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Paleotectonism in the Noachis-Sabaea region, Southern Highlands of Mars; Preliminary Modelling and Reconstruction of Events

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1. Introduction. Paleotectonism of Mars has been investigated at global to local scales [1], with particular focus on Tharsis and its components [1], [2]. Such examples include the southern and eastern margins of the Thaumasia plateau, namely the Thaumasia highlands and Coprates rise mountain ranges respectively [3], and structurally-controlled basins and associated highly-degraded massifs that are interpreted to be volcanoes such as in the extremely ancient provinces like Terra Sirenum [4] and Terra Cimmeria [5].

This is the first geologic investigation with the primary purpose of determining the paleotectonic history of the Terra Sabaea and eastern Noachis Terra region (referred here as the Noachis-Sabaea region), including faults and wrinkle ridges located to the northwest of the Hellas impact basin. Though, there have been mapping investigations, which have revealed: the general geologic history of the region such as those based on Viking data [6], centres of tectonic activity in the eastern equatorial region, including the Isidis/Syrtis Major volcanic province and Arabia Terra [1], and an investigation which resulted in the identification of macrostructures (faults with lengths exceeding 1,000 km) which transect the region with respect to Mars Global Surveyor (MGS) Mars Orbiter Laser Altimeter (MOLA), gravity, and paleomagnetic data [7].

In this on-going investigation, we are identifying, characterizing, and mapping lineaments and scarps, which we interpret to be both tectonically derived and non-tectonic features. Tectonic features include those that formed prior to the Hellas impact event and non-tectonic features are those related to the Hellas impact event and modified by Hellas impact. We are using MOLA global colorized elevation map (Fig. 1), HRSC and CTX images and stratigraphic information of the newly published global geologic map of Mars [8]. Here, we present our preliminary map, containing information which will be used to unravel the complex paleotectonic history of the Noachis-Sabaea region, including pre-Hellas, Hellas-impact, and post-Hellas deformation.

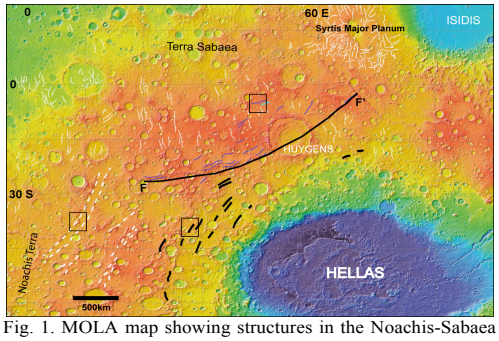

Fig. 1. MOLA map showing structures in the Noachis-Sabaea region, including three sets of grabens (set 1 indicated by bold black lines, set 2 by white dotted lines, and set 3 by purple lines). Wrinkle ridges (narrow white lines) and grabens (FF'-curvilinear black line) are also shown. Black rectangular boxes are zoomed in Fig. 2.

2. Structural observation of the area. Deformation of the Noachis-Sabaea region includes three distinct sets of graben, determined through their orientations and morphologic and topographic expressions. The set-1 grabens (Fig. 2a) are mainly concentric to the Hellas basin and may have formed due to the Hellas impact event, including stress relaxation of impact energy (hoop stress) [9]. Of the three sets, this set of grabens are the shortest in length.

Set-2 grabens (Fig. 2b) have NNE-SSW to N-S trends, with the largest one having a length and width of ~1200 km and ~80 km, respectively. These grabens, which have corrugated boundaries, contain a remnant crustal basement. Both the horst and graben have been significantly modified by wind, water and gravity-driven processes and the graben being partly infilled by sediments. In addition, Late Noachian flood volcanism has been reported to have sourced from several of the graben floors [10]. Importantly, more detailed analysis is necessary to determine whether the formation of these grabens, including their geometric patterns, were influenced by impact craters, including those buried [11]

and/or possibly basement structures no longer visible at the Martian surface.

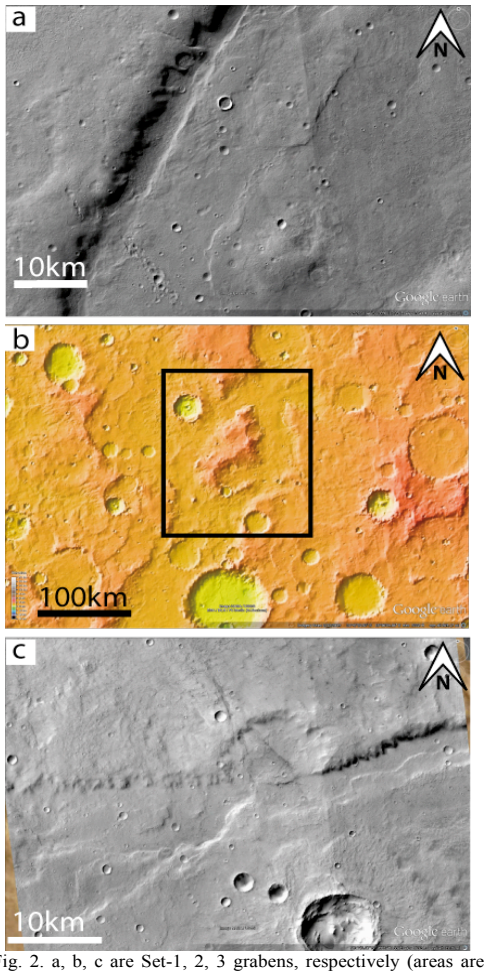

Fig. 2. a, b, c are Set-1, 2, 3 grabens, respectively (areas are marked in the Fig. 1). Fig. 2a is a CTX image and shows a half graben structure, and Fig. 2b is MOLA colourised elevation map showing a ridge-like structure within the graben (marked with rectangle). Fig. 2c is a typical shape of grabens shown in a CTX image.

Set-3 grabens (Fig. 2c) are concentrated mainly in the Terra-Sabaea part of the study region having NE-SW to E-W trends. These grabens are not extended when compared to the set-2 grabens; they are smaller in extension but form a graben network that collectively extends up to 2800 km. The Huygens impact event appears to post-date the formation of most of the grabens (based on the stratigraphic and crosscutting relations among the grabens and Huygens impact crater materials). Though, there is a ridge-like structure that deforms the central part of the Huygens basin, which marks either reactivation of a pre-existing basement structure or post-impact deformation including contraction. In addition, the northwest rim appears to be deformed. These grabens appear to terminate northeast of Huygens near the southern margin of the Syrtis Major volcanic province and a large curvilinear scarp which could mark the highly degraded rim of the Isidis impact basin rim and to the west near the longest graben of the set-2 grabens. Identification, mapping, and characterizing such details will help to unravel the paleotectonic history in the region.

3. Discussion. Our preliminary mapping in the Noachis-Sabaea region indicate several modes of origin of the tectonic structures, some are not necessarily tied to the Hellas impact event. The Hellas impact event, estimated to have occurred at ~4.0 Ga [12], for example, likely contributed to set-1 grabens, including stress relaxation following the impact event. But what about the other system of structures? There are multiple possible contributors to the present-day strain in addition to the Hellas impact event that must be thoughtfully considered. Possible contributors include the putative Arabia Terra impact [13] and the putative Utopia impact [14], the Isidis impact event and activity related to the development of the Syrtis Major volcanic province [1], and possible plate tectonism such as reported for the Terra Meridiani region of Mars [15]. The latter is of particular interest, as there is more and more evidence for an ancient dynamic Mars recorded possibly in a felsic basement [16]. Also, there has been felsic rocks [17], interpreted to be granite, in the region. Thus could the processes that resulted in the formation of some of the fault systems (e.g., set 2 and 3, and F-F') be related to the possible granite rocks, or could the felsic rocks be indicative of an ancient southern highlands basement which records dynamic activity? We will present the paleotectonic information with main focus mainly on the tectonic fabrics and their origins at the conference providing working hypotheses to help explain the mapping results.

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