JGR: Planets

Supporting Information for

Magmatic origins of extensional structures in Tempe Terra, Mars

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Introduction

Our supporting information includes additional text, tables, and images to provide further detail on the methods used in the paper. Text S1 provides the method and parameters used to generate the fault heave maps presented in Figures 2, 4, and 5. Text S2 provides step-by-step instructions to reproduce the slip and dilation tendency maps presented in Figure 6.

Text S1.

Method 1: Fault heave maps

To generate maps of fault heave in ArcMap 10.6, we created a dataset of points with values of individual fault heave for each of Tempe Terra's tectonic stages (combining all fault sets from each stage) and then interpolated this data using inverse distance weighted gridding to create a continuous raster. See below for method and parameters we used.

Part 1: Prepare input data

1. Create intersection points wherever a fault intersects a profile line.
    a. Use the *Intersect* tool between fault dataset and profile lines to generate points (creates new point dataset).
2. Calculate and assign heave for each fault intersection.
    a. Calculate vertical offset on each fault using cross sections and calculate heave from this value, assuming a 60° dip (see section 2.2).
    b. Populate each point with its corresponding heave value.
3. Create "dummy" points with heave of 0 in areas without faults (to prevent extrapolation outside of faulted regions during the gridding process).
    a. Use the *Create Fishnet* tool to make a grid of lines spaced 20km apart.
    b. Use the *Intersect* tool between these new lines and the profile lines to generate additional dummy points (creates new point dataset).
    c. Delete any points that occur over faulted areas (only pad areas without faults).
    d. Populate the dummy points with a heave value of 0.
4. Merge fault intersections with dummy points to create a new dataset for interpolation.
    a. Use the *Merge* tool to create a new point dataset.

Part 2: Interpolate data to create raster

1. Grid the point data into a continuous raster using inverse distance weighted (IDW) interpolation.
    a. Use the IDW (Geostatistical Analyst) tool (see Table S1 for parameters) to generate new raster dataset.

Table S1. Parameters for IDW tool in ArcGIS used to interpolate fault heave.

Parameter	**Value**
Input data (z value)	Point intersection dataset (Heave in m)
Output raster (cell size)	10 km (1 point per cell)
Power	2
Search Neighbourhood:	
Neighbourhood type	Standard
Major semiaxis	150 km
Minor semiaxis	30 km
Angle	Average fault strike (60° for Stage 3, 38° for Stage 2, 5° for Stage 1)
Max neighbours	6
Min neighbours	1
Sector type	4 sector
Weight field	None

Text S2.

Method 2: Slip and dilation tendency

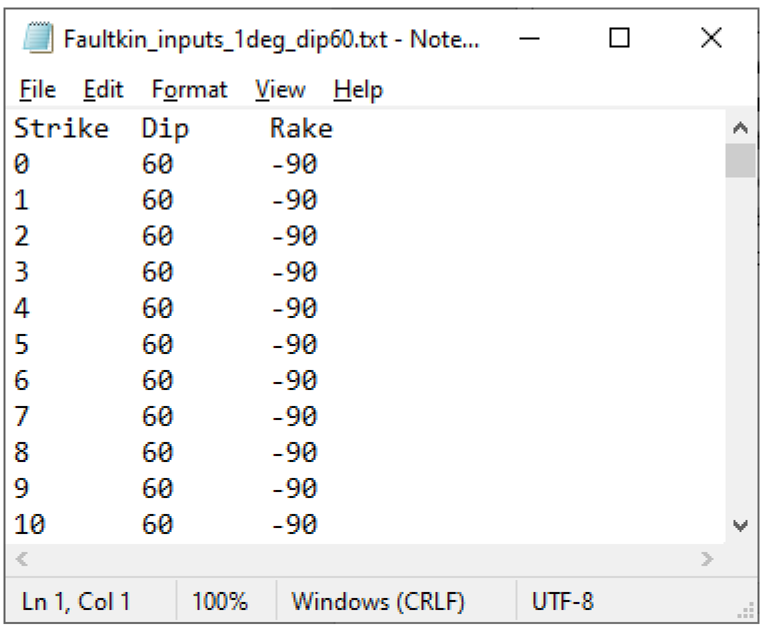
To generate maps of slip and dilation tendency, we first calculated the values of slip and dilation tendency for faults with a 60° dip using **FaultKin 8** software (available for free from: https://www.rickallmendinger.net/faultkin). We then displayed this in GIS format by assigning these values to fault segments for each of Tempe Terra's tectonic stages in **ArcMap 10.6**. See below for method and parameters we used.

Part 1: Create slip and dilation tendency values for a given stress field

1. Create text file of strike/dip/rake for theoretical faults planes with strike orientations in 1° increments from 0° to 360°, all with dip 60°, rake -90 (Figure S1).
2. Import text file into **FaultKin** and display data as faults.
3. From the *Calculations* menu, under *Slip Tendency*, run the *Slip Tendency Analysis* tool (see Table S2 for parameters).
4. Save output by selecting all faults and go to *Calculations* > *Data for Selected Faults* to copy to clipboard and paste into a new **Excel** spreadsheet.
    a. NOTE: given slip/dilation tendencies are normalised to maximum value
5. Generate absolute slip/dilation tendency values in **Excel**.
    a. For slip tendency (Ts), divide the shear stress magnitude (column: shear Magn) by the normal stress magnitude (column: normal Magn)
    b. For dilation tendency (Td), use formula to calculate $Td = (\sigma 1 - \sigma n) / (\sigma 1 - \sigma 3)$
        i. σ1 and σ3 magnitudes from Table S2 – stays same for each fault
        ii. normal stress magnitude (σn) from output data (column: normal Magn) – varies for each fault

Part 2: Assign values to faults and display in GIS format

1. Open fault data from Orlov (2022) in **ArcMap** (available for free from: https://doi.org/10.5281/zenodo.6531499).
2. Use *Split Line at Vertices* tool to convert continuous faults into segments.
3. Calculate the azimuth of each fault segment.
    a. For geodesic angle use the **Tools for Graphics and Shapes** plugin for ArcGIS (available for free from: http://www.jennessent.com/arcgis/shapes_graphics.htm) with the *Spheroidal Starting Azimuth* measurement.
4. Add new fields to the shapefile for slip and dilation tendency.
5. Populate fields with absolute values from part 1 based on each segment's azimuth.
6. Colour fault segments by attribute, using the slip or dilation tendency values e.g. with high = red and low = blue.



Strike	Dip	Rake
0	60	-90
1	60	-90
2	60	-90
3	60	-90
4	60	-90
5	60	-90
6	60	-90
7	60	-90
8	60	-90
9	60	-90
10	60	-90

Figure S1. Example text file as input for FaultKin software.

Table S1. Parameters for slip tendency calculation in Faultkin software.

	Stage 2 Stress Regime	**Stage 3 Stress Regime**
σ1 trend	0	0
σ1 plunge	90	90
σ1 magnitude	100	100
σ2 trend	27	60
σ2 magnitude	66	66
σ3 trend	117	150
σ3 magnitude	32	32
Coefficient of static (sliding) friction[1]	0.6	0.6
Pore fluid pressure (MPa)[2,3]	0	0

[1]Schultz et al. (2006), [2]Barnett and Nimmo (2002), [3]Schultz and Fori (1996)