PLANETARY TECTONICS

Sinking plates on Venus

Unlike Earth, Venus lacks discrete, moving plates. Analogue model experiments suggest that observed hints at plate recycling do indeed indicate current, localized destruction of the Venusian surface.

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Earth and its sister planet Venus are similar in size and composition, but their dynamic evolution could not be more different. Most of the surface plates on Earth are constantly produced and recycled as part of the turnover in the mantle. The surface of Venus, by contrast, has remained globally stagnant for the past 300 to 600 million years[1]: what happens on the surface of Venus appears to stay on the surface of Venus. Yet the Venusian surface displays coronae — quasi-circular, crown-like structures with elevated central rises and quasi-circular depressions next to the elevated rims — that display characteristics of both sinking plates[2,3] and ongoing self-sustained mantle upwelling[4]: two types of processes that do not usually co-occur on Earth in such a confined space. Writing in *Nature Geoscience*, Davaille and colleagues[5] report state-of-the-art laboratory tank experiments of a Venus-like setting and find that hot mantle plumes can induce localized sinking of a plate, which leads to surface signatures resembling observations of Venus.

Observations of Venus have revealed surface structures that are common in the Solar System, such as volcanic edifices, but also structures that appear to be unique to Venus, such as the coronae. The correlation of volcanism, dynamic topography and large rift systems on Venus's surface can largely be explained by large-scale mantle convection[6]. However, the evidence for mantle downwelling and lithosphere recycling at the coronae is more localized and cannot fully be attributed to these large-scale flow patterns.

Direct observation of Venus is limited to its surface and reflects only one snapshot in its evolution through time. However, investigating systematic, basic fluid dynamics of a planetary mantle with simplified, time-dependent analogue convection models provides a means to overcome these limitations and improves our understanding of the fascinating dynamics occurring within rocky planets.

Davaille and colleagues[5] present elaborate, three-dimensional and time-dependent tank experiments that reproduce a mostly rigid surface lid on top of a less viscous convective interior and incorporate realistic rheology and deformation mechanisms. This realistic planet-like setting is made possible by drying a complex rheological fluid from above while heating it from below, and removing and examining the deformed surface skin after some time of model evolution.

In the experiments, hot, active upwelling of mantle material leads to localized plate failure of the thinned lithosphere above and to the subsequent formation of short plate segments that dip into the mantle due to their excess density relative to the mantle. The dipping plate segments remain short because they are unable to drag down the remaining portions of the surface plates. They are eventually recycled by the thermal and convective processes in the mantle. Davaille and colleagues show that the resulting geometry of the trenches and the fractures at the surface compare well with the available observations of the topography and gravity of Venus.

The surface of Venus has been previously suggested to undergo short, intermittent and dramatic global resurfacing events[7]. The continuous locally occurring subduction suggested by Davaille and colleagues reflects, however, none of the three well-documented styles of mantle convection: stagnant-lid with no plate motion, mobile-lid with a fragmented plate that moves around on the mantle, or an episodic lid that has a usually stagnant plate, which breaks up and moves occasionally[8]. Instead, the subduction they identify seems to characterize an intermediate mode with slowly sinking plates but no significant plate motion at the surface. As such, it can explain both Venus's old surface and the presence of sinking plate fragments (Fig. 1).

A crucial point for this mode of mantle convection is the onset of subduction. It is

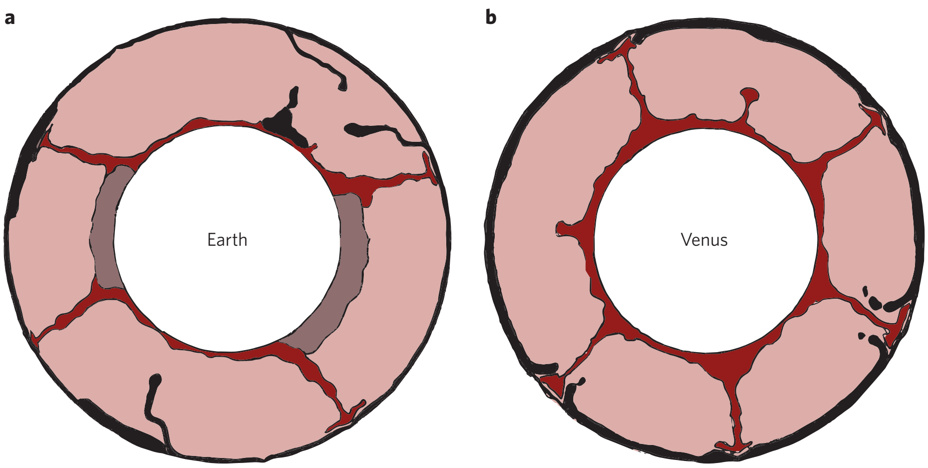

Figure 1 | Comparison of suggested mantle convection in Earth and Venus. **a**,**b**, Mobile-lid mantle convection on Earth (**a**) involves most surface plates (black), which are recycled by sinking back into the deep mantle. The ongoing plate destruction causes a more heterogeneous mantle and a surface of variable age, with young and thin oceanic plates and old and thick continental plates that remain at the surface. Mantle plumes (red) tend to occur far away from sinking plates. By contrast, the mode of mantle convection on Venus (**b**) — as suggested by Davaille and colleagues[5] — consists of a nearly immobile, mostly stagnant lid, and only localized, short sinking plate portions that are formed by (and thus spatially coincide with) hot mantle upwelling (red). The resulting surface deformation matches observations from coronae on Venus. The short sinking portions do not, in contrast to Earth, significantly move their tail ends at the surface, which explains the uniformly aged, relatively thick surface plate (black).

still one of the biggest unresolved puzzles in planetary evolution how a weak convecting mantle can lead to failure and subsequent sinking of a relatively strong plate above[9]. Many mechanisms to induce subduction have been proposed: some weaken the plate, some focus stresses inside the plate, and some add additional forcing on the plate. Narrow, hot mantle upwelling is a promising candidate for inducing subduction as it does all of the above[10]. The strong evidence for the proximity of juvenile subduction and mantle upwelling on Venus, as pointed out by Davaille and colleagues[5], now adds additional support to that theory.

Moreover, the experiments suggest that mantle plumes might have fostered the onset of plate tectonics on early Earth too: conditions on Earth back then were similar to the present-day state of Venus with hotter and weaker plates. Nevertheless, when and how exactly subduction initiates on planets such as Venus and Earth remains elusive and needs to be studied more carefully with dynamic models and, crucially, more detailed observations on the variable modes of mantle convection that occur on planetary bodies throughout our Solar System.

The tank experiments presented by Davaille and colleagues[5] lend key support to the possible presence of sinking plate fragments on Venus. The described mode of mantle convection — with only localized plume-induced subduction and very limited horizontal plate motion on the surface — can explain both the old Venusian surface and the proximity of sinking plates and upwelling mantle signatures at coronae. What happens on the surface of Venus might, after all, not necessarily stay on the surface of Venus. ❐

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Published online: 10 April 2017