GEOMECHANICAL RESTORATION AS A TOOL TO UNDERSTAND THE STRAIN HISTORY OF GEOLOGICAL STRUCTURES ON VENUS.

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Introduction: Forward modeling of inferred structural history using sequential geomechanical restoration provides useful insights into the strain history of tectonic terranes on Venus. Geological mapping and deduced cross-sectional geometric relationships are used to construct 3D ground models from specially processed Magellan radar imagery and high resolution stereo topography.

These digital ground models are constructed in Move, a structural geological modeling tool developed by Midland Valley Exploration Ltd and provided gratis for academic use. Move is able to restore the deduced structures using a variety of tools, principally kinematic restoration, unfolding, and geomechanical modeling. Forward modeling using appropriate parameters allows the strain history to be captured and stored as attributes in a final 3D model, providing deeper insights into tectonic processes on Venus.

Ground Modeling: high resolution topographic models are generated using Magellan Stereo Toolkit (MST), a freely-available NASA-funded tool (Maurice, 1997) for the production of Digital Elevation Models (DEMs) from Cycle 1 (left-looking) and Cycle 3 (stereo left-looking) Magellan data. Individual FMAP frames are inspected for 1024 × 1024 pixel regions of interest (subframes), starting with the Cycle 3 (left stereo) image, which suffers more from noise and data loss than Cycle 1. Best results are obtained by aligning the top left corners of image pair and ensuring that the left-hand column of both images contains real data. An *automatch* grid spacing of 2 pixels generates a DEM file and a pair of orthorectified images at full resolution (with DEM tie points at four pixel intervals).

The DEM is 'sharpened' using *SFS* (shape from shading) with an interval of 2 and two iterations. The *automatch* and *SFS* process is repeated four times, each time offset from the previous by one pixel (in x and then y) so that *automatch* starts with slightly different parameters in each case. The four SFS-DEMs are corrected for spikes, pits, y-oriented artefacts (introduced by *SFS*), and other obvious artefacts, and then averaged to produce a final DEM with a nominal resolution of 300 m horizontally and better than 100 m vertically.

Image Processing. Magellan left and right SAR imagery and emissivity data can be combined into a full color image that significantly aids map interpretation. In the absence of true orthorectified imagery, Magellan right-looking data are warped into the left-looking geometry and both datasets converted to actual backscatter values and corrected for emissivity. The datasets are converted to asperity (roughness at radar wavelength) and averaged, forming the red channel, and inverted to form the blue channel. The green channel is formed from asperity multiplied by emissivity. The luminosity component is formed from the left minus right datasets. All channels are stretched to $\pm 3\sigma$ centered on the channel mean. The resulting image, blue indicates very smooth and low emissivity material (e.g. dark halos), green represents intermediate roughness and emissivity (typically plains), while yellow and pink are normal emissivity and rough to very rough (e.g. tesserae).

Model Building. Using the high resolution DEM and image as a base map, structures and units are identified and 'extruded' onto a series of cross-sectional slices on which more plausible geometries are drawn. These slices are used with the map to produce a final 3D interpretive ground model.

Restoration: Move is capable of forward and reverse 3D restoration. Kinematic algorithms include simple shear (for listric faults in extensional tectonic regimes, where anticlinal rollover structures have developed on non-planar normal faults), flexural slip unfolding (for fault bend folds, detachment folds and fault propagation folds), fault parallel flow (best suited for modeling hangingwall movement in fold and thrust belts where the majority of the deformation occurs discretely between bed interfaces (i.e. by flexural slip), and trishear (in which strata thin over anticlines and thicken in adjacent synclines, observed in some compressional and extensional fault-related fold systems). Geomechanical modeling uses a mass-spring approach to restore surfaces and is useful when the deformation mechanism is uncertain.

Strain analysis. Accumulated strain is tracked during each stage of the restoration process, and attached to the rock volume. A number of assumptions must be made for Venus, particularly unknown rock types and material parameters, such that the resultant strains must be taken as indicative but nonetheless informative. Initial results indicate that Earth-like accumulated strains may be common on Venus.

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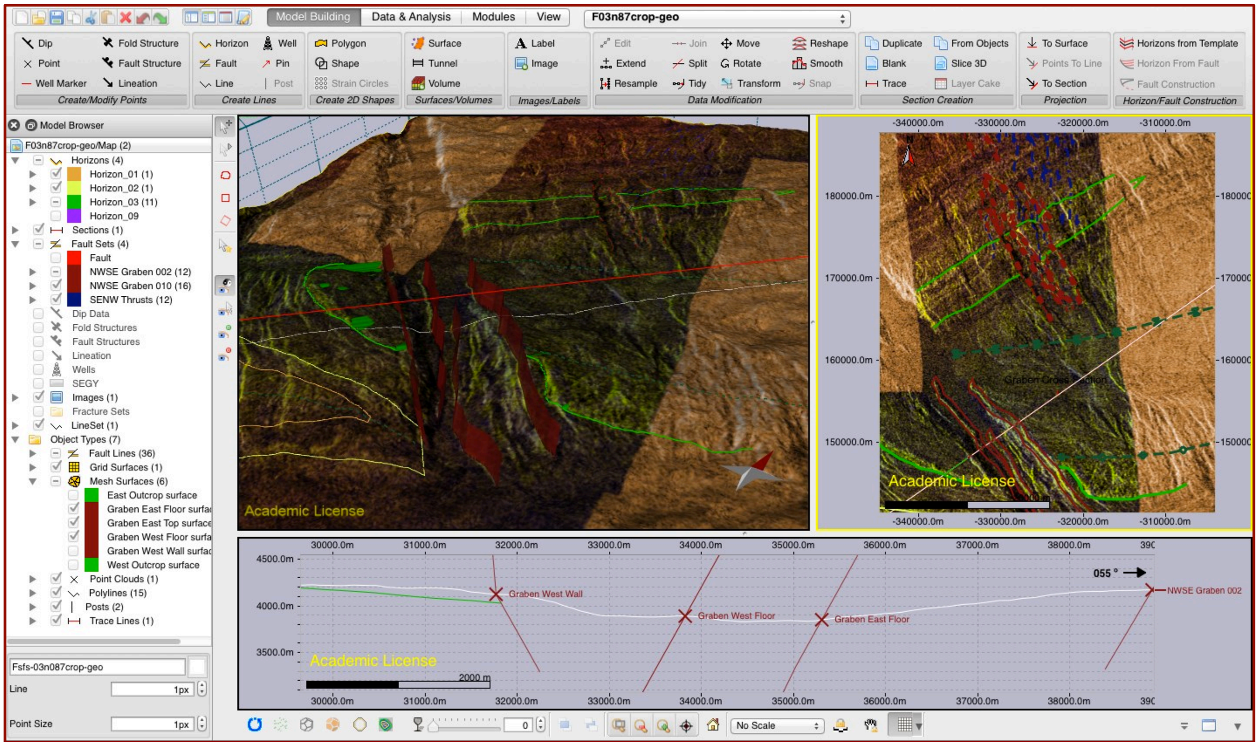

Above: stages in the construction of a 3D model of tesserae at 3˚N, 87˚E. *Top right.* plan view used for initial geological mapping. *Bottom.* cross-sectional slice on which is drawn an interpretive geological section. *Top left.* several geological sections are combined with the map data to produce the final 3D interpretive ground model.

Below: having deduced the 3D geometry and geological history, kinematic and geomechanical modeling is used to restore the geological structures in sequence. Forward modeling tracks the accumulated strain and fracturing.