EPSC Abstracts
Vol. 8, EPSC2013-195, 2013
European Planetary Science Congress 2013

Evidence for catastrophic ice lake collapse from Aram Chaos (Mars)

M. Roda (1), M. G. Kleinhans (1) and T. E. Zegers (1)
(1) Universiteit Utrecht, Fac. of Geosciences Budapestlaan 4, 3584 CD Utrecht, The Netherlands (m.roda@uu.nl)

Abstract

Morphological and geological analyses of Aram Chaos suggest large scale collapse and subsidence (1500 m) of the entire area, which is consistent with a massive expulsion of liquid water from the subsurface in one single event. Morphological analysis of Aram Valley suggests a complex process starting with the outflow of water from two small channels, continuous groundwater sapping and headward erosion ending with catastrophic lake rim collapse and carving of the Aram Valley, synchronous with the 2.5 Ga stage of Ares Vallis formation. The water volume and the formative time scale needed to carve the Aram channels indicate that a single, rapid (maximum tens of days) and catastrophic (flood volume of $9.3{\cdot}10^4$ km^3) event carved the outflow channel. We conclude that the sub-ice lake collapse scenario can explain the features of Aram Chaos - Valley system as well as the time scale needed for its formation.

1. Aram Chaos

Aram Chaos is situated in a circular basin with a diameter of 280 km centered in 2.5°N and 338.5°E and It is connected to Ares Vallis by a 15 km wide and 2.5 km deep outflow channel, Aram Valley [1]. Observations in 3D, in particular from HRSC stereo data, provide evidence that the current Aram Chaos terrain was originally a large impact basin, which was almost entirely filled before fracturing and subsidence occurred, resulting in the present day morphology. The fracture pattern was analyzed in terms of fracture density and fracture orientation to infer the fracture mechanism. The fracture spacing is highly variable, ranging from tens of kilometers down to locally small values below the resolution limit, where cohesion appears to be entirely lost. No preferred orientation is obvious in the fracture patterns of the fractured units. Only a weak alignment of fractures with the rim orientation exists in the outer zone. The fracture pattern includes interfering patches of radial fractures, which partly originate from loci of very high fracture density. The fracture density increases in the area around the outflow channel (north and south) and a more abrupt escarpment characterizes the southern rim of the Aram crater with respect to the northern part, which presents a more gradual slope of the rim. Geological, morphological and structural analyses on Aram Chaos suggest a large scale collapse and subsidence of the entire area (1000-1500 m).

2. Outflow channels

Three outflow channels are detected along the rim of Aram Chaos: two small channels are located in the northeastern part of the rim while in the eastern part a large valley (Aram Valley) cuts the entire rim.

2.1 Minor channels

Along the north-east rim of the Aram Chaos other two small channels are visible. They have a similar and constant slope (0.019 the northern and 0.020 the southern) and a general U-shaped profile. The northern channel is 5 km wide with a width/depth ratio of 50; the southern channel is 4 km wide with a width/depth ratio of 40. Their inlets are located around -1800 m. The outlets are truncated by the erosional features of Ares Vallis at an elevation between -3500 and -4000 m. These features represent the remnants of late erosive events in Ares Vallis (2.8–2.5 Ga) [2]. This indicate that the two outflow channels were active before or during the late carving of Ares Vallis. Furthermore, the high channel slopes, quite similar to the slope of pristine Aram Chaos rim, suggests that they could be representatives of the early outflow stages recorded in the Aram Chaos.

2.2 Aram Valley

The Aram Valley is a deep (2.5 km) V-shaped valley, with a low width/depth ratio (6-8), which represents an outflow channels from the Aram Chaos to the

Ares Vallis. The inlet of the valley along Aram Chaos boundary is characterized by a high number of relative small and deep channels and radial grooved terrains overlying the fractured and knobby units. The valley slope, obtained by removing from the profile two landslides which occur along the northern rim of the Aram Valley, is quite constant with a gentle gradient (0.004) toward the Ares Vallis. The present-day valley slope is lower then the initial slope suggested by the profile along the north and south rims (0.047 for the rim N and 0.028 for rim S) of the outflow valley. With the current rim morphology it is difficult to explain why the Aram Valley formed in this particular location.The valley inlet is now located near -2000 m but the cross-sections suggest that it would reach at least -1500 m at Aram Chaos rim peak. However, no other outflow remnants were found, with the exclusion of two small channels along the north-eastern side. The steepest subsurface gradient was likely localized between Aram Chaos and Ares Vallis (0.018 – 0.023 compared to 0.012 – 0.016 of western part) making groundwater flow likely towards Ares Vallis with the outlet located between -3000 and -3500. The Aram Valley is graded to the final erosive surface of Ares Vallis with no evidence for intersecting or truncating flood grooves or a knickpoint occurrence at the confluence. This observation clearly supports the interpretation that the water outflow from the Aram Valley was synchronous with final erosive event of Ares Vallis (about 2.5 Ga, [2]).

It is now possible to infer a relative chronology of the Aram Chaos outflows, which started with two relative small channels along the north-eastern part of the rim and continued in the larger Aram Valley, once the groundwater headcutting was completed. This process was active for a relative short period, coeval with the late stages of Ares Vallis formation. The formative time scale and water volume determination indicates the occurrence of a very rapid (tens of days) and catastrophic (volume of flood of $9.3{\cdot}10^4$ km^3) events able to carve the Aram Valley and two other small channels. This means that a large amount of water would have to be available at the source of the outflows [1].

3 Comparison with formative models

The first group of proposed mechanisms imply interaction of volcanic activity with the cryosphere [3]. In this model the fracturing affecting chaotic terrains are regarded as pre-existing faults related to impact crater, subsequently re-activate by melting of the cryosphere. This is inconsistent with the results from the geological analysis of Aram Chaos, where the subsidence (rim fault) and fracturing are coeval. Although the water volume and the water flux generated by volcanic-cryosphere model is not estimated, the amount of water released from the cryosphere, which depends primarily on porosity and permeability, is low (10^0–10^2 km^3, 10^3 km^3 only for extreme values of permeability) in comparison with the volume of water needed to carve the outflow channels ($9.3{\cdot}10^4$ km^3 for Aram Valley). For the second mechanism, the aquifer water models [4, 5], numerical and analogue modeling suggests that a very high number of outflow events are needed to archieve the amount of water sufficient to carve the outflow channels. The catastrophic characteristic of the outflow mechanism and its formative time scale suggested by the Aram Valley analysis are in conflict with this interpretation. The sub-ice lake model, proposed by [6], is able to explain the strong subsidence and fracturing of the chaotic terrains as well as the large amount of water need to carve the outflow channels in a catastrophic way.

References

[1] Roda, M., Kleinhans, M.G., Zegers, T.E., subm. Aram Chaos: evidence for catastrophic ice lake collapse on Mars. Icarus.

[2] Warner, N., Gupta, S., Muller, J.P., Kim, J.R., Lin, S.Y., 2009. A refined chronology of catastrophic outflow events in Ares Vallis, Mars. Earth and Planetary Science Letters 288, 58–69.

[3] Meresse, S., Costard, F., Mangold, N., Masson, P., Neukum, G., 2008. Formation and evolution of the chaotic terrains by subsidence and magmatism: Hydraotes Chaos, Mars. Icarus 194, 487–500.

[4] Carr, M.H., 1979. Formation of martian flood features by release of water from confined aquifers. Journal of Geophysical Research 84, 2995–3007.

[5] Andrews-Hanna, J.C., Phillips, R.J., 2007. Hydrological modeling of outflow channels and chaos regions on Mars. Journal of Geophysical Research 112, E08001.

[6] Zegers, T.E., Oosthoek, J.H., Rossi, A.P., Blom, J.K., Schumacher, S., 2010. Melt and collapse of buried water ice: An alternative hypothesis for the formation of chaotic terrains on Mars. Earth and Planetary Science Letters 297, 496–504.