is necessary. A further 180° of rotation may be needed to explain recent surface fractures, placing Bright Plains at the location of the green box.