EARTH SCIENCE

Megafloods downsized

A fresh look at the Channeled Scablands of North America shows that the ancient floods that scarred that landscape were smaller than is commonly assumed. This result could revise estimates of similar floods on Mars. SEE LETTER P.229

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The enormous canyons of the Channeled Scablands in the northwestern United States, many of which contain no rivers, puzzled geologists for decades. The gradual realization that these canyons were carved thousands of years ago by huge floods spawned by melting glaciers challenged the idea that Earth's surface is shaped by gradual, steady erosion. However, on page 229, Larsen and Lamb[1] show that at least one of the canyons was formed by a succession of much smaller floods, a finding that has implications for flood-carved canyons on Mars.

When the geologist J Harlen Bretz proposed in the 1920s that the Channeled Scablands were created by a catastrophic flood[2], his ideas were attacked relentlessly by geologists who subscribed to the mainstream view that erosion is slow and steady, and who wanted to distance their profession from the notion of a biblical deluge. Bretz did not identify the source of the flooding until the 1940s, when his colleague Joseph Pardee found evidence[3] that ancient Lake Missoula, which formed at the margin of the melting Cordilleran ice sheet roughly 15,000 years ago, had drained catastrophically to the west. This discovery led to the gradual acceptance of Bretz's flood hypothesis, which was later supported by studies that considered the mechanics of large flows through canyons[4]. Subsequent analyses of sediments deposited throughout the region showed that the Channeled Scablands had experienced not one but many floods[5].

Although the flood origin of the Channeled Scablands is no longer disputed, the sizes of the individual floods remain uncertain. It has become common practice to place an upper bound on the flow rate of the floods by assuming that they filled the present-day canyons to the brim. Estimated flood magnitudes based on this assumption[6] range up to 60 cubic kilometres per hour — nearly 100 times the average flow rate of the Amazon River today[7]. But these estimates might be much too large. Glaciologists have argued that it is difficult for ice sheets to store enough water to produce such enormous floods[8]. The brimful-flood model also requires the unlikely scenario that each flood passing through the canyons was larger than the one that preceded it, because the canyon deepens as each successive flood erodes the bedrock (Fig. 1a).

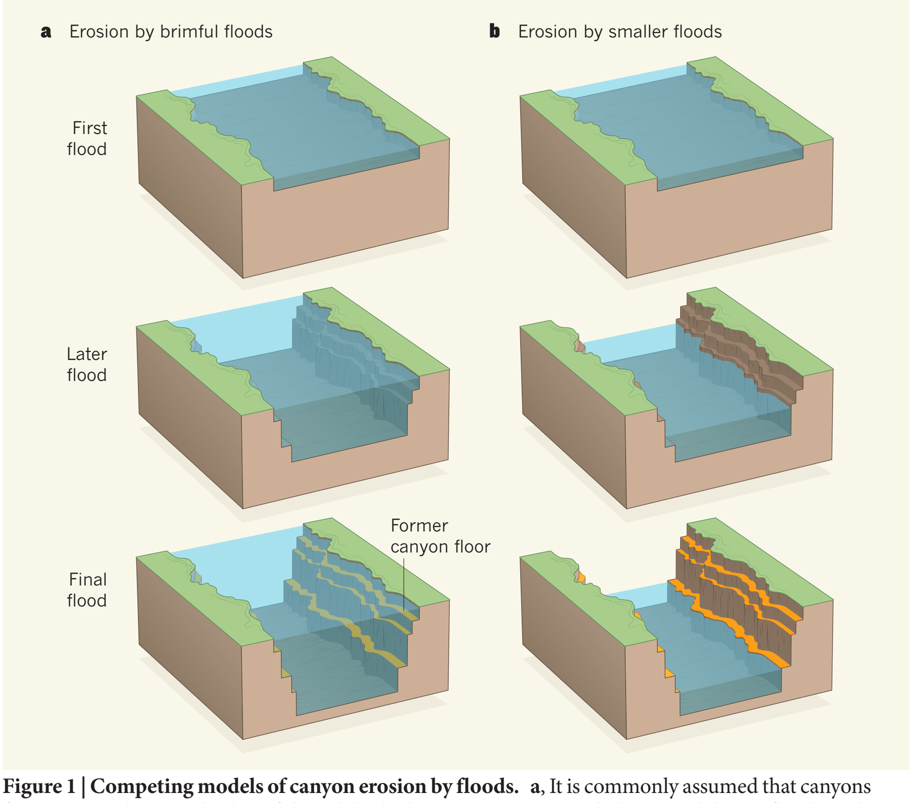

Figure 1 | Competing models of canyon erosion by floods. **a**, It is commonly assumed that canyons form in accordance with a brimful model, which requires progressively larger and deeper floods as the canyon erodes. **b**, Larsen and Lamb[1] use remnants of former canyon floors to show that Moses Coulee was instead shaped by a sequence of smaller floods.

Larsen and Lamb wade into this debate and present evidence that a series of consistently sized, moderate floods eroded the canyons of the Channeled Scablands. In this scenario, the first flood filled the shallow, newly formed canyons to the brim, but subsequent floods only partly filled the deepening canyons (Fig. 1b). They studied Moses Coulee (Fig. 2), a canyon in which a series of bench-shaped terraces preserves the remnants of former canyon floors that were abandoned by the flood water as the canyon was progressively eroded.

Using previous estimates of the forces required to erode blocks of rock from the canyon floor, and a computational model of flood flow through the canyon, the authors constrained the minimum flow rate corresponding to each remnant canyon floor. Their calculated flow rates are consistent with the presence of gravel bars that the most recent floods deposited in the canyon. Brimful floods would have instead suspended the gravel (and even larger boulders) high in the flow, preventing deposition. Larsen and Lamb conclude that Moses Coulee was eroded by repeated floods of no more than 2 $km^3 h^{-1}$. This flow rate is by no means small — it is more than three times that of the Amazon River[7] — but it is much smaller than the maximum of 10 $km^3 h^{-1}$ that is implied by the brimful model for Moses Coulee.

Floods as large as those discussed by Larsen and Lamb have not been observed in recorded history. This makes it difficult to test some of the authors' assumptions, such as the estimated

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Figure 2 | Moses Coulee. Upstream view along the east wall of Moses Coulee, a canyon in the Channeled Scablands of Washington state.

forces required to erode blocks of rock, and the notion that the floods were just large enough to erode their beds. It will also be challenging to confirm that similarly modest floods formed other Channeled Scabland canyons, because not all canyons contain features that record the progress of canyon incision in the same way as the well-preserved terraces in Moses Coulee. However, observations of erosion by smaller, modern floods[9] support the principles behind the authors' approach.

Larsen and Lamb's results raise the possibility that the largest known floods in the Solar System were smaller than previously estimated. Numerous floods crossed the surface of Mars during the past few billion years, carving enormous canyons that dwarf the Channeled Scablands. The source of the flood water remains a mystery, but each flood probably originated either when water erupted from an underground aquifer, or when a surface reservoir, perhaps created by melting ice, suddenly drained — a scenario similar to that of Lake Missoula. Brimful flow rates estimated from high-water marks in the biggest Martian canyons are tens of times greater than the largest estimates for the Channeled Scablands[10]. The immensity of these floods is even more shocking given the cold, dry conditions that have characterized the surface of Mars for at least the past 2 billion years.

Larsen and Lamb do not attempt to model the Martian floods, but their results support previous suggestions[11,12] that the canyons on Mars could have been carved by a succession of smaller floods. Such a scenario could help to resolve the discrepancy between flow rates estimated from canyon topography and geological constraints on water supply rates[11]. A succession of floods would have required repeated replenishment of the water source, which has implications for Mars's ancient climate. A detailed study of water flow through Martian canyons that is based on erosional and fluid-dynamical constraints would help to clarify the magnitude of their catastrophic origins. The case of the Channeled Scablands reminds us that Earth still has many lessons to teach us about alien worlds. ■

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1. Larsen, I. J. & Lamb, M. P. *Nature* **538,** 229–232 (2016).
2. Bretz, J. H. *J. Geol.* **31,** 617–649 (1923).
3. Pardee, J. T. *Geol. Soc. Am. Bull.* **53,** 1569–1600 (1942).
4. Baker, V. R. *Geol. Soc. Am. Spec. Pap.* **144,** 1–73 (1973).
5. Waitt, R. B. *J. Geol.* **88,** 653–679 (1980).
6. O'Connor, J. E. & Baker, V. R. *Geol. Soc. Am. Bull.* **104,** 267–279 (1992).
7. Wohl, E. E. in *Large Rivers: Geomorphology and Management* (ed. Gupta, A.) 29–44 (Wiley, 2007).
8. Clarke, G. K. C., Leverington, D. W., Teller, J. T., Dyke, A. S. & Marshall, S. J. *Quat. Sci. Rev.* **24,** 1533–1541 (2005).
9. Lamb, M. P. & Fonstad, M. A. *Nature Geosci.* **3,** 477–481 (2010).
10. Baker, V. R. *Nature* **412,** 228–236 (2001).
11. Manga, M. *Geophys. Res. Lett.* **31,** L02301 (2004).
12. Andrews-Hanna, J. C. & Phillips, R. J. *J. Geophys. Res.* **112,** E08001 (2007).

AGEING

Measuring our narrow strip of life

In line with previous research, a demographic analysis corroborates the presence of a limit to human lifespan, indicating that increases in life expectancy are likely to slow down or stop over the coming years. **SEE LETTER P.257**

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The British author Annie Besant once wrote[1]: "out of the darkness of the womb, into the darkness of the grave, man passes across his narrow strip of life." The ration of time allocated to humans is of profound personal and scientific interest. On page 257, Dong *et al.*[2] turn to the demographic literature to analyse whether there is a limit to human lifespan — and find evidence to suggest that there is.

Before discussing the study at hand, we should define some relevant terms. Lifespan describes how long an individual lives. Life expectancy is a population-based estimate of expected duration of life for individuals at any age, based on a statistical 'life table'. And maximum lifespan is the age reached by the longest-lived member of a species.

Human life expectancy has risen fairly steadily and rapidly over the past 150 years[3] in most countries. In 1990, colleagues and I predicted that this increase would slow over time[4], and this has proved to be the case[5]. Maximum lifespan also seems to have risen steadily[6], but this too might have reached an upper asymptote — no one is known to have lived longer than Jeanne Calment, who died in 1997 at the age of 122. Thus, the debate about life's limits is ongoing.

Some scientists speculate that fixed limits to