Abstract: Regional geologic mapping of Venus has revealed lava-filled basins at a wide range of scales and in several different tectonic and geologic environments. On the basis of their characteristics, these basins are interpreted in terms of processes of crustal and depleted mantle layer formation and loss. Intratessera Basins (50-200 km in diameter and found in most tessera occurrences, postdating tessera formation) are candidates for 'eclogite sinkholes' formed by the loss of eclogite roots associated with local crustal thickening during tessera formation. Upland Basins (300-450 km in diameter and found on the margins of Ishtar Terra) may involve larger regions of crustal loss. Plains Basins (500-1000 km in diameter and ubiquitous in the lowlands, synchronous with or just postdating tessera) may be the surface manifestation of instabilities associated with the loss of a depleted mantle layer.

Introduction and Background: Analysis of Magellan global imaging data has revealed a wide range of volcanic1 and tectonic2 structures. Further analysis from regional mapping3 has revealed lava-filled basin-like structures at a wide range of scales and in several different tectonic and geologic environments, that were not classified and discussed in detail in these earlier studies. In this study the nature and mode of occurrence of these basins is described and several interpretations for their origin are considered.

Intratessera Basins: These features are circular to elongate in shape, typically in the 50-200 km diameter range and hundreds of meters to over a km in depth, occur within tessera, generally cut across the tessera fabric and thus postdate it, and have circumferential fractures, graben, and wrinkle ridges. They are filled with volcanic plains often with several distinguishable units, and plains surfaces are often populated by small shield volcanoes, all less than about 20 km diameter. No large edifices are seen. Plains surfaces are commonly depressed and deformed by a network of wrinkle ridges. Intratessera basins are distinguished from many other occurrences of intratessera plains which are local low areas, but do not have this combination of structures. A typical Intratessera Basin is seen in Tellus Regio (42N, 89.5), and occurs on the regionally highest part of the tessera. On the basis of their associated structures and sequence, these features appear to form by disruption of the tessera terrain, downsagging and circumferential deformation, volcanic flooding, continued subsidence, deformation and flooding.

Upland Basins: Three of these features are associated with the margins and flanks of Western Ishtar Terra; just outboard of the junction of Akna and Freyja Montes (74N, 318; ~300 km diameter), NW (68N, 347; ~400 km diameter) and SE (59N, 3; ~400-450 km diameter) of Maxwell Montes (see also4-5). These structures are generally larger than Intratessera Basins (<200 km) and more irregular, but share several common characteristics; they disrupt the trends of tessera terrain, are presently topographic lows, have broadly circumferential and interior fractures, graben and wrinkle ridges, and have families of broad arcuate ridges within them, sometimes in near-circular form. The basins are flooded by volcanic plains, and the most recent plains surfaces appear to be deformed by subsidence.

Plains Basins: In contrast to Intratessera and Upland basins, plains basins display a wide range of sizes, are more diverse, often more subtle, and very widespread. They are often much larger than Intratessera and Upland basins, and their diversity suggests that they may form from several different processes. Prominent Plains Basins often occur adjacent to tessera: three exist just NW of Alpha where they are irregular in shape and 500-600 km in diameter, with their margins defined by complex narrow (typically 25-100 km wide) bands of terrain standing slightly higher than adjacent plains and exhibiting both compressional (wrinkle ridge) and extensional (graben) deformation. These basins both share common boundaries and show evidence for superposition. They are filled with volcanic plains, which in turn have subsided and been deformed by networks of wrinkle ridges. Other, less well-defined basins surround Alpha to the N and E. Similar types of structures in the 400-600 km diameter range are seen E of Tellus Regio tessera (35-60N), and more degraded and less certain versions occur W and S of Tellus, ranging up to 800-1000 km in diameter. Similar structures are seen to the N and S of Ovda Regio.

Analysis of the topography and images (particularly at the C1, C2, and C3 scale) in the intervening plains regions between tesserae reveals abundant evidence for similar features, although they are usually less well-defined. Shapes range from circular to kidney shaped and occasionally somewhat rectangular. Sizes range from the 400-600 km diameter seen immediately adjacent to tessera, to over 1000 km for very poorly defined structures seen in intervening plains regions. In many cases, smaller basins are irregularly superposed on the larger ones.
CRUSTAL LOSS ON VENUS: Head, J. W.

Discussion: On the basis of classification of modes of crustal formation6-7, Venus appears to be an example of vertical accretion of secondary crust (derived from partial melting of planetary mantles). On Earth, at least in recent geologic history, secondary basaltic crustal production is concentrated at divergent plate boundaries, is transported laterally, and is subducted. On one-plate planets, secondary crust tends to accrete vertically, and in the case of the Moon, produces a thin veneer of mare basalt deposits on the primary highland crust.8 On larger one-plate planets, such as Venus, crustal production rates can be high enough so that over geologic time basaltic crust can accumulate to thicknesses measured in several tens to hundreds of km. Thermal evolution models for the history of Venus9 strongly indicate that basaltic production rates should be high enough so that the crust quickly grows to thicknesses that are limited solely by the basalt-eclogite transition. In this scenario, crustal thicknesses in excess of about 70-90 km result in the conversion of the crustal root to eclogite,10-11 and the loss of the denser root depending on the thermal structure, layer thickness, reaction rates, and strain rates. Thus, a steady-state environment of global vertical crustal accretion might be characterized by the constant interplay of addition of volcanic layers to the surface and loss of eclogite from the bottom, presumably as diapirs descending through the underlying accreting depleted mantle layer as an eclogite mist, rain, or hail, depending on the variables cited above. It is presently unclear whether the scale of instability would be manifested at the surface.

Active tectonic crustal shortening and thickening processes, such as has occurred during tessera formation, should also cause the descent of basaltic crust to depths in thermal environments favoring eclogite formation. In these cases, dynamic thickening processes could rapidly place the deepest basaltic crust within the eclogite stability field and shortly thereafter, density inversion, formation of negative diapirs, and surface deformation and flooding could occur, as mantle ascended into the negative eclogite mist and underwent pressure-release melting.

Another process that accompanies the vertical accretion of basaltic crust is the formation and loss of the complementary depleted mantle layer (DML), and models of its evolution9 suggest that it will episodically grow to thicknesses of about 200 km at which time the combined thermal and chemical buoyancy forces will be net negative and result in the development of instabilities and foundering of the layer. Although the scales of instabilities have not yet been predicted in detail, it is clearly anticipated on the basis of layer thicknesses that they would be considerably in excess of those associated with basalt-eclogite transition crustal losses.

Interpretation and Conclusions: Characteristics shared by the Intratessera and Upland Basins suggest that following crustal thickening, downwelling and marginal deformation was accompanied by localized volcanism and that subsidence continued subsequent to the final volcanic plains emplacement. This sequence is interpreted to be the result of the development of negative eclogite diapirs locally at the base of thickened basaltic crust, the descent and loss of these diapirs causing crustal thinning and subsidence, their replacement by mantle which undergoes pressure-release melting producing surface volcanism, and thermal equilibration of these regions causing final subsidence and deformation of the plains surface. Larger Plains Basins (500-1000 km in diameter and ubiquitous in the lowlands) appear to be too large to reflect simple instabilities in thickened crust and probably have several origins. On the basis of their relatively old age (synchronous with or just postdating tessera) one possible origin may be the surface manifestation of instabilities associated with the loss of a thick depleted mantle layer12. Theoretical and modeling treatments of the development of these instabilities and DML instabilities are underway to provide a more rigorous basis for comparison and interpretation of the origin of the range of basins described here.


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