TECTONIC EVOLUTION OF GANYMEDE'S FURROWS.

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Introduction: The oldest geologic unit of Ganymede's surface is the dark terrain, which is subsequently crosscut by younger swaths of light terrain [1]. The dark terrain shows low albedo, high crater density and morphotectonic structures called furrows. The furrows are straight to curved fragments of brittle troughs, which show two rims with high albedo that bound a low albedo floor. Furrows are arranged with circumferential and radial setting at the regional scale, and are generally thought being the remnants of a multi-ring impact basin similar to the Valhalla basin on Callisto [2, 3]. According to their setting, mostly located in Galileo Regio and Marius Regio, the furrows have been classified into two main systems: the concentric furrows of Lakhmu Fossae system, crosscut by the radial furrows of the Zu Fossae system [3]. The data of Galileo Regio allow the identification of structures at local scale. Many furrows of Lakhmu Fossae have been preserved until the present day in their pristine form, while some of them have been reworked by local-scale structures with complex morphology. In addition, within the main systems, local scale linear structures occur with a well-defined NE-SW trend. Such structures are considered the precursors of light grooved terrain formation [3]. In this abstract we investigate the furrow systems at both the regional and local scale to understand the tectonic history of the dark terrain of Galileo Regio (extending approximately from 180°-120° W to 0°-60° N). Moreover, we prepare an evolutionary model explaining both the dynamics and the induced kinematics responsible for the formation of the furrows.

Data and Methods: Our analysis is based on the Voyager high-resolution mosaic (485.7 m/pixel) of Ganymede images produced by [4]. We mapped the tectonic structures of Galileo Regio and we performed geostatistical analyses of the attributes of the mapped data that allow to identify the structural systems within the study area. In particular, attributes such as structure length, sinuosity, azimuth, spacing within the adjacent structures have been quantitatively characterized. The orientation of each structure has been measured and displayed by rose diagrams to understand their azimuthal distribution. We then measured the Length/Spacing ratio (L/S, [4]) to characterize the fracture intensity in Galileo Regio and to quantify the fracture infilling process, which refers to the nucleation of new brittle structures between pairs of pre-existing structures during progressive brittle deformation [5]. Moreover, a paleo-stress analysis has been performed to better infer the past tectonic stresses (maximum and minimum horizontal stress, i.e., SHmax and Shmin, respectively) that caused the formation of the furrows. For this analysis, we consider the dip of the structures as nearly vertical. In addition, geomorphological indicators allow us to understand the sense of movement of the mapped structures.

Structural systems of Galileo Regio: A total of four structural systems have been recognized within Galileo Regio: i) the already known Lakhmu and Zu Fossae; and ii) the NE-SW system and Precursor system, proposed by this work for the first time (Fig. 1). Each system is defined by structures with similar attributes, well defined orientations and a stress field that indicates the tectonic regime responsible for the formation of the system itself.

In this way, our analyses confirm that Lakhmu Fossae furrows result from extension, compatible with a giant impact [6]. With a trend opposite to the Lakhmu Fossae tectonics, extension occurred also for the formation of the NE-SW system.

On the other hand, the analyses show that strike-slip played a key role in the formation of the Zu Fossae system and the Precursor system. In particular, transpression consistent with Uruk Sulcus's tectonics has been identified as responsible for Zu Fossae system.

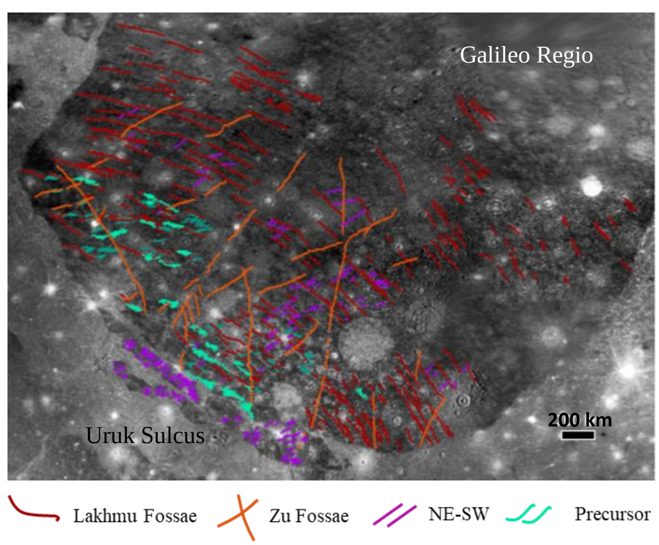

Figure 1: Structural mapping of Galileo Regio.

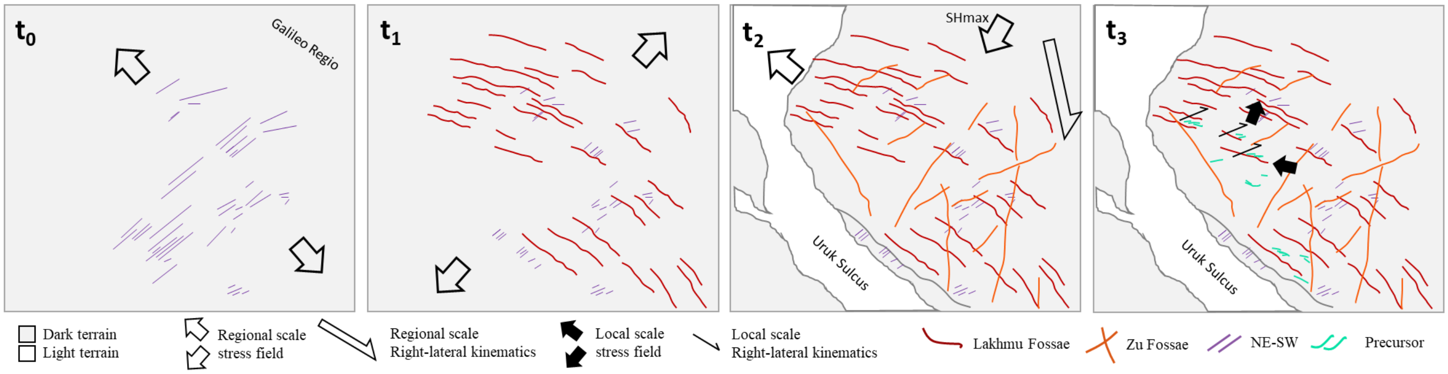

Figure 2: Tectonic model of Galileo Regio. t_0) extensional regime that led to the formation of the NE-SW system; t_1) formation of the Lakhmu Fossae system caused by impact; t_2) right-lateral strike-slip responsible for the Zu Fossae system formation and the tectonic reworking of the light terrain of Uruk Sulcus; t_3) present-day configuration, the Precursor system is originated by right-lateral kinematics at the local scale.

Discussion and Conclusions: Galileo Regio has been affected by a series of tectonic events occurred in the geologic history of Ganymede. Our analysis allows to identify the tectonic phases and to unravel their chronological sequence (Fig. 2). We recognize two extensional events: i) one associated to the impact that originated the multi-ring basin, i.e., the Lakhmu Fossae (t_1 in Fig. 2); and ii) the second with an opposite trend, i.e., the NE-SW system (t_0 in Fig. 2). Between t_1 and t_2 we assume extensional activity as responsible for the formation of the light terrain of Uruk Sulcus [7]. This could have occurred during t_1 by contributing to the formation of the Lakhmu Fossae. In fact, the occurrence of such system in a high-strain zone may have allowed its conservation during the latest tectonic events (t_2 and t_3 in Fig. 2). In this way, the extension has been removed and covered by two strike-slip events: iii) a kinematics consistent with the right-lateral transpression that has affected Uruk Sulcus [4] and formed the Zu Fossae (t_2 in Fig. 2); and iv) a right-lateral strike-slip that contributes to the new-generation furrows, i.e., the Precursor system, which leads to the rejuvenation of the dark terrain towards its possible future transformation into light one (t_3 in Fig. 2).

Therefore, we can assume that the dark terrain of Galileo Regio has been deformed at first by extension and later by strike-slip, which represents the same tectonic process that have affected the light grooved terrain of Uruk Sulcus. This work confirms the key role that transpression has played in the leading hemisphere of Ganymede and the reactivation of the furrows in Galileo Regio, which have followed a deformation history beginning from an impact origin to a tectonic remodeling. The obtained results from this study will be used for the scientific preparation of dedicated high-resolution observations that will be taken with the JANUS instrument [8] onboard the JUICE mission [9].

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