THERMAL EVOLUTION OF VENUS MOUNTAIN BELTS. Noriyuki Namiki and Sean C. Solomon, Department of Earth, Atmospheric, and Planetary Sciences, Massachusetts Institute of Technology, Cambridge, MA 02139.

Introduction. The linear moutain belts of Ishtar Terra were recognized from *Pioneer Venus* topography to be distinctive landforms not found on the smaller terrestrial planets [1]. Arecibo radar images showed that much of Akna, Freyja, and Maxwell Montes consist of banded terrain [2] indicative of large-scale compressive deformation [3]. The improved resolution of the imaging and topographic data from *Venera 15* and *16* [4,5] led to better definition of the deformational features and initial hypotheses regarding the origin and evolution of the mountain belts [6,7]. From an analysis of radar images and topographic data from the Freyja Montes, Head [8] proposed that the mountain belt formed as a result of a sequence of large-scale underthrusts of the lithosphere of the North Polar Plains beneath Ishtar Terra.

We are developing thermal models for the evolution of the mountain ranges of Ishtar Terra, with initial focus on Freyja Montes. There are several motivations for such models. If Freyja Montes formed in response to large-scale horizontal convergence by the development of major underthrusts [8], then whether the imbricated blocks between sequential thrust zones originated as layers of underthrust lithosphere or only as upper crustal layers stripped off from the lower lithosphere at a weak ductile zone in the middle to lower crust is closely tied to the mechanical properties of the thrust zone and their dependence on the time-dependent thermal evolution of crust and mantle in the region. The thermal structure of the convergence zone is also intimately tied to the origin and nature of volcanism in Ishtar Terra. Volcanic activity has been widespread on Lakshmi Planum [1,4]. The sequence of tectonic and volcanic events that occurred in the region [7,9] suggest that the volcanism may be at least partly related to the heating and partial remelting of a crustal layer thickened by convergence and underthrusting.

Approach. We adapt the numerical method of Bird and others [10,11] to test quantitatively this lithospheric convergence hypothesis. We solve the two dimensional heat equation

$$\rho C_P \frac{\partial T}{\partial t} = \nabla (k \nabla T) + A$$

where T is temperature, t is time, ρ is density, C_P is specific heat, k is thermal conductivity, and A is heat production. The kinematics of convergence and underthrusting are specified *a priori* (Fig. 1), and this equation is solved by a finite difference technique.

Model Assumptions and Parameter Ranges. We assume a geometry as indicated in Fig. 1 and a constant surface temperature T_s. Frictional heating along the brittle portion of the main boundary thrust is included as constant heat flux $v\tau$, where v is the convergence rate and τ is the shear stress; adiabatic heating of underthrusting plate is neglected. The properties of crust and mantle (Table 1) are assumed to be those of basalt and peridotite on the basis of the Venera lander results [12] and of the assumed gross similarity in bulk composition of Venus and Earth. The base of the lithosphere is taken to be the point at which the temperature reaches 0.9 T_m, where T_m is the melting temperature of peridotite. The asthenosphere is assumed to be convecting vigorously, so that an adiabatic gradient applies. The temperature distribution in the asthenosphere is assumed to be unaffected by underthrusting.

Obvious key parameters are the crustal thickness h_C, surface heat flux q_S, crustal heat production A_C, τ, v, and the geometry and evolution of underthrusting. The ranges of h_C, q_S, and τ are constrained from previous inferences on the thickness of the Venusian elastic lithosphere [13-15]. A_C is calculated from the U, Th, and K contents of surface rock at the Vega 1-2 and Venera 9-10 landing sites [16]. The range of v is determined so that it includes the estimates of divergence rates in the equatorial highlands [17-19]. The dip angle δ of underthrusting is constrained only by

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terrestrial analogy. The ranges of these variable parameters are summarized in Table 2.

Assessment. Initial models are aimed toward understanding the factors that control the thermal assimilation of any mantle portion of underthrust segments of lithosphere, the development of a weak ductile layer in the middle to lower crust which might provide nucleation zones for new thrust fault systems, and the initiation of partial remelting in the lower crust. Results to date indicate that these processes depend strongly on the thermal structure and crustal thickness of the lithosphere prior to underthrusting and on the convergence rate.

References. [1] H. Musursky et al., *JGR, 85*, 8232, 1980; [2] D.B. Campbell et al., *Science, 221*, 644, 1983; [3] S.C. Solomon and J.W. Head, *JGR, 89*, 6885, 1984; [4] V.L. Barsukov et al., *JGR, 91*, D378, 1986; [5] Yu. N. Alexandrov et al., *Science, 231*, 1271, 1986; [6] L.S. Crumpler et al., *Geology, 14*, 1031, 1986; [7] A.A. Pronin, *Geotectonics, 20*, 271, 1986; [8] J.W. Head, *Geology*, in press, 1990; [9] K.P. Magee and J.W. Head, *LPS, 19*, 713, 1988; [10] P. Bird et al., *JGR, 80*, 4405, 1975; [11] M.N. Toksöz and P. Bird, *Tectonophysics, 41*, 181, 1977; [12] Yu. A. Surkov et al., *JGR, 89*, B393, 1984; [13] M.T. Zuber, *JGR, 92*, E541, 1987; [14] R.E. Grimm and S.C. Solomon, *JGR*, 93, 11911, 1988; [15] S.C. Solomon and J.W. Head, *LPS, 20*, 1032, 1989; [16] Yu. A. Surkov et al., *JGR, 92*, E537, 1987; [17] W.M. Kaula and R.J. Phillips, *GRL, 8*, 1187, 1981; [18] J.W. Head and L.S. Crumpler, *Science, 238*, 1380, 1987; [19] R.E. Grimm and S.C. Solomon, *JGR, 94*, 12103, 1989.

Table 1. Properties of Crust and Mantle

Parameters	Crust	Mantle
density [kg/m^3]	$\rho_c = 2900$	$\rho_m = 3400$
thermal conductivity [W/m-K]	$k_c = 2.0$	$k_m = 3.0$
specific heat [J/mol-K]	$C_{pc} = 700$	$C_{pm} = 850$
heat production [W/kg]	(see Table 2)	$A_m = 1.5\text{x}10^{-12}$
melting temperature [K]	1453 + 7.25 P[kbar]	1423 + 12.5 P[kbar]
surface temperature [K]	$T_s = 750$	

Table 2. Ranges of Key Parameters

h_c	5 - 100 [km]
q_s	20 - 200 [mW/m^2]
τ	0 - 100 [MPa]
A_c	(15 - 650) x 10^{-12} [W/kg]
v	1 - 100 [mm/yr]
δ	15° - 60°

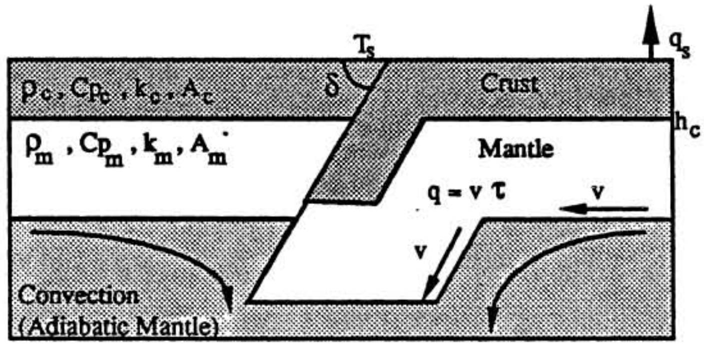

Fig. 1. Schematic of thermal evolution model