River and landscape topography, combined, can reveal the geologic history of a planet

By Devon Burr

Rivers develop on planetary bodies from the interplay of climate and topography. In planetary contexts, rivers and their effects are used to constrain short- and long-term climate models. However, rivers are also controlled by the short- and long-wavelength topography of the planetary surface. Rivers thus provide a means to constrain the generation of topography. On page 727 of this issue, Black et al. (1) compare topography at a range of scales with mapped river drainages to provide new insights into the topography-generating mechanisms on Earth, Mars, and Titan.

Earth is particularly suited for comparing topography and river drainage. Its volatile cycle is hyperactive, relative to others in the solar system, and results in abundant river drainages, which are ready-made arrows pointing the way downhill within the channels. The surrounding topography, however, need not trend downhill in the same direction, for example, when antecedent rivers persist in their original flow direction even during uplift of the regional topography (2). The eastern tributaries of the Tennessee River illustrate discrepant drainage and topography, although the causes for this are still under investigation (see the figure) (3).

Quantifying such discrepancies between drainage and topography gives a new understanding of the mechanisms by which this topography is generated. Plate tectonics on Earth generates topography at plate margins, where two plates converge to create mountains, such as the Himalayas, or where subduction and melting of one plate generates volcanic orogens, such as those that formed the South American Andes Mountains. Although often extending thousands of kilometers along the end-to-end dimension, the plate-marginal topography is much shorter in width (or wavelength), typically less than a few hundred kilometers. Conversely, topography generated by other processes tends to be longer in wavelength, although exceptions do exist.

Comparison of river drainages and landscape topography by Black et al. shows that on Earth, the downstream flow directions of rivers are not particularly well correlated with the landscape topography. This poor correlation means that rivers on Earth often drain across, or even upslope, through their surrounding landscapes. In other words, at locations of short-wavelength deformation, compared with those for Titan. The volatile cycle on Titan, dominated by hydrocarbons instead of water, has produced a range of fluvial drainages (6). The rectangular character of many of these drainages, including a high percentage of the polar drainages, suggests some kind of tectonic control (7). Black et al. found that the correlation of topography and drainage is strong at lower latitudes but weaker at the north pole. Thus, some long-wavelength mechanism, such as variation in shell-thickening, may dominate the generation of topography globally on Titan, but with some shorter-wavelength mechanism operating at the poles. The low- and mid-latitude rivers on Titan tend to flow over the icy bedrock, but at the poles, they can incise and flow through the bedrock, consistent with findings of deeply incised river valleys at the poles (8).

The technique might be applicable on other planetary bodies with nonvolatile flow; Black et al. suggest application to lava channels on Venus or nonwater-volatiles networks hypothesized for Pluto. The present results weigh against the hypotheses of plate tectonics on Mars (4, 5) and lend support for tectonic processes operating at the poles on Titan (7, 9, 10). However, previous Titan work found evidence for tectonic processes in the south polar region, whereas this new work supports short-wavelength deformation at Titan’s north polar region. This inconsistency between the geomorphologic mapping (9, 10) and new analysis (7) remains to be reconciled and the cause(s) for this asymmetric deformation on Titan to be better understood.

REFERENCES

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