ORIGINS AND AGE CONSTRAINTS OF THE PALOS CRATER FLOOR DEPOSITS AND TINTO VALLIS, MARS. A.I. Rauhala[1] and V.-P. Kostama[1], [1]Astronomy Division, Department of Physics, P.O. Box 3000, FI-90014, University of Oulu, Finland, <anssi.rauhala@oulu.fi>.

Introduction: The ~53 km Palos crater (2.7°S, 110.8°E) is a candidate open-basin paleolake located in the ancient Martian highlands of northern Tyrrhena Terra [1–3]. The rim of Palos crater is breached from the south by a ~180 km long channel/valley called Tinto Vallis [4–7], while the northern breach on the Palos rim serves as a possible source for the ~300 km long "Palos outflow channel" [7] (Fig. 1). Palos crater has been considered as a potential site of fluvial deposits [8–10], whereas Tinto Vallis has been proposed to represent a valley influenced by extensive groundwater sapping [4–5], or alternatively, a volcanic channel carved by flowing lava [6–7]. We have set out to further assess the type of the deposits in the area, and also the episodes that led to their formation by combining geomorphological and hydrological analysis with high resolution crater counting.

Origin of Tinto Vallis: The possible volcanic origin for the sinuous eastern branch of Tinto Vallis was implied on the basis of consistent general morphology with the volcanic rilles when considering appearance, slopes, sinuosities and dimensions of cross-sectional profiles [6–7]. Several points of critique can be made against these claims:

(1) The downstream development of Tinto Vallis and typical rilles are completely opposite. Tinto Vallis gets progressively deeper and wider consistent with some terrestrial valleys, whereas on typical cases of Lunar and Venusian rilles the width and depth tapers downstream or stays constant [11–13].

(2) The slopes of Martian valley networks seem to range from 0.2% to 1.7% with the average being around 0.6% [14]. Slopes of lunar rilles seem to be around 1.0%, although the available statistics are scarce [15]. Nevertheless, the "allegedly steep" slope of Tinto Vallis (~0.4%) seems to be more consistent with the average slopes of Martian valley networks than sinuous rilles.

(3) Preliminary results have shown that a positive correlation exists between the lengths and sinuosities of lunar rilles [13]. Thus without further knowledge of similar correlation between Martian valleys, the comparison of the sinuosity of one valley to the wide range observed in Lunar rilles is inconclusive.

(4) The width-to-depth ratios of Martian valleys range to well over 100 with most of the values clustering around 5 – 25 [16]. Also the ratio seems to decrease as the valley depth increases [16]. For an unusually deep valley, the ratio of Tinto Vallis (~5) fits well into the observed range, although it is also consistent with the ratios observed in Lunar Rilles (4 – 11) [6]. On the other hand, typical ratios for Venusian rilles seem to be around 30 – 50 [13]. With such a wide range observed in both volcanic channels and fluvial valleys, the width-to-depth ratio cannot be conclusively used in determination between the two processes.

Also the other presented arguments can be disapproved with, for example the comparison between the pit chains in the Tinto Vallis source area and roofed lava tubes [6] is debatable in light of the current views on the volcanic rille formation [11]. In summary, it seems that most of the points arguably supporting the volcanic origin of Tinto Vallis are rather inconclusive or actually turn out to be more consistent with fluvial origin.

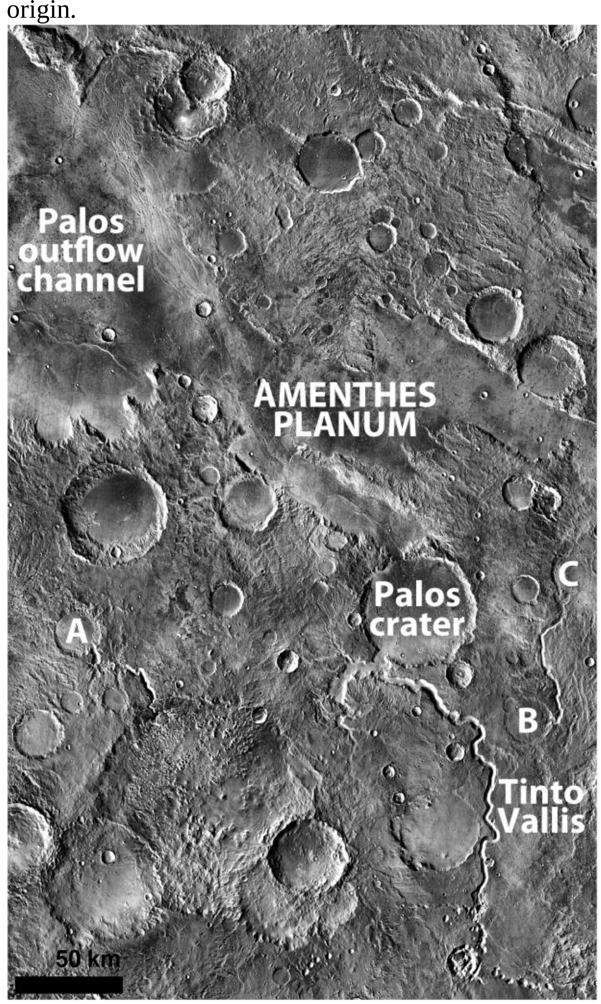

Fig. 1: The relation of the features mentioned in the text. Letters A, B and C refer to other paleolake candidates in the area to which crater counting measurements were also performed.

Age of Fluvial Features: Previous authors concluded that the Palos outflow channel and the eastern main branch of Tinto Vallis formed nearly at the same time, around 3.2 – 3.5 Ga ago [7]. (All ages refer to "Hartmann & Neukum" model [17]). They constrained the age of Tinto Vallis by measuring crater model ages for an ejecta field superposed on the valley floor (~3.44 Ga), and also for the youngest plains incised by the valley (~3.58 Ga).

However, one additional constraint should be considered. The current volume of eastern Tinto Vallis is ~266 km³, which is enough to create ~120 m thick layer if the excavated materials are delivered on the Palos crater floor. This would be enough to completely fill average ~2.5 km craters [18] and effectively erase the previous cratering record. Thus the age of Palos crater floor should likely reflect the formation age of Tinto Vallis.

The oldest unit on the Palos crater seems to be the terrace-form in the eastern side of the crater floor (~3.69 Ga). Previous authors presented similar age of ~3.63 Ga for some undefined portion of Palos floor. Inclusion of these ages as an upper constraint would mean that Tinto Vallis was active around ~3.7 – 3.5 Ga ago, during a time which is often associated with the end of widespread valley incision [19]. It would also mean that Tinto Vallis and Palos outflow channel formed in two clearly distinct fluvial episodes. In general, the crater counting ages measured for the Palos crater floor units, surrounding plains and other paleolake candidates in the area seem to cluster around three distinct time periods: ~3.7 – 3.4 Ga, ~3.3 – 3.0 Ga and ~1.8 – 1.6 Ga.

Discussion: Revised scenario is proposed: Tinto Vallis developed to its current form as a fluvial valley in the end of Noachian, around ~3.7 – 3.5 Ga ago. This time period was also the main lake phase in the Palos crater. Hydrological analysis indicates that the watersheds currently draining into the Palos crater and Tinto Vallis source area reach to the northern edges of Hesperia Planum (HP). It is possible that before the emplacement of Hesperian ridged plains (~3.6 – 3.5 Ga ago [20]) the watersheds extended further to the HP. Valleys in the HP area that are now encased in volcanic materials [21] likely contributed to the formation of Tinto Vallis and Palos crater lake. Ultimately the fluvial activity in the region waned, likely following from a global climate change.

Next major episode in the Palos area was the formation of the smooth plains in the adjacent Amenthes Planum and partial volcanic infilling of the Palos crater floor trough the northern breach around 3.5 – 3.3 Ga ago. This infilling created the observed lobate margins [6-7] and higher elevation units on the western side of the Palos crater floor. Second major fluvial episode in the area happened around 3.3 – 3.0 Ga ago. Most notable event of this episode was the formation of Palos outflow channel which is reminiscent of the terrestrial outburst rivers. Likely source for the Palos outflow was the outburst of groundwater from Palos crater, possibly enhanced by ice damming. Similar ages are found on parts of the valleys on adjacent highlands so the formation of outflow might have led to a second lake phase in the Palos crater and accumulation of ice to the highlands via lake-atmosphere feedback.

Last major episode of resurfacing in the area seems to have happened around 1.8 – 1.6 Ga ago. This episode is mostly witnessed in lower elevation units of Palos and nearby paleolake candidates. The resurfacing was possibly caused by glacial/glaciofluvial processes or groundwater upwelling, although the latter is the more unlikely option in terms of current views on Martian history.

Conclusions: According to our observations, the previously presented possible volcanic origin of Tinto Vallis seems unlikely. Rather the morphology and morphometric constraints suggest fluvial valley origin.

Palos crater floor deposits and related fluvial features form a geological site where evidence of major volcanic and fluvial/glacial activity can be observed throughout the Martian history. Our results strengthen the hypothesis that Palos crater once served as a conduit for water and fluvial materials transferred from Hesperia Planum to Amenthes Planum.

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