
**Background and Purpose:**
- Two main types of valley networks (VNs) exist on Mars: (1) VNs that occur in the Noachian highland terrain, which are the majority; and (2) VNs that are associated with "volcanic edifices, plateaus and in association with a few craters" (pg. 62), which are much fewer in number.
- Understanding the age of these VNs has important implications for the ancient climate on Mars, as well as ancient climate shifts, and the aim of this work is to:
  1. Determine if there is any difference in age of formation between the two types of VNs
  2. Determine if the transition in VN formation was abrupt or more gradual
  3. Determine if VN ages can provide information on the cause of VN formation and its cessation

**Previous Work:**
- Past attempts to date VNs have included using craters directly superposed on the VNs and dating the incised terrain (upper age limit only) and typically suggest a Mid-Late Noachian age
- Alternatively, Craddock and Maxwell (1993) and Maxwell and Craddock (1995) suggest that Noachian crater degradation in the highlands was dominated by fluvial erosion, and so the age where a fresh and uneroded population of craters first began to develop represents the end of VN formation. This method yields an age around the Noachian/Hesperian boundary.

**Method:**
- The authors studied 26 highland VNs (Type 1) and 4 VNs outside of the highlands (Type 2)
- They use a method that employs a buffer on either side of the valley that is one and a half times the diameter of the crater size being examined, and includes only craters superposed on the VN
- This method provides a minimum age for VN formation.
- Both Neukum and Hartmann production functions are used, along with Tanaka (1986) period boundaries

**Results:**
- The highland VNs typically date to around the Noachian/Hesperian boundary with a mean age of 3.53 Gyr (Hartmann) or 3.75 Gyr (Neukum). (Blue data points in figure below)
- Variation in highland VN ages can be explained by:
  1. Statistical age differences, with VN formation ceasing at the same time
  2. Real age differences, with VN formation ceasing over a period of a few hundred Myr
- The four VNs outside the highlands all have younger ages, ranging from the Late Hesperian to Early Amazonian, with each of these four VNs having a distinct age. (Red data points in figure below)
Major Implications:
- These results are consistent with the hypothesis that there was a widespread change in surface conditions at the Noachian/Hesperian boundary causing VN formation to stop rather abruptly.
- VN formation cessation ages correlate with the time where Craddock and Maxwell (1993) and Maxwell and Craddock (1995) propose fresh craters began to steadily accumulate, which may indicate that crater degradation in the Noachian was largely controlled by fluvial activity.
- Many crater lakes are fed by VNs and so it is likely that decline in VN formation also led to the end of lacustrine activity in those lakes fed by VNs.
- Phyllosilicate formation in the Noachian is suggestive of high water-rock interaction; however, the era of phyllosilicate formation is thought to have stopped much earlier than then end of VN formation. Two explanations for this difference are proposed here:
  1. VN formation ended after phyllosilicate formation, the latter of which may have occurred in a climate with an even more active hydrological cycle.
  2. The observed difference in age of the end of VN and phyllosilicate formation is inaccurate, and the end of VN formation and phyllosilicate formation was simultaneous.
- These results cannot definitively differentiate between a “warm and wet” and “cold and snowy” environment in the Noachian, both of which could have resulted in widespread VN formation.
- The young VNs are thought to be sourced from localized fluvial activity and may be related to: geothermal melting of volcanic summit snowpack, outflow channels or large impact craters.
  - These three scenarios to form young VNs can all occur in a modern Martian climate, and so a “cold and dry” scenario must still be considered for Noachian VN formation.

Questions for Discussion:
- Which scenario for the explanation of highland VN age differences seems more plausible? Why?
- Is the correlation between the results presented here and the Craddock and Maxwell (1993) and Maxwell and Craddock (1995) “fresh crater stabilization age” sufficient evidence to infer heavy fluvial degradation of craters in the Noachian? How might this affect our understanding of the Martian cratering record?
- Which explanation for the difference between the era of VN formation and phyllosilicate formation is more convincing? Has our understanding of this relationship changed in the past few years?