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GRANT TITLE:

The Nature and Origin of Periodically Spaced Tectonic Features on Mars

PRINCIPAL INVESTIGATOR:

Dr. Thomas R. Watters
Center for Earth and Planetary Studies
National Air and Space Museum
Smithsonian Institution
Washington, D.C. 20560
(202) 357-1457

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INTRODUCTION

This document is to serve as the final report of a grant funded under the MEVTV program, NASA Grant NAGW-1106 which was initially funded in May of 1987. The focus of this investigation was to characterize and model the periodically spaced wrinkle ridges observed in ridged plains material on Mars. The investigation centered on the wrinkle ridges in ridged plains material on the Tharsis Plateau. Wrinkle ridges are interpreted to be structural in origin, resulting from buckling followed by reverse or thrust faulting of the ridged plains material (Watters, 1988). The study extended beyond Tharsis to other ridged plains units, particularly those in Hesperia Planum. As a corollary to this study, an analysis of the spacing of the anticlinal ridges of the Yakima Fold Belt of the Columbia Plateau in the NW United States was undertaken.

SUMMARY OF RESULTS

Analysis of Ridge Spacing

Ridge spacing was evaluated by dividing the Tharsis ridge system into six provinces: Coprates, Lunae Planum, Chryse, Tempe Terra, Amazonis and Phaethontis. Some of the provinces where divided into domains on the basis of significant variation in orientation of the ridges and, in some areas, contacts with other geologic units. The average spacing of the ridges in the Tharsis ridge system, excluding ridges on the intercratered plains of Memnonia, is 30 km (Watters, 1991). Mapping and spacing analysis of wrinkle ridges in Hesperia Planum revealed two sets of ridges, one with a NW-SE dominant trend and the other with a NE-SW trend. Both sets of ridges have an average spacing of approximately 30 km.

The regular spacing of the anticlinal ridges formed in the flood basalts of the Columbia Plateau were also measured. These anticlines are good terrestrial analogs to first-order ridges in the wrinkle ridge assemblages on the Moon and Mercury as well as Mars (Watters, 1988). The Yakima Fold Belt was subdivided into three domains based on the same criteria used for the Tharsis ridge system. The northern, central and southern domains have mean spacings of 19.6, 11.6 and 27.6 km respectively with a total range of 4-36 km and a mean of 20.4 km (n = 203) (Watters, 1989).

Buckling Model for the Periodically Spaced Ridges

Buckling models were formulated in an effort to explain the periodic nature of the ridges on Mars and the anticlinal ridges of the Columbia Plateau. In this model, it is assumed that the ridged plains material: 1) deformed at the free surface under little or no confining pressure and, 2) behaves like a series of thin linearly elastic or linearly viscous plates with essentially frictionless contacts. Free slip between layers is

assumed based on the likely presence of regolith interbeds in the ridged plains volcanic sequence. The presence of such interbeds in a flood basalt sequence is consistent with subsurface data in Mare Serenitatis and Mare Crisium on the Moon and the Columbia Plateau (Watters, 1989, 1991). The multilayer rests on a mechanically weak regolith substrate of finite thickness which is in turn resting on a rigid boundary. The rigid basement does not participate in the deformation, thus no assumption of whole lithosphere deformation is necessary to explain the periodically spaced ridges. The observed wavelengths of many of the ridges can be explained by these models for a range in: 1) the strength contrast between the ridged plains material and the underlying megaregolith; 2) thickness of the ridged plains material; 3) thickness of the megaregolith; and 4) number of layers (Watters, 1991).

The work on the anticlinal ridges of the Columbia Plateau was published in the Geological Society of America Special Paper 239: Volcanism and Tectonism in the Columbia River Flood-Basalt Province. The work on the wrinkle ridges in the Tharsis province was published in the Journal of Geophysical Research. Support from this project resulted in a paper that has been submitted to Geology and a paper in preparation that will be submitted to the Journal of Geophysical Research as well as a number of abstracts.

As part of the MEVTV Study Project, I co-convened a workshop on "Tectonic Features on Mars". This workshop was held at the Hanford Science Center in Richland, Washington, April 20-22, 1989. The objectives of the workshop were to determine the state of our knowledge of tectonic features on Mars and assess kinematic and mechanical models for their origin. The Columbia Plateau was chosen for the location of the workshop because many of the structures that occur in the area may serve as potential analogs to martian tectonic features. The final day of the workshop was devoted to a field trip through the Yakima fold belt. The field trip emphasized the geometry and mechanical response of the basalts to folding and faulting. In my admittedly bias opinion, it was the best of the MEVTV workshops.

PUBLICATIONS LIST: MEVTV FINAL REPORT

Papers That Acknowledge MEVTV Support:

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Abstracts:

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Watters, T.R., The Periodic Nature and Possible Origin of Anticlinal Ridge Spacings on the Tharsis and Columbia Plateaus, NASA TM-4041, p. 473-475, 1988.

Watters, T.R., Periodically spaced wrinkle ridges in ridged plains units of Mars, in MEVTV Workshop: Early Tectonic and Volcanic Evolution of Mars (H. Frey, ed.), LPI Tech. Rpt. 89-04, Lunar and Planetary Institute, Houston, p. 85-87, 1988.

Watters, T.R. and M.J. Tuttle, Evidence of a shear system associated with the deformed basalts of the Columbia Plateau: Implications for the ridged plains units on Mars, Geol. Soc. Am., Abstracts with Programs, v. 20, p. A148, 1988.

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Watters, T.R. and D.J. Chadwick, Crosscutting periodically spaced first-order ridges in the ridged plains of Hesperia Planum: Another case for a buckling model, in MEVTV Workshop on Tectonic Features on Mars, T.R. Watters and M.P. Golombek eds., 68-70, Lunar and Planetary Institute, Houston, 1989.