JOURNAL OF GEOPHYSICAL RESEARCH, VOL. 87, NO. B12, PAGES 9755–9774, NOVEMBER 30, 1982

Evolution of the Tharsis Province of Mars: The Importance of Heterogeneous Lithospheric Thickness and Volcanic Construction

SEAN C. SOLOMON

Department of Earth and Planetary Sciences, Massachusetts Institute of Technology, Cambridge, Massachusetts 02139

JAMES W. HEAD

Department of Geological Sciences, Brown University, Providence, Rhode Island 02912

The Tharsis province of Mars is a broad region characterized by anomalously elevated topography, a positive free-air gravity anomaly, and extensive volcanic and tectonic activity. The evolution of this region has spanned up to 4 b.y. of Martian history. The traditional explanation of the Tharsis province is that uplift of the lithosphere caused by a thermal, chemical, or dynamical anomaly in the Martian mantle or crust led to lithospheric fracturing and to the later volcanic emplacement of thin plains units and large shields. By this explanation the majority of the topographic anomaly is due to uplift. The stress field predicted for lithospheric uplift, however, does not match the generally radial trends of observed extensional fractures. Strictly thermal or compositional explanations for the support of the Tharsis rise encounter problems with the magnitude and duration of the required lateral variations in mantle density. For these reasons, we propose a new model for the origin and evolution of the Tharsis province which emphasizes that the topography of Tharsis may be produced largely by construction, rather than uplift. The model is based on the premise that the elastic lithosphere of Mars was laterally heterogeneous early in Martian history; such heterogeneity is discernible later in Martian history from the variable tectonic response of the lithosphere to local surface loads. Stress due to both global and local causes was concentrated in zones of thin lithosphere, including at least a portion of the Tharsis region. As a result, fracturing was also concentrated in such zones and favored localization of volcanism by providing access to the surface for mantle-derived magma. The heating associated with volcanism maintained the lithosphere locally thin, so that further fracturing and volcanism were concentrated in the same area. The Tharsis rise was thus built primarily by volcanic construction. Most visible tectonic features, by this model, were produced by the response of the lithosphere to loading, not by uplift. Early in the history of Tharsis the lithosphere responded to volcanic loading by nearly local isostatic compensation, while later additional loads have been partly supported by the finite strength of the globally thick elastic lithosphere of Mars. This mechanism for the evolution of Tharsis led to permanent topographic and gravity highs and a greatly thickened crust in the Tharsis region. A major advantage of the model is that no anomalous dynamical or chemical properties need to be sustained in the Martian mantle beneath Tharsis for billions of years. The mantle beneath Tharsis would thus play a passive rather than an active role in the regional volcanic and tectonic activity, much like the role of the mantle beneath major midocean ridges on earth. This and other models for the origin and evolution of the Tharsis province can be further tested by establishing the detailed chronology of tectonic features in the region.

INTRODUCTION

The Tharsis province of Mars, by virtue of its large scale and its complex and extended history of volcanic activity [*Carr*, 1974; *Wise et al.*, 1979*a*], is a focal point for discussions of Martian geological evolution. Approximately 8000 km in diameter and occupying an area equal to 25% of the surface area of Mars, the Tharsis region is marked by a broad topographic rise standing as much as 10 km above the surrounding terrain. A positive gravity anomaly coincides with the long-wavelength topographic high [*Christensen and Balmino*, 1979]. Swarms of extensional fractures and graben extend outward from Tharsis for thousands of kilometers in a crudely radial array. The crest and flanks of the Tharsis topographic rise consist generally of volcanic plains, capped by a number of volcanic shields and other constructs. The summits of several of the largest shields stand over 20 km above the local elevation. The duration of faulting and volcanism represented by the tectonic and volcanic features of Tharsis extends over a large fraction of Martian history.

The traditional explanation for the origin and evolution of the Tharsis province is that uplift of the lithosphere caused by a thermal or chemical anomaly in the mantle or crust led to lithospheric fracturing and to the volcanic emplacement of thin plains units and later of the large shields [*Carr*, 1974; *Wise et al.*, 1979*a*]. The topographic rise, by this view, is regarded as primarily due to uplift rather than to construction. With this explanation, Tharsis is a Martian analog to the 'active mantle' class of terrestrial rifts as described by *Sengör and Burke* [1978]. Evidence cited in support of this uplift model for Tharsis includes the broad domical shape of the topographic high, the large elevation of surface units mapped as relatively old on the basis of the density of craters and fractures, and the generally radial trends to most extensional fractures in and near the Tharsis area. There are, however, several problems with this model. The stresses predicted for lithospheric uplift on the scale of Tharsis do not match the distribution of observed tectonic features. Mantle support involving a strictly thermal mechanism requires

Paper number 2B0820.
0148-0227/82/002B-0820$05.00