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The topographic form and length of Parga and Dali Torques†, and the fact that they lie on a great circles, has in the past led to the suggestion that these and similar features were spreading ridges. The higher resolution of the Magellan data has led to the rejection of this hypothesis on the basis that no significant horizontal motion is evident and that features such as transform faults that are typical of mid-oceanic ridges on Earth are not present on Venus. However, it is entirely possible, indeed probable, that the surface expression of a spreading ridge system would be different on Venus. The most popular hypothesis for corona formation and evolution postulates the impingeing of a rising upper mantle diapir on the crust or lithosphere [1] but this model fails to explain the frequent occurrence of coronae in chains along tectonic rift zones. In addition, the proposed evolutionary sequence fails to account for the formation of arachnoidal structures and the observation that many coronae have either incomplete annuli or annuli that have been deformed by or incorporated into regional fracturing. This in part appears to have arisen as a result of the fact that the classification scheme of Stofan *et al.* [2] does not include arachnoids, and attempts to exclude coronae from the exterior environment (which clearly has a major impact on the morphology of coronae). Upper mantle upwelling and diapirism is thought to occur beneath terrestrial spreading ridges and we propose that a similar process may occur on Venus beneath torques.

Without subduction to provide a large horizontal stress, there would be no significant plate motion as found on Earth but even so mantle circulation patterns on Venus may be similar to Earth's [3]. Thus, upper mantle plumes may align themselves along great circles as is the case under terrestrial spreading ridges, resulting in the chains of coronae that are observed. Deeper mantle plumes (i.e., those generated at the core-mantle boundary) would generally be unrelated to these upper mantle plumes and would give rise to regional tectonic rises such as Western Eistla Regio. However, where deep mantle and upper mantle plumes interact (such as at Iceland on Earth), particularly pronounced activity may result. This may be the case at Atla Regio, which appears to be at the junction of several corona chains. Rabinowicz *et al.* [4] have modelled the three dimensional convection pattern beneath terrestrial spreading ridges using five distinct geophysical models of the upper mantle structure. For each case they have initially modelled the circulation pattern beneath a motionless upper plate, the results of which are in good agreement with the structures found on Venus and suggest an alternative evolutionary sequence, which we present below, to the diapiric model of Janes *et al.*. [1].

Prior to the formation of the corona chain, the mantle is initially cool but is slowly heated from within by the decay of radioactive nuclei. Mantle circulation is initiated in a 65 km thick layer [4] immediately below the lithosphere by the formation of concentrated downwelling cold plumes surrounded by upwelling diffuse sheets of warm material. This circulation imposes stresses on the lithospheric plate which result in the formation of arachnoids above the downwelling plumes and extensive linear fracturing and graben formation above the diffuse upwelling sheets. Typical parameters [4] are a whole layer viscosity of 3×10^{19} Pa s and a Rayleigh number equal to 50 000, corresponding to an average arachnoid size of 90 km and a typical spacing (centre to centre) of 140 km, in close agreement with the observed size and spacing of arachnoids on Venus [5].

This pattern of circulation continues until the mantle layer has warmed sufficiently to undergo partial melting by adiabatic decompression in the uppermost third of the layer. This lowers the effective viscosity of the upper layer to approximately 1×10^{18} Pa s [4]. The lower viscosity upper layer reverses the circulation pattern so that upwelling occurs in large plumes and downwelling

† Herein, the term Torques, meaning a chain or necklace, will be used in place of corona chain; hence Parga Chasma will be referred to as Parga Torques and the Atla-Latona-Artemis corona chain will be referred to as Dali Torques

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material is concentrated into narrow sheets at the margins of the upwelling plumes. This circulation pattern results in the formation of coronae: the downwelling sheets correspond to the intensely deformed annuli of coronae which themselves are centred on upwelling plumes. These plumes supply large volumes of melt to the interiors of the coronae resulting in the flood volcanism which produces the interior plains and volcanic constructs. The average diameter of coronae produced by this model is 230 km, with an annulus 25 km wide. This is a little less than the average observed diameter of 250 to 300 km [2]. The spacing (centre to centre) of the coronae is typically 370 km (at Parga Torques) but each corona is connected to its neighbours by several narrow linear downwelling zones. Small downwelling plumes, usually about 30 km in diameter, are periodically generated within the coronae themselves and may result in localised radial fracturing in the interior. The limited crustal spreading that appears to be taking place at Parga Torques is apparently accommodated principally in the compressive fractures at the annuli of the coronae.

This is contrasted to Dali Torques, which is composed of exceptionally large coronae and has large amount of crustal extension. The region between Artemis Corona and Ovda Regio illustrates the interaction between the relatively young fracturing of northern Artemis Corona (estimated to be less than 300 Ma old) and the older tessera of southern Ovda Regio. This tessera is estimated to be more than 500 Ma in age and is believed to be the result of compressive folding and fracturing associated with mantle downwelling. The age determinations are derived from crater counts and are open to some doubt, given the unreliability of crater counts in general on Venus and in particular on the complex terrain within tesserae. It is therefore possible that both Artemis Corona and Ovda Tesserae are contemporaneous in age, with the compression in the tesserae accommodating the extension across northern Artemis. South of Artemis, however, there are no tesserae to accommodate the crustal extension within the corona. Here crustal extension appears to be accommodated entirely within the 100 to 150 km wide annulus of the corona which appears to have many features in common with terrestrial subduction zones and indicates that subduction is, or has been, occurring there.

It appears that while plate tectonic processes do not operate at a global scale on Venus, they may operate on a regional and local scale. Coronae appear to be linked closely to plate tectonic processes, and in fact Artemis Corona may be regarded as a micro-plate in itself. Thus Venus may represent an important link between Earth at the one extreme, where tectonic activity is dominated by plate motion, and the smaller, one plate terrestrial planets such as Mars, dominated by hot spot volcanic processes.

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