AN ALLUVIAL DEPOSITIONAL ANALOG FOR SOME VOLCANIC PLAINS ON VENUS;

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Overview. Many types of landforms that are commonly associated with basaltic volcanism on Earth are widespread on the Venusian lowlands [1]. Geochemical evidence supports a dominance of mafic silicate volcanism on Venus [2-3]. The interpretation of some uniquely Venusian landforms, especially canali, is less certain. Canali are volcanic channels that resemble terrestrial river channels more than any known volcanic features on Earth, Moon, or Mars (Fig. 1). Canali are long and sinuous and have shallow cross sections (depth:width ~0.01-0.04). Any given canale maintains a fairly constant width for hundreds to thousands of kilometers. Hildr is over 6800 km long, the longest known channel of any type in the Solar System [4]. Some canali are leveed, whereas others apparently are not so at available radar image resolutions. Some canali possess features that indicate a history of meander migration, including meander cutoffs (oxbows) and meander scrolls (Fig. 1), whereas other canali appear to have had fairly stable courses. To be sure, canali are not dried river channels, because many have volcanic sources and terminal lava flows. Peculiar circumstances seem to be implied in the origin of canali, perhaps involving a chemically exotic lava [3, 4-7] or an ordinary silicate lava erupted under other extraordinary conditions [8]. The model presented below, based on an alluvial analog, suggests that canali-forming lavas had physical properties that allowed them to mimic the hydraulic and sedimentologic behavior of terrestrial rivers. As discussed below, carbonate lavas are most consistent in this regard, but highly fluid silicate lavas might have eroded canali under certain unusual circumstances.

Geomorphic analogs. The closest known volcanic analogs of canali are lunar-type sinuous rilles, which occur on the Moon, Mars, and Venus, and similar but much smaller lava channels on Earth [9-10]. Compared with canali, lunar-type sinuous rilles are relatively short (1 - 500 km), and terrestrial lava channels are shorter still (100 m to 50 km, [9-10]). However, canali do not appear to be simply large versions of lunar-type sinuous rilles, because canali are distinguished by many morphologic aspects besides length. Unlike canali, lunar-type sinuous rilles and terrestrial lava channels are comparatively deep (depth:width generally ~0.05-0.3), and they tend to become narrower and shallower downstream. The meander habits of canali and lunar-type sinuous rilles are distinctly different, apparently reflecting different formational mechanisms (Fig. 2).

Some terrestrial river channels are better morphologic analogs for many canali than known volcanic channels. The meander habits, relatively constant widths, and low depth:width ratios of canali resemble these aspects of terrestrial river channels in aggrading, low-gradient alluvial plains. Evidence for extensive meander migration, a hallmark of many rivers, is exhibited by some canali, but not by lunar-type sinuous rilles. One canale even has a terminal lava delta that resembles some fluvial deltas. The morphologic resemblance of canali to river channels suggests that fluvial processes on low-gradient alluvial plains may approximate the hydraulic regimes of canali-forming flows better than do processes involving silicate lava rivers. The thermal regimes of canali-forming flows also may have been comparable with those of rivers (i.e., rates of cooling and crystallization may have been similar -- zero for many rivers; very low for canali-forming flows).

The river channel analog: Implications for processes and lava compositions. River channels acquire their morphologic attributes partly as a result of continual adjustments of the hydraulic flow regimes, sediment loads, and bed shapes of streams to variations in water input. The physical properties of water (especially viscosity, density, and freezing point in relation to ambient surface temperature) critically affect the forms of river channels and help distinguish them from silicate lava channels. Rivers commonly are near the threshold between mechanical erosion and sediment deposition [11]. The spatial patterns and temporal cycles of erosion and deposition cause gradual lateral migration of river meanders; over periods of 100-1000 years, meanders of alluvial rivers commonly relocate over distance scales of about one meander wavelength.

The alluvial model of canali and their plains deposits implies that the surface rocks in these areas are in lateral and vertical accretion sequences comparable with those of terrestrial flood plains. If this analog is strictly correct, then the principal type of sediment should be preexisting plains material and/or sediment eroded from the source area. However, on Venus we are dealing with a lava of some type, so that a large fraction of sediment could be crystalline precipitates of the lava itself.

The dynamic balance between erosion and deposition, as implied by the alluvial analog, may indicate extremely low viscosities of the lava, probably lower than the viscosity of basalt (10^2-10^3 p). Several types of silicate lava have viscosities much lower than that of basalt [4-5], including strongly silica-undersaturated, mafic alkaline lava, lunar-type Fe-Ti basalt, picrite, and komatiite. Even less viscous are carbonate lavas, which have viscosities of just a few centipoises, comparable with the viscosity of water (~2 cp) [12].

The ability of canali lavas to flow thousands of kilometers in shallow, low-gradient channels whose depth and width remain fairly constant suggests not only a low viscosity, but also a low rate of crystallization (hence, probably a low melting temperature). Many canali have associated lava flows, so that the liquidus (and probably solidus) temperature of the lava was greater than Venusian ambient conditions (475^{O} C). If the liquidus

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temperature was only slightly greater, then this property could help explain the dimensional characteristics of canali. A liquidus temperature like those of fluid types of silicate lavas (~1200°-1500° C) probably would have caused rapid cooling and large downstream increases in lava viscosity and depletion of liquid, thus shallowing and narrowing the lava channel. The high temperature of Venus' surface compared with Earth's and the Moon's is a negligible factor if the Venusian lavas are silicate; this is because the T^4 dependence of radiative heat loss means that the high Venusian surface temperature causes only about a 7% reduction in heat loss rates of a basaltic flow compared with basalt flows on Earth or the Moon, if other factors are held constant. (In fact, convective cooling may have caused flows to cool faster on Venus because of its dense atmosphere.) Therefore, if the canali-forming lavas are silicates, then a factor other than Venus' warm surface must have been responsible for the extraordinary characteristics of canali. On the other hand, the warm Venusian surface could cause a carbonate lava (with a liquidus temperature as low as 510° C) to cool 10 to 100 times more slowly than a terrestrial basalt flow.

In sum, canali-forming lavas may have had silicate or nonsilicate compositions. However, to the extent that the alluvial analog of canali and associated plains may be correct, a "waterlike" lava, such as carbonatite, could be indicated. The compositions of Venus' atmosphere and rocks, so far as they are known, are consistent with large amounts of carbonates on the surface [3,13] and with widespread carbonate volcanism.

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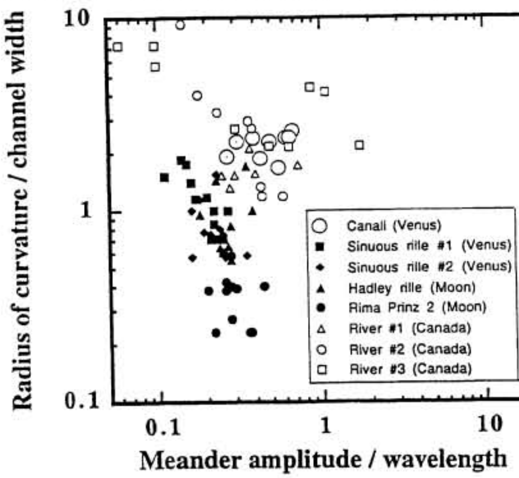

Fig. 2. Meander characteristics of canali, lunar-type sinuous rilles on Venus and the Moon, and river channels on Earth.

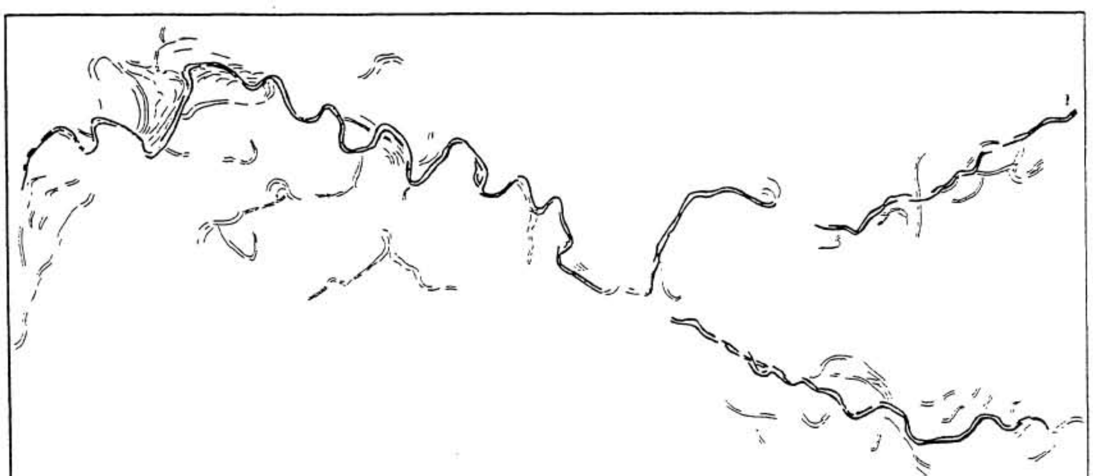

Figure 1. Map of meandering canali (bold lines) and features interpreted as meander scars (thin lines), including cutoff meanders and meander scrolls. Center near lat 33.5° S., long 158.5°. Mapped from Magellan SAR mosaic F-MIDRP. 35 S 157;1. Map spans 289 km from left to right (west to east).

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