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Palos crater and Tinto Vallis, Mars: Analysis of proposed fluvial and volcanic scenarios

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Abstract

Geomorphological interpretation and crater counting are used in constraining the formation time and mechanism of Tinto Vallis. Further implications for the regional history are analysed. Results show that Tinto Vallis formed ∼3.6–3.5 Ga ago as a fluvial valley, likely by catastrophic flooding and steadier groundwater influenced erosion. Temporal and spatial relationships indicate that Tinto Vallis and Palos crater possibly served as a conduit for material transport between Hesperia and Amenthes Planum.

1. Introduction

The ∼53 km Palos crater (2.7°S, 110.8°E) located in the northern Tyrrhena Terra is a candidate open-basin paleolake whose rim is breached from the south by a ∼180 km long Tinto Vallis [2, 5], while a breach on the northern rim serves as a source for the ∼350 km long "Palos outflow channel" [3] (Figure 1). Both fluvial [2, 3] and volcanic [3, 5] origin has been proposed for Tinto Vallis. The actual mechanism and time of formation is crucial when considering the origin of Palos crater floor deposits and possibility of Hesperia–Amenthes fluvial chain.

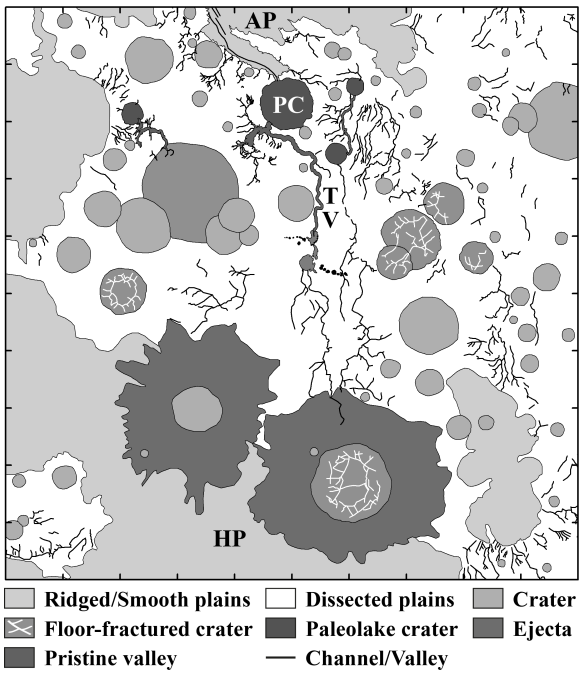

Figure 1: Geomorphological map of the study area. (AP = Amenthes Planum, HP = Hesperia Planum, TV = Tinto Vallis, PC = Palos crater.)

2. Origin of Tinto Vallis

It has been argued that the general morphology of Tinto Vallis is notably similar to sinuous rilles based on appearance, slopes, sinuosities, width-to-depth ratios, lack of tributaries and pit crater chains (indicative of lava tubes) near the source area [3, 5]. However, several arguments can be made against these claims.

Most importantly the downstream development of Tinto Vallis and typical sinuous rilles is completely opposite. Tinto Vallis gets progressively wider and deeper, whereas the rilles generally get shallower and narrower downstream. Downstream tapering would be expected from a thermally eroded volcanic channel or valley: with increasing distance to the vent the temperature and erosive efficiency of lava decreases [4]. On the other hand, fluvial valleys seem to widen downstream due to base level fluctuations [6]; additions from tributaries are not necessary.

Modeling and observations indicate that pit crater chains are related to tectonic modification, not lava tubes [8]. Also the claim that Palos crater outlet could have been volcanically incised [3, 5] is problematic since it would most likely require overflow of the rim and thus complete filling of Palos crater with volcanic materials. Furthermore the comparison of morphometric properties shows that Martian valleys are analogue-wise the most compatible option (Figure 2).

Since the analyses of surrounding areas and claimed similarities reveal no factors solely in favor of volcanic

origin, and several arguments can actually be found against it, we conclude that Tinto Vallis was formed by fluvial erosion. Superposition relationships and crater counting measurements of likely fluvial deposits on Palos crater floor can be used in constraining the age of Tinto Vallis to $\sim$3.6–3.5 Ga.

Tinto Vallis	Martian valleys	Lunar rilles	Venusian rilles
Sinuosity (*)	✓	✓	✓
W/D ratio (~ 5)	✓	✓	✗
Slope (~ 0.2°)	✓	✗	✓
Downstream widening	✓	✗	✗

(*) Multiple ways to measure and equally many different values

Figure 2: Comparison between typical values found on analogue features and Tinto Vallis. Martian valleys are analogue-wise the most compatible option.

3. Discussion and Conclusions

In addition to the typical "sapping morphology" of Tinto Vallis, the importance of groundwater in the area is hinted by the numerous paleolake candidates, all of which seem to have relatively small drainage areas. In the imminent vicinity there is also many floor-fractured craters which are otherwise rare in the area, but can be associated with groundwater discharge [7]. Preliminary climatic modeling indicates that Amenthes region was among the last isolated places where precipitation might have fueled aquifer recharge as Mars was drying out [1].

Outflow-like morphology near the source area of Tinto Vallis hints that catastrophic flooding might have contributed to the formation of Tinto Vallis in addition to steadier groundwater influenced erosion. Unfortunately the source area is largely obscured by later processes thus making interpretations harder. One possibility is that the flooding was related to basin overspillage following from a tectonic loading caused by the formation of ridged plains on Hesperia Planum (HP). This interpretation is further supported by indications of abundant tectonic modification near the source area and markedly similar formation ages of Tinto Vallis and HP [9].

There is some indications that the currently observed Tinto Vallis formed on top of older valley network [3]. This combined with the previous discussions, and the fact that the drainage basin and degraded valleys contributing to Tinto Vallis extend to the borders of HP, strengthens the notion that prior to the formation of ridged plains Tinto Vallis with the degraded valleys and Palos crater might have formed a Hesperia–Amenthes fluvial chain through which materials were deposited.

In conclusion, Tinto Vallis likely formed as a fluvial valley $\sim$3.6–3.5 Ga ago, affected both by catastrophic flooding and steadier groundwater influenced fluvial erosion. Prior to plains formation Palos crater and Tinto Vallis likely served as a conduit for materials transported from Hesperia Planum to Amenthes Planum.

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