WHAT VERITAS WILL SEE IN VENUS ARTEMIS CORONAE: AN EARTH EARLY ARCHEAN PLATE TECTONICS SYSTEM ?

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Introduction: Why does Earth has Plate Tectonics when Venus does not ? How does Plate Tectonics starts ? These questions must be answered if we ever want to understand our past, our future, and exoplanets! However, modeling plate failure remains challenging due to the complexity of mantle rheology. But the development of new visualization techniques and the use of complex-rheology fluids in the laboratory open a new area for planetary geodynamic modeling, as observations of surface patterns (i.e. faults, folds, ridges, trenches) can be quantitatively related to convective instabilities inside the laboratory mantle analog. The challenge then is to have good enough informations on planetary geomorphology to be able to compare it with the physical predictions of the laboratory. We take here the example of Artemis Coronae on Venus. We show that it is a very exciting place: it could possibly display both subduction and accretion due to plume-induced subduction [1,2]; and it could in fact be a small Plate Tectonics system in the making. This could be an analog to what happened in the Archean Earth before the establishment of global Plate Tectonics. But our way forward in understanding this area/era is now limited by the poor resolution of Magellan data: this made the high resolution data of VERITAS all the more needed.

Laboratory experiments: We use colloidal aqueous dispersions of silica nanoparticles. Their rheology depends strongly on the solid particle fraction, φ_p, deforming in the Newtonian regime at low φ_p, and transitioning to strain-rate weakening, plasticity, elasticity, and brittle properties as φ_p increases [4]. So, as the system is dried from above, a dense skin grows on the surface, akin to a planetary lithosphere (fig.1). When it is also heated from below, hot plumes develop. When a hot plume impinges under the skin (fig.1top), it triggers a new mode of subduction: as the upwelling plume material breaks the lithosphere and flows above the denser skin, it forces it to sink. The subduction trenches are localized along the rim of the plumes and strong roll-back is observed (fig.1side). Subduction always occurs along partial circles, which is due to the brittle character of the upper part of the experimental lithosphere [2].

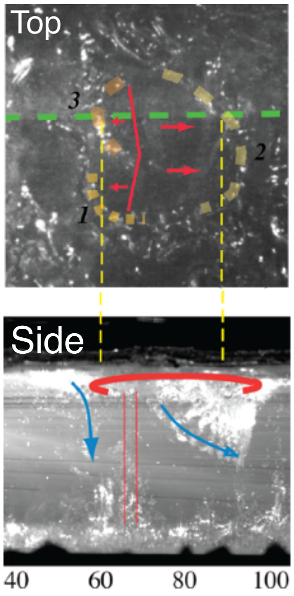

Fig.1: Plume-induced subduction

Moreover, as roll-back subduction proceeds, the coronae expands and an accreting ridge system develops inside the coronae. The ridge shape is governed primarily by the axial failure parameter Π_F, which depends on the mechanical properties of the lithospheric material (fracture toughness K_{1c} and plastic strength σ_Y) and the axial elastic lithosphere thickness Z_{axis} [3]:

$$\Pi_F = \frac{K_{1c}}{\sigma_Y\sqrt{Z_{axis}}} = \frac{K_{1c}}{\sigma_Y}\sqrt{\frac{-V}{\kappa\,.\,Log(\frac{Tc-Tm}{T_0-T_m})}} \quad .$$

The axial elastic thickness is a function of the spreading velocity V and temperature structure at the lithosphere. Its appears a mechanical length scale $Z_m = (K_{1c}/\sigma_Y)$, through which all the length scales of the problem can be recovered [3]. And the different regimes of accretion on present-day Earth mid-ocean ridges are recovered (fig.2).

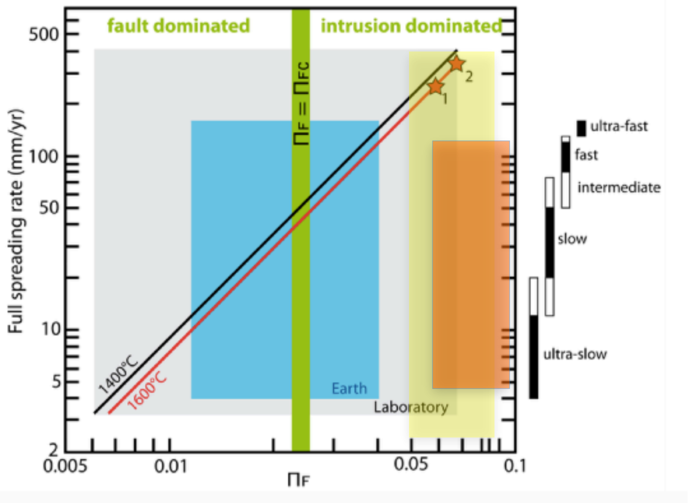

Fig.2: Domains of ridge activity as a function of the axial failure parameter and the spreading velocity. In gray, the domain covered by the laboratory experiments; in blue, present-day Earth mid-ocean ridges; in yellow Archean Earth; in orange, present-day Venus in Artemis coronae.

Experiments with the largest Π_F present a quite unstable ridge axis with a large lateral sinuosity, transform faults, and numerous microplates (fig.3). Moreover, axis jumps are frequent and some of them can even cause folding and subduction onset along the former abandoned section of the ridge axis.

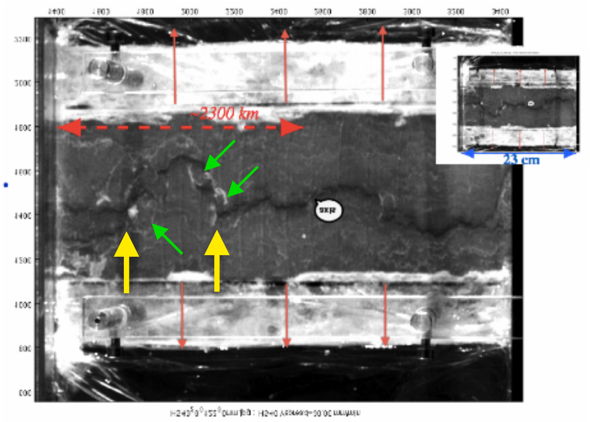

Fig.3: Ridge shape for high spreading velocity and/or thin axial elastic thickness. The axis is the dark line indicated by the white bubble. As all the length scales of the system scales with Zm, the dashed double arrow shows the length in the laboratory equivalent to the 2300 km-diameter of Artemis on Venus. The red arrows indicate the spreading direction, the yellow ones the transform faults, and the green ones the microplates.

Artemis Coronae and Archean Earth: Scaling analysis of the laboratory experiments predicts that plume-induced subduction (PIS) could nowadays happen on Venus. Inspection of Magellan data indeed suggest that this process could be happening around Quetzelpetlal and Artemis coronae [1,2,5]. Given Venus hot surface temperature, the axial failure parameter inside Artemis should be greater than 0.06, which put it in the large Π_F-regime that we described in the previous section. Magellan data indeed shows a large feature, Britomartis Chasma, that has already been proposed to be an accretion ridge [5]. It displays a large sinuosity, comparable to what is predicted by the laboratory experiments (fig.3 and 4). The topography data resolution is not good enough to see transform faults nor microplates, though. But their presence would explained well some of the largest axis offsets and radiating patterns, respectively (fig.4). Moreover, the center of Britomartis presents a deep trough, next to a very tall ridge. This may be due to core complex formation [6]. But it could also be due to folding and initiation of subduction following an axis jump. The Magellan topographic data does not have a sufficient resolution to discriminate between the two options. The coexistence of an accreting ridge and subduction within the coronae would made Artemis interior the unique exemple of a nascent Plate Tectonics system. With a mantle 200°C hotter than at present, the Earth Archean lithosphere would have a thermal structure closer to present-day Venus. We could therefore expect that the same PIS and the same type of mid-ocean ridge could exist. Learning more about present-day Artemis system would therefore bring valuable insights into the onset of plate tectonics.

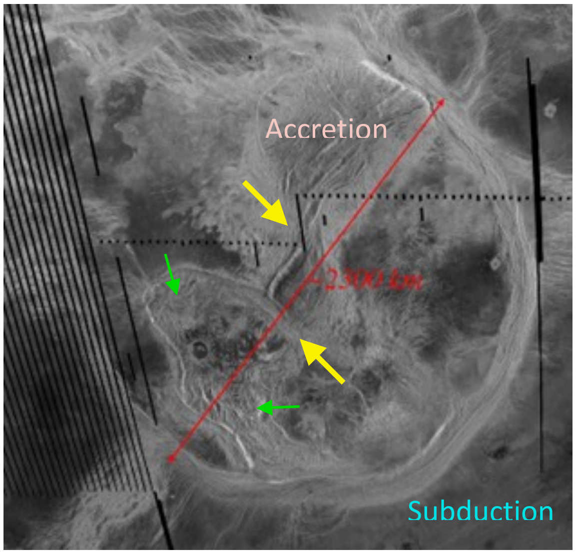

Fig.4: Magellan Radar image of Artemis Coronae, Venus. The rolling back trench is to the South-South East of the image, and the accretion ridge is mostly above the red double arrow and North-West of the image. The yellow arrows indicate the potential transform faults, and the green ones the potential microplates.

Conclusions: We need urgently global gravimetry and topography fields for Venus, of a quality similar to what we have for the other silicates planets of the solar system. This is what the VERITAS mission from NASA is designed to do [7], and it is important that the community can get this data as soon as possible.

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