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3D high-resolution thermomechanical modeling of Venus coronae and novae

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513 coronae and 64 novae are large (typically several hundred km across) circular surface features on Venus, whose complex structures, with traces of tectonic and magmatic activity as well as their mutual relationship remain enigmatic. Several competing hypotheses were proposed for both coronae and novae based on variability of their sizes, shapes, internal structures and topography, yet little work has been done for quantitative testing of these hypotheses. Here we demonstrate based on new high-resolution three-dimensional thermomechanical numerical model that formation of medium sized (50-300 km) novae and coronae can be explained by tectono-magmatic interaction of mantle plume with hot and thin lithosphere, which has thick low-viscosity lower-middle crust and thin brittle upper crust characterized by elevated surface temperature. According to this model, the process is initiated by decompression melting of hot plume material, which penetrates to the bottom of the lower crust. This melting produces large amount of mafic magma intruding into the ductile lower crust and triggering crustal melting and convection. The crustal convection cell exists for up to several tens of millions years where plume magma and partially molten lower-middle crustal rocks interact and mechanically mix causing gradual thinning and then breaking and fragmentation of the brittle upper crustal lid. The long time span of the convection cell is maintained by the plume heat, which causes gradual warming and melting of crustal rocks. Up to six subsequent stages of the convection cell evolution are found in the experiments : (1) pre-nova stage, (2) young and (3) mature nova stages, and (4) advancing, (5) subsiding and (6) fossil corona stages, which differ in term of crustal structure and fracturing and topography patterns. Novae forms at the initial stage of the process by radial fracturing of the uplifted region above the actively rising convection cell center. At the later stage, such novae can be converted into coronae by concentric fracturing of thinned upper crustal lid and subsequent overthrusting of partially molten lower-middle crustal rocks over the surface of the down-bending brittle upper crust. Concentric normal faults form in the extensional outer rise region of the downbending upper crust, which is to some degree similar to terrestrial outer rise bending regions of subducting oceanic slabs . In contrast, concentric thrust faults form in the advancing front of the overriding crustal wedge supplied by partially molten rocks rising and spreading from its interior. Deep trench-like depression forms in between these two contrasting tectonic regions, which is again similar to the situation in subduction zones. The process thus resembles terrestrial subduction with the important difference been that no slab is formed due to the high surface temperature of the crust. In contrast, subducted upper-crustal lid warms up rapidly and recycles into the convection cell. Model further suggests that coronae and novae fracture pattern and topography evolve with time with different stages been corresponding to various types of these patterns observed on Venus. One of the important model predictions is that novae should be mostly young and tectonically active since they are transient features which form during relatively short (few million years) initial stages of coronae development.