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Mechanisms for Lithospheric Heat Transport on Venus: Implications for Tectonic Style and Volcanism

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The tectonic and volcanic characteristics of the surface of Venus are poorly known, but these characteristics must be closely related to the mechanism by which Venus rids itself of internal heat. On the other solid planets and satellites of the solar system, lithospheric heat transport is dominated by one of three mechanisms: (1) plate recycling, (2) lithospheric conduction, and (3) hot spot volcanism. We evaluate each mechanism as a candidate for the dominant mode of lithospheric heat transfer on Venus, and we explore the implications of each mechanism for the interpretation of Venus surface features. Despite claims made to the contrary in the literature, plate recycling on Venus cannot be excluded on the basis of either theoretical arguments or present observations on topography and radar backscatter. Landforms resulting from plate convergence and divergence on Venus would differ substantially from those on the earth because of the high surface temperature and the absence of oceans on Venus, the lack of free or hydrated water in subducted material, the possibility that subduction would more commonly be accompanied by lithospheric delamination, and the rapid spreading rates that would be required if plate recycling removes a significant fraction of the internal heat. If plate recycling occurs on Venus, the rolling plains and lowlands provinces would be approximate analogs to terrestrial ocean basins in terms of age, igneous rock type, and formative process; highlands on Venus would be roughly analogous to terrestrial continents. The hypothesis that lithospheric conduction dominates shallow heat transfer on Venus leads to the prediction that the lithosphere is thin. If Venus has a global heat loss per mass equal to that for earth, then temperatures marking the base of the thermal lithosphere on earth would be reached on Venus at an average depth of about 40 km. Unless the mantle convective planform can maintain lithospheric regions of persistently low heat flow or unless the present atmospheric greenhouse on Venus is geologically recent, then such a lithospheric thickness leads to the conclusion that the topographic features contributing to the 13 km of relief on the planet must be geologically young. The hypothesis that hot spot volcanism dominates lithospheric heat transfer on Venus leads to the prediction that the surface must be covered with numerous active volcanic sources. In particular, if a typical Venus hot spot has a volcanic flux equal to the average flux for the Hawaiian hot spot for the last 40 m.y., then 10^4 such hot spots are necessary to remove the Venus internal heat by volcanism. Such a number would produce enough volcanic material to resurface the entire planet to a depth of 1 km every 2 m.y.; few areas of the planet would escape resurfacing for geologically long periods of time. We find that none of the mechanisms for lithospheric heat transfer on Venus can be excluded as unimportant at present; it is likely that, as on earth, a combination of mechanisms operates on Venus. The strongest conclusion to emerge from this evaluation is that most of the major topographic features and probably many of the surface geological units on Venus are young by comparison with the surfaces of the smaller terrestrial planets.

INTRODUCTION

The mechanism by which a solid planet transports heat across the outer 100 km of its interior plays a pivotal role in determining the styles and magnitudes of tectonic and volcanic activity at the planet's surface. Among the planets can be found examples of bodies in which one of three distinct mechanisms has dominated heat loss (Figure 1), and the resulting geological histories for these bodies differ profoundly. For the earth, the majority of mantle-derived heat is delivered to the surface through plate recycling: the processes of creation, cooling, and subduction of oceanic lithosphere [*Sclater et al.*, 1980]. For the smaller terrestrial bodies, including Mars, Mercury, and the earth's moon, heat transport has occurred principally by conduction through a globally continuous lithospheric shell [*Solomon*, 1978], and the levels of both tectonic and volcanic activity have been much more limited than on earth [*Head and Solomon*, 1981]. For Jupiter's moon Io, eruptions at individual volcanic centers, or 'hot spots,' dominate the lithospheric heat flux [*Matson et al.*, 1981; *Reynolds et al.*, 1980; *O'Reilly and Davies*, 1981] and result in geologically rapid rates of global resurfacing [*Johnson et al.*, 1979].

For Venus, the available radar imaging and altimetry data [*Goldstein et al.*, 1976, 1978; *Campbell et al.*, 1976, 1979; *Campbell and Burns*, 1980; *Pettengill et al.*, 1980; *Masursky et al.*, 1980] are at too coarse a horizontal resolution to allow the tectonic and volcanic features diagnostic of one or more of these mechanisms of lithospheric heat transfer to be discerned unequivocally. As a result, debates have ensued over such issues as whether the surface of Venus displays features indicative of lithospheric recycling analogous to terrestrial plate tectonics [*Masursky et al.*, 1980; *Phillips et al.*, 1981; *Arvidson and Davies*, 1981; *Head et al.*, 1981; *Kaula and Phillips*, 1981; *Arvidson and Guinness*, 1982; *Brass and Harrison*, 1982; *Phillips and Malin*, 1982]. Rather than simply continuing such a debate, we take in this paper a different approach to the coupled questions of lithospheric heat transport and volcanic and tectonic activity on Venus.

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