TIMING OF TECTONIC SHORTENING IN WESTERN ARABIA TERRA AND IMPLICATIONS FOR THE EXOMARS 2022 ROVER LANDING SITE.

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Introduction: Oxia Planum, the landing site of the ExoMars 2022 Rosalind Franklin rover [1], is located in transitional terrain between the Arabia Terra highlands and the Chryse Planitia lowlands. Here, the Noachian landscape has been exhumed [e.g., 2, 3] and modified by tectonism as expressed by a regional fabric of 'wrinkle ridges'. The impact of tectonism, on both regional and global scales, on the geological history of western Arabia Terra is poorly understood and could have implications for palaeohydrology [4] and the elevation of proposed shoreline features.

To provide constraints on the tectonic evolution of the region, we mapped tectonic features in western Arabia Terra (Fig. 1) and analyzed the timing of tectonic events using their cross-cutting relationships with impact craters (Fig. 2).

Our study site is a ~1 million km^2 area centered on Kilkhampton crater in Oxia Planum (Fig. 1). The widespread tectonic features in the study area are thrust-fault-related landforms, termed shortening structures [e.g., 5, 6]. They occur across the region including near the ExoMars rover landing site and in the channel floors of Coogoon, Mawrth, and Ares Valles.

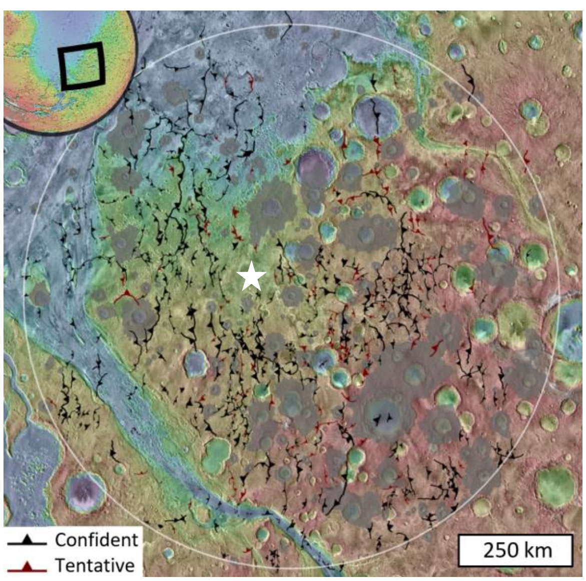

Figure 1. *Inset: MOLA topographic map showing location of western Arabia Terra. Main: Regional map of tectonic shortening structures in the study area (**white circle**). Star shows ExoMars rover landing site.*

Methods: We digitized tectonic shortening structures at a scale of 1:50,000 using 6 m/pixel Context Camera (CTX) images [7], 100 m/pixel Thermal Emission Imaging System (THEMIS) daytime infrared images [8], and 463 m/pixel gridded Mars Orbiter Laser Altimeter (MOLA) [9] topographic data. To compensate for illumination bias and to prevent east-west oriented structures being overlooked, we also used High Resolution Stereo Camera (HRSC) [10] hillshades constructed using multiple sun angles. Our mapping approach was structural-based and we recorded fault vergence, scarp height, fault trace orientation, cross-cutting relationships, morphological complexity (i.e., wrinkle ridge, lobate scarp, or high-relief ridge), and our confidence in each feature's tectonic interpretation.

To determine impact crater cross-cutting relationships, we used CTX images, and checked the Robbins crater catalogue [11] to identify craters with diameter ≥10 km. For each crater we recorded the relationship (or lack thereof) with any tectonic features and classified craters into three classes of degradation based on the most common morphologies observed in the study area (*craters with preserved impact ejecta*, *eroded craters without impact ejecta*, and *highly eroded craters and ghost craters*). For all three, we used Crater Size Frequency Distributions (CSFD) to determine a model age of that population type. For each class we also determined the N(10) value, which is the number of craters ≥10 km diameter per 10^6 km^2 count area [12]. We used these values to explore the timing of burial/erosional processes and consider the timing of tectonic events.

Observations and Results: We identified numerous shortening structures in western Arabia Terra, with a combined length of ~17,000 km (Fig. 1). Shortening structures are distributed across the highland-lowland transition region and deform all global geomorphic units [12], but the highest density (structure length per unit area) occurs in the *Middle Noachian highland unit* and the *Early Hesperian transition unit*. The shortening structures have a dominant north-south orientation.

We find a model age of ~4.0 Ga since formation of *highly eroded craters and ghost craters*, ~3.9 Ga since formation of *eroded craters without impact ejecta*, and

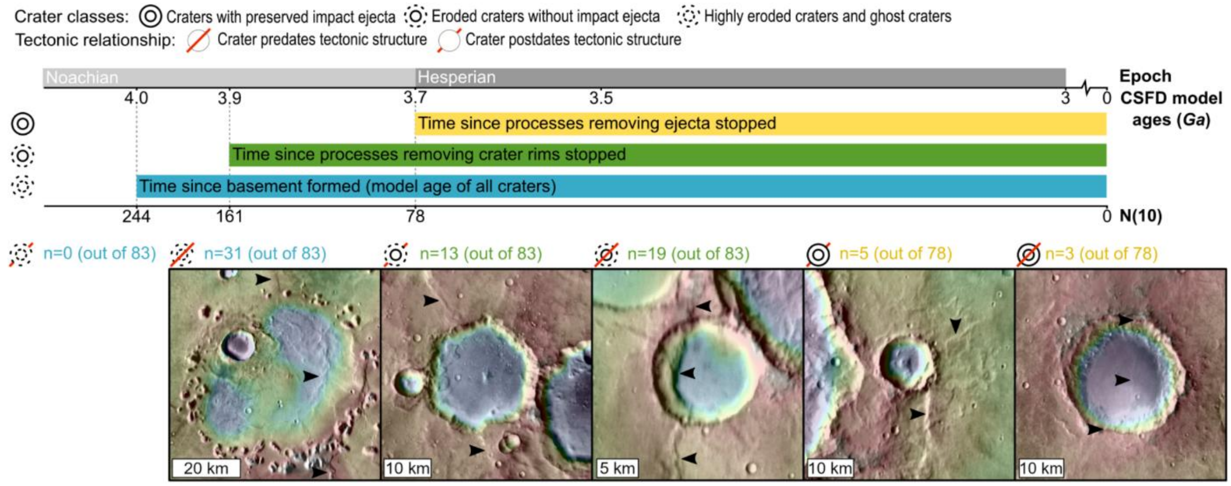

Figure 2. *Model ages of impact crater classes in the western Arabia Terra study area. The first graph shows the CSFD ages and N(10)values of all craters in each crater class (including craters without a tectonic relationship). The panels show craters with tectonic relationships, with the black arrows indicating shortening structures (THEMIS Day IR and MOLA).*

~3.7 Ga for *craters with preserved impact ejecta* (Fig. 2). In each crater class, we see craters which pre- and postdate shortening structures, except for the oldest craters (*highly eroded and ghost*) for which we find no evidence of pre-existing tectonic features.

Discussion: The different crater classes and CSFDs are based on crater degradation morphology, so they tell us about the erosional history of western Tempe Terra. Since ~3.7 Ga, erosion of ejecta significantly declined, ~3.9 Ga is the time before which crater rims are generally not preserved and hence the time at which their degradation rates declined, and ~4.0 Ga is the minimum time since basement formation.

The relationship between craters and shortening structures can tell us about the timing of tectonic activity. Because we observe *craters with ejecta* which are tectonically deformed, we know that tectonic activity has occurred since ~3.7 Ga. We do not see any evidence of shortening structure predating ~4.0 Ga (*highly eroded and ghost craters*), which suggests that there was no tectonic deformation before then, or that tectonic features were active both before and after these craters formed, or that tectonic features formed prior to these craters and have since been completely eroded.

The stratigraphic relationship between craters and shortening structures and the occurrence of tectonic features in map units of all ages, coupled with the heterogenous distribution of features across units, indicates that multiple phases of tectonic activity occurred. In ongoing work we investigate the five crater subclasses to explore how the tectonic events are distributed through time.

Conclusion: We present a CTX-scale tectonic mapping survey in western Arabia Terra and cross-cutting relationships between impact craters and shortening structures. We suggest that multiple phases of tectonic activity, or one continuously active phase, were responsible for the widespread tectonic deformation. We find no evidence of tectonic deformation before ~4.0 Ga, but tectonism occurred 4.0–3.7 Ga and since ~3.7 Ga.

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