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Potential Seismically Active Target Regions on Venus

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Venus represents a terrestrial planet similar to Earth in size and mass, but its evolution has been different enough to lead to the formation of a different planetary environment. Understanding the interior processes that shape Venus' surface, and their present-day activity, is one of the fundamental tasks for the next decade(s) of Venus science. While evidence has been found for present-day volcanic activity on Venus, recent work also suggests that seismic activity can be expected on the planet [1]. Here, we shortlist and investigate areas that can provide key insights on different contexts where seismic activity could take place at present: Ishtar, Thetis, Lada, Atla, Beta, and Artemis corona. We will herein describe these regions and reasons for their inferred seismic activity (Figure 1). Moreover, we identify terrestrial analogues on Earth which may provide further insights into their seismic characteristics.

Ishtar Terra

Ishtar Terra, the second-largest highland region on Venus, spans approximately 4,000,000 km². It features Lakshmi Planum, an interior plateau surrounded by towering mountain belts, including Maxwell Montes - the highest point on Venus inferred to also have the thickest crust - and outlying tesserae. This elevated region is underpinned by a deep crustal root. Structural units within Ishtar Terra exhibit evidence of both vertical and horizontal crustal movements, indicative of crustal shortening due to lithospheric thickening [2]. Ishtar Terra presents an intriguing prospect for seismic activity. We expect seismic activity to be the deepest due to the suggested thickened cold crustal layer [3], with more distributed directionality compared to regions like Thetis Regio (see below).

Thetis Regio

Thetis Regio, an uplifted region 3 km above mean planet radius, constitutes the eastern part of

Aphrodite Terra, the largest highland on Venus. Thetis Regio is composed primarily of tessera terrain: rugged and highly deformed terrain displaying different trends of parallel ridges and troughs. Given its resemblance to a Canadian shield-like tectonic scenario with increased heightened seismic activity at the edges, we infer the potential for seismic activity on the margins of Thetis Regio.

Atla Regio

Atla Regio, located within the BAT (Beta-Atla-Themis) region, hosts some of the most recent suggested volcanic and rifting activity on Venus. It features a distinct four-armed 'triple-junction' rift system, numerous large volcanic centers, and associated coronae, exhibiting topographic highs and gravity lows akin to terrestrial Large Igneous Provinces linked to active mantle plumes. Notable volcanic features include Maat Mons, the tallest volcano on Venus, for which the clearest evidence of ongoing volcanic activity has been presented [4]. Atla Regio commands attention with its intense volcanic activity alongside active fissure eruptions. Moreover, situated proximal to observable rifting and featuring "African rift-like" tectonic characteristics, Atla holds geological significance. Foreseen seismogenic thickness implies shallow seismic activity [5].

Lada Terra

Lada Terra, located at high southern latitudes on Venus, features elevated topography with numerous coronae, volcanoes, extensional belts, and deformed terrains. The main highland is dominated by the large Quetzalpetlatl corona and two massive intersecting rift zones. Long-wavelength gravity anomalies suggest a deep thermal upwelling underneath Lada Terra at present-day, yet it was not previously categorized as a "hot spot" [6]. Lada Terra might indeed represent a precursor stage of advanced rifting.

Artemis corona

Artemis is found on the southern side of the Aphrodite Terra and is by far the largest corona on Venus (26000 km diameter), and in fact one of the largest circular structures on a rocky planet in our solar system. Artemis' interior is depressed relative to the surrounding plains and features a large rift-like chasmata. The SE margin of Artemis hosts a deep, arcuate trough surrounded by compressional arcs which rise above the plains. The topographic features of the Artemis rim have been interpreted as resulting from plume-induced retreating subduction, consistent with several geodynamic studies [7,8].

Beta Regio

Beta Regio is considered a "rift-dominated" topographic rise similar to Atla Regio. It is intersected by the prominent north-to-south Devana Chasma. Geological mapping indicates early uplift, rifting, and volcanism attributed to a hot mantle diapir, consistent with the related positive geoid anomaly. We identify the region as active, yet possibly with a lower seismicity than above-mentioned regions, more akin to a Hawaiian-type hotspot. This area serves as a valuable reference for comparing expected activity levels with other target regions.

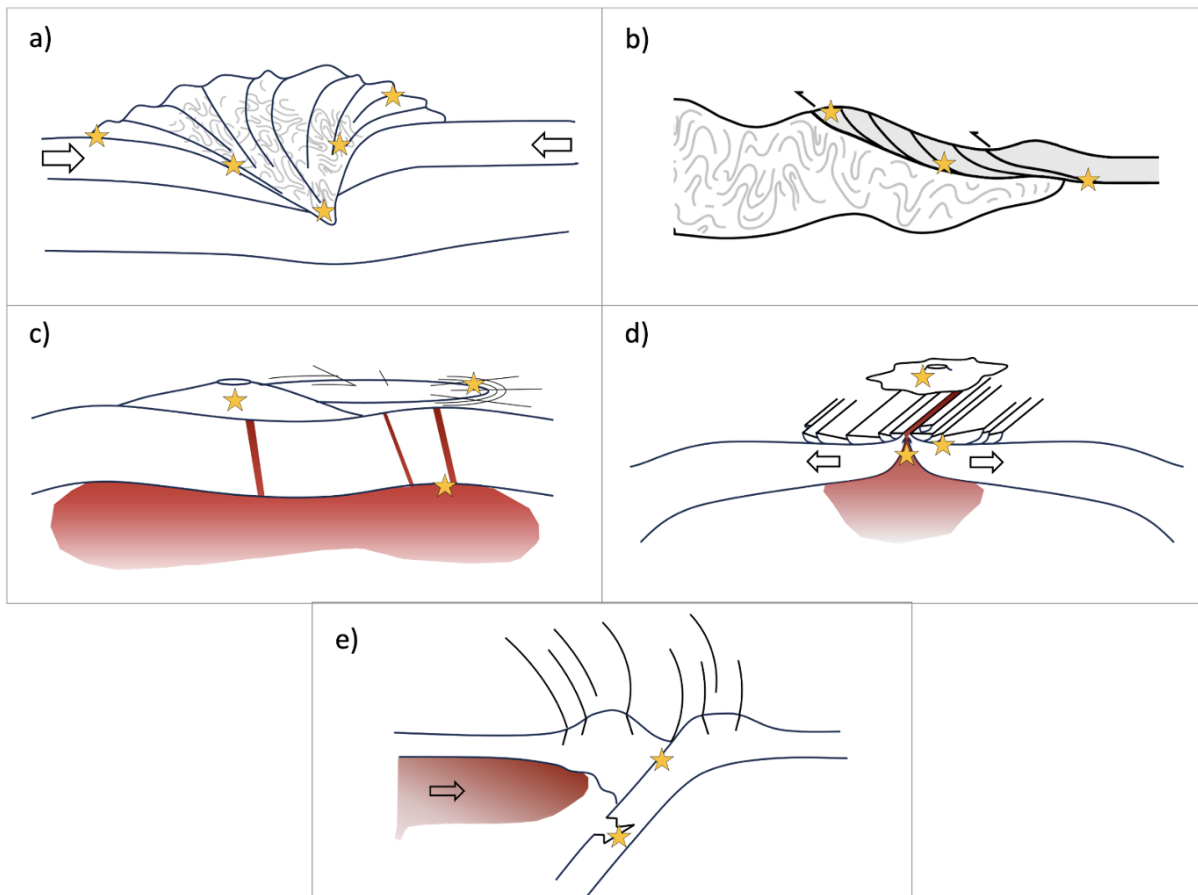


Figure 1. Schematics of the relevant settings in terms of tectonic context and observation of seismic activity. a) Ishtar-like setting. b) Thetis-like setting. c) Lada-like setting. d) Atla-like setting. e) Artemis corona rim setting. Stars highlight different environments at various depths where quakes are more likely to occur for each scenario.

In the context of forthcoming Venus missions like VERITAS and EnVision, identifying potential areas of seismic activity on Venus can yield highly valuable insights in addition to the missions' science goals. These missions aim to unravel the mysteries of Venus's geology and surface processes, shedding light on its tectonic history and volcanic activity. VERITAS (Venus Emissivity, Radio Science, InSAR, Topography, and Spectroscopy) will, amongst other data, provide detailed maps of Venus' surface and study its geology using e.g. radar and infrared imaging [9]. EnVision aims to investigate Venus's atmosphere, surface, and interior structure to understand its geological evolution [10]. By pinpointing these target regions, this study provides crucial information for mission planning and target prioritization. Moreover, these insights will be valuable for future mission concepts that aim to detect seismic activity on Venus.

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