Abstract. On Venus, present evidence indicates a crust of predominantly basaltic composition and a relatively young average age for the surface (several hundreds of millions of years). Estimates of crustal thickness from several approaches suggest an average crustal thickness of 10–20 km for much of the lowlands and rolling plains and a total volume of crust of about $1 \times 10^{10}$ km$^3$, approximately comparable to the present crustal volume of the Earth ($1.02 \times 10^{10}$ km$^3$). The Earth's oceanic crust is thought to have been recycled at least 10–20 times over Earth history. The near-coincidence in present crustal volumes for the Earth and Venus suggests that either: (1) the presently observed crust of Venus represents the total volume that has accumulated over the history of the planet and that crustal production rates are thus very low, or (2) that crustal production rates are higher and that there is a large volume of "missing crust" unaccounted for on Venus which may have been lost by processes of crustal recycling.

Known processes of crustal formation and thickening (impact-related magma ocean, vertical differentiation, and crustal spreading) are reviewed and are used as a guide to assess regional geologic evidence for the importance of these processes on Venus. Geologic evidence for variations in crustal thickness on Venus (range and frequency distribution of topography, regional slopes, etc.) are outlined. The hypothesis that the topography of Venus could result solely from crustal thickness variations is assessed and tested as an end-member hypothesis. A map of crustal thickness distribution is compiled on the basis of a simple model of Airy isostasy and global Venus topography. An assessment is then made of the significance of crustal thickness variations in explaining the topography of Venus. It is found that the distinctive unimodal hypsometric curve could be explained by: (1) a crust of relatively uniform thickness (most likely 10–20 km thick) comprising over 75% of the surface, (2) local plateaus (tessera) of thickened crust (about 20–30 km) forming less than 15% of the surface, (3) regions of apparent crustal thicknesses of 30–50 km (Beta, Ovda, Thetis, Atla Regions and Western Ishtar Terra) forming less than 10% of the surface and showing some geologic evidence of crustal thickening processes (these areas can be explained on the basis of geologic observations and gravity data as combinations of thermal effects and crustal thickening), and (4) areas in which Airy isostasy predicts crustal thicknesses in excess of 50 km (the linear orogenic belts of Western Ishtar Terra, less than 1% of the surface).

It is concluded that Venus hypsometry can be reasonably explained by a global crust of generally similar thickness with variations in topography being related to (1) crustal thickening processes (orogenic belts and plateau formation) and (2) local variations in the thermal structure (spatially varying thermal expansion in response to spatially varying heat flow). The most likely candidates for the formation and evolution of the crust are vertical differentiation and/or lateral crustal spreading processes. The small average crustal thickness (10–20 km) and the relatively small present crustal volume suggest that if vertical crustal growth processes are the dominant mechanism of crustal growth, than vertical growth has not commonly proceeded to the point where recycling by basal melting or density inversion will occur, and that therefore, rates of crustal production must have been much lower in the past than in recent history. Crustal spreading processes provide a mechanism for crustal formation and
evolution that is consistent with observed crustal thicknesses. Crustal spreading processes would be characterized by higher (perhaps more Earth-like) crustal production rates than would characterize vertical differentiation processes, and crust created earlier in the history of Venus and not now observed ("missing crust") would be accounted for by loss of crust through recycling processes. Lateral crustal spreading processes for the formation and evolution of the crust of Venus are interpreted to be consistent with many of the observations derived from presently available data. Resurfacing through vertical differentiation processes also clearly occurs, and if it is the major contributor to the total volume of the crust, then very low resurfacing rates are required.

Although thermal effects on topography are clearly present and important on both Venus and the Earth, the major difference between the hypsometric curves on Earth (bimodal) and Venus (unimodal) is attributed primarily to the contrast in relative average thickness of the crust between the two terrains on Earth (continental/oceanic; 40/5 km = 35 km, 8:1) and Venus (upland plateaus/lowlands; about 30/15 km = 15 km, 2:1) (35 – 20 km = a difference of 20 km). The Venus unimodal distribution is thus attributed primarily to the large percentage of terrain with relatively uniform crustal thickness, with the skewness toward higher elevations due to the relatively small percentage of crust that is thickened by only about a factor of two. The Earth, in contrast, has a larger percentage of highlands (continents), whose crust is thicker by a factor of eight, on the average, leading to the distinctive bimodal hypsometric curve.

Data necessary to firmly establish the dominant type of crustal formation and thickening processes operating and to determine the exact proportion of the topography of Venus that is due to thermal effects versus crustal thickness variations include: (1) global imaging data (to determine the age of the surface, the distribution and age of regions of high heat flux, and evidence for the nature and global distribution of processes of crustal formation and crustal loss), and (2) high resolution global gravity and topography data (to model crustal thickness variations and thermal contributions and to test various hypotheses of crustal growth).

1. Introduction

Venus and Earth have many similarities to each other relative to the smaller terrestrial planetary bodies but one of the major differences is observed in the global hypsometry. The Earth is characterized by two modes representing the continents and ocean basins, and Venus by a single distinctive mode slightly skewed toward higher elevations (Pettengill et al., 1980; Masursky et al., 1980). In an assessment of mechanisms of lithospheric heat transfer on Venus (Solomon and Head, 1982), Morgan and Phillips (1983) tested the hypothesis that conductive heat loss is an efficient heat loss mechanism and that most of the topography of Venus could result from spatially varying thermal expansion in response to spatially varying heat flow. They developed a model relating surface elevation to lithospheric thickness and heat flow and found that about 93% of the mapped topography of Venus could be explained solely by plausible lithospheric thickness variations and that about thirty-five hot spots could account for the heat loss of the planet. The remaining topography (at high elevations) could be accounted for by crustal thickness variations.

In this paper processes of crustal formation and evolution are examined and the role of crustal thickness variations in the production of topography is assessed. First, evidence for crustal composition, age, average crustal thickness, and total crustal volume on Venus is reviewed, and it is shown that the present crustal volume of Venus is comparable to that of the present Earth, and that unless rates