INTERPRETATION OF THE GRAVITY ANOMALY OF ATALANTA PLANITIA, VENUS.

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Summary. With a diameter of about 1500 km and a depth of about 2 km, Atalanta planitia is one of the largest and deepest basin on Venus. It is nearly circular and comparable in size to Beta regio, but has a remarkably smooth topography. The apparent depth of compensation (ADC) analysis performed both in the space and spectral domains using the spherical harmonic coefficients of degree up to 120, suggests that Atalanta planitia is the result of either a broad upper mantle downwelling or a delaminated material sinking underneath. The long wavelength features (more than 800 km) are partly dynamically compensated at depths around 120 to 160 km, and partly compensated by accumulation of high-density basaltic material at a depth of about 60 km, resulting from crustal thickening. The short wavelength features (less than 600 km), are mostly compensated at a depth of about 20 km, the average crustal thickness in that region.

Global Analysis. Gravitational potential and surface topography maps of Venus are produced at 0.5 by 0.5 degree resolution based on degree 12 to 120 spherical harmonic coefficients. Harmonics of degrees less than 12 are excluded considering that long wavelength features primarily arise from global processes. Using these maps, a global ADC map is computed in the space domain assuming Airy compensation and adopting Haxby and Turcotte (1978) formula. Ishtar terra, western Aphrodite terra and Alpha regio are delineated as low ADC areas (20-30 km), suggesting crustal convergence over mantle downwelling beneath (Bindschadler et al., 1990; 1992). Compared to western Aphrodite, eastern Aphrodite terra has a much greater ADCs, exceeding 120 km in Atla regio. Beta, western Eistla and Imdr regios, as well as Atalanta, Rusalka and east Aino planitiae have large ADCs, reaching as deep as 180 km in Rusalka planitia. However, the ADC values are smaller than those previously determined (Herrick et al., 1989; Smrekar and Phillips, 1991; Simons et al., 1994). The difference is largely due to the use of different techniques and different ranges of harmonic degrees. The relatively large ADC (above 120 km), and remarkably smooth topography (shows only small wrinkle ridges and ridge belts), suggest that Atalanta planitia is probably a surface expression of a young and deep mantle downwelling (Bindschadler et al., 1992).

Local Analysis. The globally determined ADC depends on the range of harmonic degree (Simons et al., 1994) and is influenced by distant features. A local determination of ADC as a function of wavelength is therefore more informative. We investigate the dependence of ADC on the wavelength for 28 different 3380 x 3380 km regions. The regions are circularly tapered to better fit the geometry of their prominent features, and suppress edge-effects resulting from the Fourier transformation. The ADC of a given region is determined as a function of wavelength using the spectral domain relationship between the gravitational potential and the surface topography, assuming a constant ADC over a small range of wavelengths (Arkani-Hamed, 1996). The ADCs are obtained for wavelengths ranging from 3170 km to 320 km, corresponding to the spherical harmonics initially considered (degrees 12 to 120). Statistics for wavelengths longer than 3170 km are not reliable because of the small amount of wave numbers involved, and those for wavelengths shorter than 320 km are mainly dominated by noise.

Atalanta planitia shows relatively deep ADCs, ~160 km, for wavelengths longer than 800 km, and shallower ADCs, ~20 km, for wavelengths shorter than 600 km. This ADC dichotomy suggests that the region probably has two distinct compensation mechanisms, one at great depth for the long wavelength features, and one closer to the surface for the short wavelength features, confirming the hypothesis that Atalanta planitia is the result of a broad and deep mantle downwelling (Bindschadler et al., 1992).

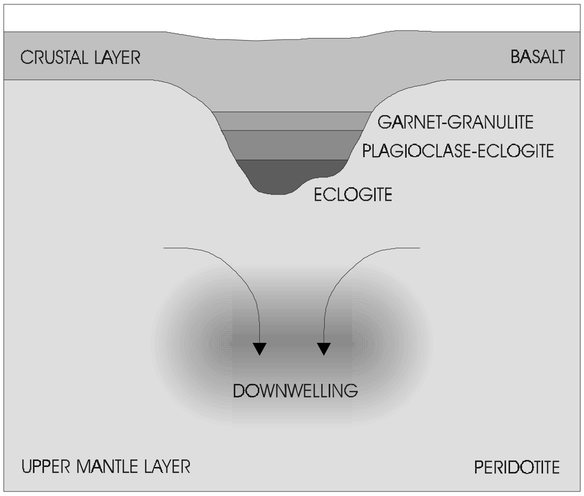

Figure 1. Atalanta planitia model.

Crustal Thickening Model. A thickening basaltic crust overlying a mantle downwelling experiences phase changes, at high pressures basalt undergoes phase transitions to higher density garnet-granulite, plagioclase-eclogite and eclogite as pressure rises. We investigate the effects of these phase transitions on the compensation of Atalanta planitia. The ADC dichotomy, however, cannot be produced by a thickening crust alone. An extra mass is required in deeper mantle to give rise to a high ADC of about 160 km. The objective is to reproduce the observed gravitational potential from a combination of a multi-phase basaltic thickened crust and an extra surface mass distribution located at depth, representing the effects of the downwelling mantle or sinking of a delaminated eclogetic block (Figure 1).

Among the parameters considered are the crustal thickness prior to thickening, the thermal gradient in the crust and mantle, and the density changes due to the phase transitions. We examine three different density models, a) a constant density for each phase, b) a variable density of each phase determined from thermodynamic relationships, and c) a variable density based on experimental measurements (Ito and Kennedy, 1971; Wood, 1987). Two methods are used to determine the depth at which the extra surface mass distribution has to be placed in order to produce the observed gravitational potential. One method is to determine a single depth such that the power spectra of the gravitational potential arising from the thickened crust and the extra surface mass fits the power spectrum of the observed gravitational potential. The other method considers a single depth for a certain range of wavelengths, and determines a range of depths corresponding to the wavelength ranges.

Different rates of crustal thickening are examined. The magnitude of the surface mass and its location are strongly dependent on the thickening rate and the initial thickness of the crust prior to thickening. Larger crustal thickening requires a shallower extra mass, suggesting the need for dynamic compensation at shallow depths. The geophysical implication of the results will be discussed.

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