FAULT POPULATIONS AND STRAIN EVOLUTION IN ULYSSES FOSSAE, MARS. S. Shahrzad[1], E. K. Bramham[1], M. Thomas[1], E. Mortimer[1], S. Piazolo[1], and P. K. Byrne[2]. [1]School of Earth and Environment, University of Leeds, UK, (eessha@leeds.ac.uk) [2]Department of Earth and Planetary Science, Washington University in St. Louis, MO, USA.

Introduction: The heavily faulted terrain of Ulysses Fossae, Mars is located at 10°N, 123°W, amongst the volcanoes of the Tharsis Rise (Figure 1). Olympus Mons is situated ~600 km to the west, the Tharsis Montes to the east, and the Ulysses Patera volcano immediately to the south. Ulysses Fossae has been the target of only a few dedicated studies [e.g., 1, 2], but is a distinct location in that it displays faults that appear radial to Olympus Mons, which are some of the only evidence for far-field tectonic stresses associated with that volcano. We therefore carried out an in-depth volcanotectonic investigation of this area to illuminate the complex deformational history of the region around the Olympus Mons volcano in particular, and the Tharsis volcanic province in general. In this study, we mapped and analyzed the morphology, strike, and strain of the faults observed in Ulysses Fossae, to determine the sequence and character of deformation in the area.

Methods: We used Context Camera (CTX) images, with a resolution of 6 m/pixel [3], to map all identifiable faults in the Ulysses Fossae study site at a scale of ~1:250,000; mapping from Tanaka et al. [4] provided outlines for the three Hesperian geological units in the study area. To measure strain, Mars Orbiter Laser Altimeter (MOLA) data were used to create topographic profiles of select areas in Ulysses Fossae. The MOLA data were complemented by stereo-derived digital elevation models derived from High-Resolution Stereo Camera (HRSC) images, yielding a global topographic dataset with a resolution of 200 m/px [5]. Crater statistics derived from these three units with the “Cratertools” ArcMap tool and the Craterstats v.2 program [6, 7] were used to calculate absolute model ages.

Preliminary Results and Discussion: In total, we mapped 5,164 faults in Ulysses Fossae (Figure 2), with fault patterns ranging from linear to curved. Detailed analysis of the mapped faults, including investigating cross-cutting relationships, morphology, and orientation, allowed us to classify the faults into nine main populations. The fault groups are numbered based on their relative ages, with Group 1 being the oldest and Group 9 the youngest (Table 1). On the basis of strike, the majority of these populations reflect influence from local volcanic centers, as they display fault patterns radial to Olympus Mons, Pavonis Mons, and Ulysses Patera (Figure 1). One of the older populations, Group 4 (Figure 2), dated to be Early Hesperian, appears to solely be the result of regional extension associated with the growth of Tharsis.

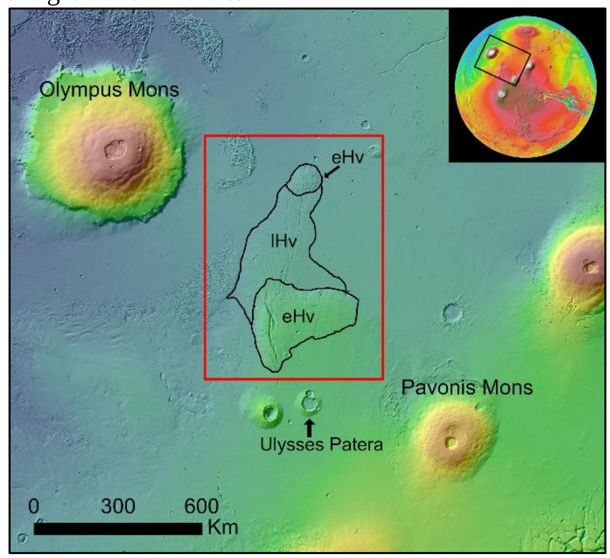

Figure 1. The location of Ulysses Fossae (black outline) with the study area outlined in red. Note the delineation of Hesperian units lHv and eHv in black, as mapped by Tanaka et al. [4]. The central location of the study area in between the Tharsis volcanoes Olympus Mons, Pavonis Mons and Ulysses Patera is highlighted. MOLA colorized hillshade is used as background.

The youngest fault population, Group 9 (Figure 2), from the late Hesperian/Early Amazonian, consists of slightly curved grabens with a sigmoidal geometry and en echelon map patterns, and appears to have formed by reactivation of the two older mapped fault populations, Groups 2 and 4 (Table 1). We also measured the estimated strain for the nine fault groups, which yielded values of extensional strain generally between 0.15 and 0.65%, with the outlier being the high strain value for Group 9 with 1.58% (Table 1). Additionally, we acquired crater statistics for the geological units in the study area to calculate absolute model ages to aid in our understanding of the history of Ulysses Fossae. We find that two of the units categorized as Late Hesperian by Tanaka et al. [4] are in fact Amazonian in age (Table 2).

Summary and Conclusions: Our mapping resulted in the recognition and analysis of nine fault groups, which together suggest several stages of structural activity in the Ulysses Fossae region. Results from relative and absolute model age analysis so far point to a complex history involving radial fault growth from the several surrounding proximal volcanoes (Olympus Mons, Pavonis Mons, and Ulysses Patera), later reactivation of pre-existing fault populations, and some influence from the regional extension of the Tharsis rise.

Further investigations based on this initial work will include additional strain measurements for each set, to aid in determining differences between regional and local extensional events, and ultimately to better understand the history of volcanism and tectonism in this region of Mars.

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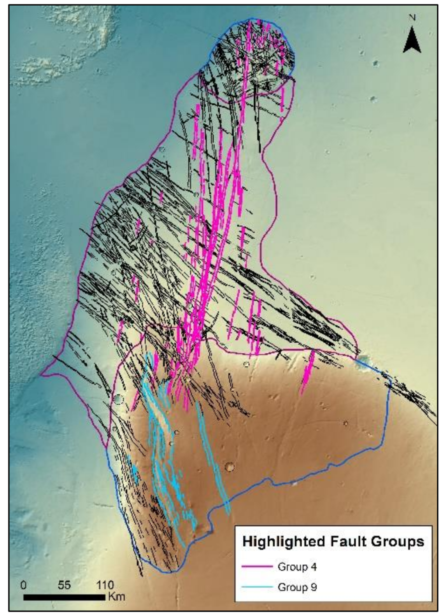

Figure 2. Mapped faults (black) in Ulysses Fossae on MOLA background. Units eHv (early Hesperian) are outlined in blue, and unit lHv (late Hesperian) is outlined in purple.

Group	*N(f)*	*Σ l (km)*	*Age [4]*	*Strike*	*Strain (%)*	*Potential Source*
1	147	591.92	eH	ENE	0.43	-
2	324	2045.18	lH	NNW	0.36	Ulysses Patera
3	631	4638.58		NNW	0.47	Ulysses Patera
4	777	4911.36	lH	N/S	0.66	Regional extension
5	316	1972.73	lH	N/S	0.16	Ulysses Patera
6	1758	8812.63	lH/eA	NW/SE	0.63	Olympus Mons
7	891	6939.45		NW/SE	0.55	Pavonis Mons
8	172	777.27	lH/eA	NE	-	-
9	148	1563.44	lH/eA	NNW	1.58	Regional extension/reactivation
Total	5,164	32,252.56				

Table 1. Mapped fault groups in Ulysses Fossae. Group number denotes relative age from oldest (Group 1) to youngest (Group 9). *N(f)* shows number of faults in each group, *Σl* is the cumulative length of the faults in each group. The *Age* is the geological period (where eH = early Hesperian, lH = late Hesperian, and eA = early Amazonian) to which the fault group is assigned in this study, using geological unit ages determined by Tanaka et al. [4]. *Strike* describes the main fault orientation for the group, and *Strain (%)* is the average estimated extensional strain for each fault group. *Potential Source* indicates whether we attribute a fault set to a proximal volcano (e.g., Ulysses Patera) or if we regard it as a result of large-scale regional extension.

Unit name	*Tanaka age [4]*	*This study (2022)*	*Tanaka [4] period*	*New period (2021)*
Early Hesperian Volcanic Unit (eHv) – North	3.35-3.7 Ga	3.4 Ga (+0.1/-0.3)	Early Hes	Early Hesperian
Late Hesperian Volcanic Unit (lHv)	3.0-3.35 Ga	2.5 ± 0.2 Ga	Late Hes	Amazonian
Early Hesperian Volcanic Unit (eHv) - South	3.35-3.7 Ga	2.4 ± 0.2 Ga	Late Hes	Amazonian

Table 2. Comparison between the unit ages (note that unit eHv is divided into North and South, to correspond with Fig. 1), from Tanaka [4] and the results from this study.