INSIGHTS TO THE EVOLUTION OF THE TEMPE TERRA REGION, MARS: REFINEMENTS OF GEOLOGIC AND TECTONIC UNITS. Neesemann, A.[1], van Gasselt, S.[1], Hauber, E.[2], Neukum, G.[1], [1]Freie Universitaet Berlin (FUB), *Institute of Geological Sciences / Planetary Sciences and Remote Sensing, Malteserstr. 74-100, 12249 Berlin, Germany,* [2]*Insitute of Planetary Research, German Aerospace Center (DLR), Rutherfordstr. 2, 12489 Berlin, Germany* (A.Neesemann@gmx.de)

Introduction: The tectonic and volcanic history of Mars is mainly concentrated on the Tharsis rise and its adjacent area. Many investigations with the aim of classifying the tectonic and volcanic events in time and space, that led to the complex surface features, have been conducted by various authors [1]-[4]. As a further contribution to a better understanding of this region we chose Tempe Terra with its complex pattern of graben and faults with rift-related volcanism [5], [6] in the northeastern sector of the Tharsis bulge. In contrast to former studies which are primarily about the investigation of the extension direction, fault lenght displacement or strain measurements [7]-[11] we classified the faults in sets of different ages to estimate changes in orientation with time.

Geomorphology: Tempe Terra is an approx. $2.1 \cdot 10^6$ km^2 plateau of old cratered Noachian to early Hesperian highland materials situated on the northeastern reaches of Tharsis. In addition to the rift system which cuts the plateau and on which analysis of this work is focussed Tempe embodies a variety of geologic features such as pre- to post-rifting volcanism, mountain ranges and sedimentary deposits such as dunes or flow structures. At first sight, the rift system can be divided into at least two fault systems with different orientation (see Tab. 1) and shape. The background pattern known as the Mareotis Fossae consists of sets of long, subparallel linear faults trending around 30°. Single faults especially in the northeastern region had been exposed to erosion for a long time. As a result graben floors are mostly filled with wind-blown sediments and slopes are degraded whereby the initial depth of the graben can be only assumed. The much more complex and predominant fault system Tempe Fossae is an interesting study area to obtain a better understanding of the stages of tectonic activity around Tharsis. For a detailed description of the two systems see [5], [6].

Data: For this study we made use of various data from different spacecrafts resp. camera systems and measuring instruments depending on the geologic question for detailed photogeological mapping of Tempe Terra. Image data received by the HRSC (High Resolution Steoreo Camera) with their large surface coverage at a high resolution of 12.5 m/px [13], [14] are used to characterize the boundaries of the mapped units. To achieve the best and up-to-date results images from the Context Camera (CTX) on board the Mars Reconnaissance Orbiter (MRO) [14] with a resolution of 5.8 m/px were used for a detailed characterisation of the single units. For an absolute age determination of units with a small area extent like vent structures, lava flow lobes, fissures etc. or where recurfacing processes are predominant CTX images were used as well.

Methods: Crosscutting relations are the most definitive age criteria but are not always clearly discernable due to erosion or sedimentation [15]. This problem remains quite the same even through investigation by HRSC or CTX image data with their higher resolution when compared to earlier image data (mainly Viking Orbiter (VO) data). Another problem is, that smaller faults caused by low stresses do not necessarily cut larger but probably older faults. Therefore relations between faults with extreme differences in dimension mostly require determination by multiple crosscuttings of several faultsets. Nevertheless, some crosscutting relations could be worked out with high reliability. In order to quantify these crosscutting relations extension of faults into geologic units or by their superposition of known relative age were included. The latest geomorphologic maps which cover parts of the Tempe Terra by [16], [17], are based on VO images. In the context of this work we mapped the overall area of Tempe Terra in order to refine the boundaries or subdivide. Mapping of units resp. structures of smaller area extent which have not been mapped in the past or have been partly incorrectly interpreted due to limitations of image resolution will now help to improve relations of the different faultsets. Another key role is the absolute age determination of the refined units via crater size-frequency distributions, using the model II described by [18]

Prelimenary Results: In this study we determined a total of 8876 individual faults via HRSC images. Until now, 3854 could be divided into 16 fault-sets with differences in orientation, dimension and time and space (table 1). With the new results the fault-system of Mareotis Fossae has to be subdivided

Table 1: Results of fault investigation around Tempe Terra.

Set	Sum of faults	Orientation
01	14/12	61-58°
02	5/4	~90°
03	216/204	30°
04	18/5	135-113°
05	87/111	90-83°
06	88/106	76-73°
07	14/14	14-16°
08	17/18	tangential
09	783/778	50-45°
10	119/103	35-30°
11	122/110	~60°
12	77/42	30°
13	112/106	35-18°
14	64/119	47-34°
15	107/61	30°
16	101/117	tangential
undefined	2630/2392	

Given the high resolution of the HRSC and CTX image data we were able to identify a total of 8876 faults. Already 3854 have been divided into 16 individual sets with different orientation and crosscutting relations (decreasing in age from set 01 to 16). The 5022 still undefined faults will be classified into the existing (or new) sets in future work.

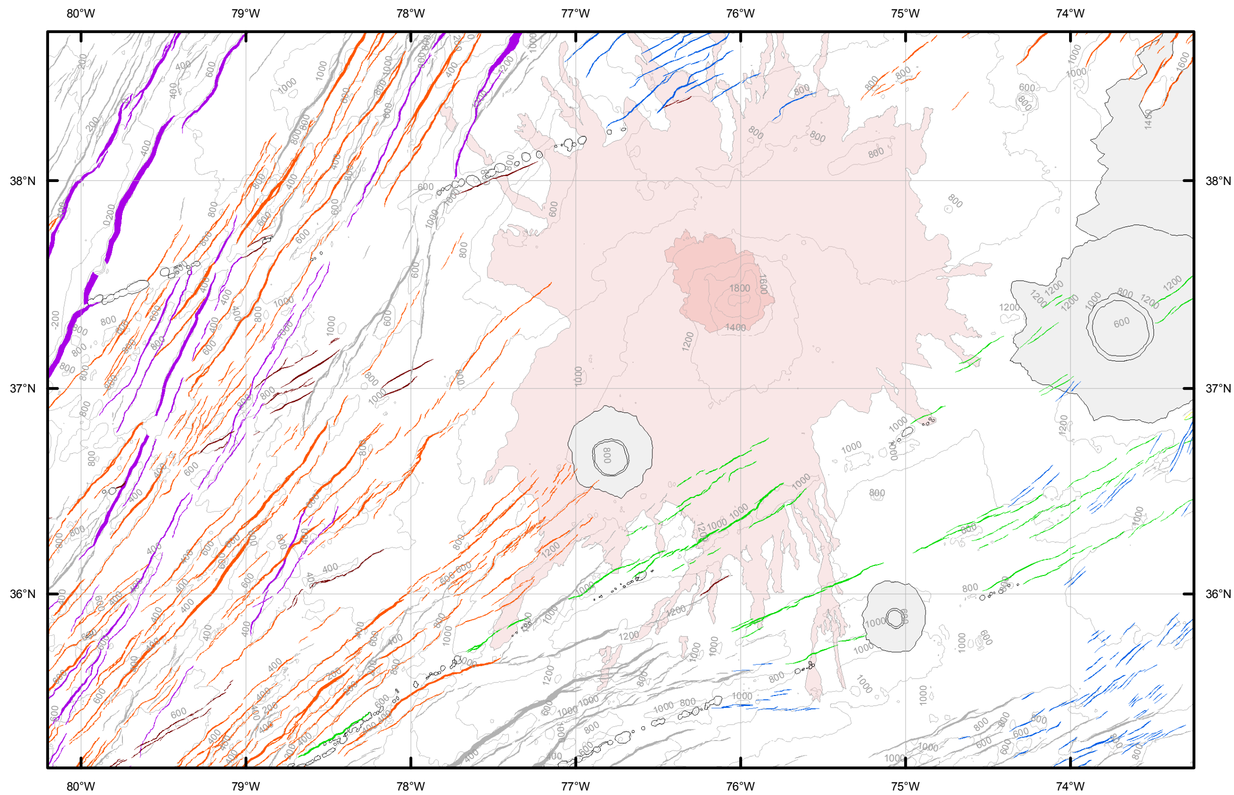

Figure 1: Geomorphologic overview of Labeatis Mons

into more phases of activity. There are at least 6 phases ranging from the middle to Early Noachian with reactivation during late Hesperian (cutting unit Hpd 2.95-3.33 Ga) and even through middle Amazonian times (cutting unit Atm 755-846Ma). Especially in the western part of Tempe Terra collapse structures within the grabenfloors like pit craters are typical. A few but huge vent structures of late Amazonian age (Arf 251-38 Ma), which follow the same orientation may be related to the reactivated Mareotis Fossae. In relation to Mareotis Fossae which kept its orientation within a range of <15° through time the faults and graben of Tempe Fossae are variable. The earliest extensional surface expression is a set of faults in the SW area which trends 90-83°, so they are approx. parallel to Ceraunius Fossae to the west. Crosscutting reveals the relative sequence of the other fault-sets. An interesting fact is, that fault orientation changes with time from 90° to the main strike direction of 45°. Therefore we assume a change in the direction of the stress fields which culminated in the formation of the main graben, or, more precisely in the structure interpreted as a rift-system [5]. Absolute age determination in relevant areas shows that the majority of the faulting occured during 3.72 Ga (cutting unit Htm) and 3.65 Ga (superposed by unit Hr). The superposition of lava flows not older than 822 Ma (absolute age determination after modell II [18]) originated from Labeatis Mons (37.4N/75.9W) by tangential faults reveals that tectonism even with low intensity has occured during the Middle Amazonian.

References [1]Solomon S. and Head J.W. (1982) *JGR Vol 87(B12)* pp. 9755-9774. [2]Plescia J. and Saunders R.S. (1982) *JGR Vol 87* pp. 9775-9791. [3]Kronberg P. and Hauber E. (1999) *5th International Conference on Mars*. [4]Anderson R. et al. (2006) *LPSC XXXVII*.[5]Hauber E. and Kronberg P. (2001) *JGR Vol 106* pp. 20.587-20602. [6]Hauber E. et al. (2009) *Earth and Planetary Science Letters*. [7]Golombek M. et al. (1994) *LPSC XXV* pp. 443-444. [8]Golombek M. et al. (1996) *JGR Vol 101(E11)* pp. 26119-26130. [9]Harrington B., et al. (1999) *Fifth International Conference on Mars*. [10]Wilkins S. et al. (2002) *Geophysical Research Letters Vol 29 NO.18*, 1884. [11]Fernández C. and Anguita F. (2007) *JGR Vol 112*. [12]Neukum G. et al. (2004) *ESA Spec. Publ. 1240* pp. 17-35. [13]Jaumann R. et al. (2007) *Planet. Space Sci. Vol 55* pp 928-952. [14]Malin M. et al. (2007) *JGR Vol 112*. [15]Scott D.H and Dohm J.M. (1990) *LPSC XX* pp. 503-513. [16]Scott D.H. and Tanaka K.L. (1986) *USGS I-Map 1802-A*. [17]Moore H. (2001) *USGS I-Map 2727*. [18]Hartmann W. et al. (2001) *Space Science Reviews Vol 96* pp. 165-194.