extension is proportional to the seepage rate. This implies that the rate of growth should slow as the tributary heads approach the drainage divides, where inflow is reduced. As seepage channels erode and grow towards divides, they also elaborate into a network by branching at their tips. The authors suggest that the creation of new tributaries is directly related to the size of the contributing drainage area. This results in a linear increase in the branching of the networks with increasing drainage area.

The rate of channel growth that Abrams and colleagues describe has the interesting property of being 'reversible', which means the equation can be solved for the starting values. Thus, it can be used to calculate the age and timing of the network development. Using this interpretation, they find that the channel network is roughly 0.73 million years old, which is broadly consistent with the age of the sediments. The quantification of such a relationship allows the history of seepage-driven networks to be defined, and could provide a means for estimating the age of surface features on Earth and on Mars.

However, further study is required to substantiate the relationships proposed by Abrams and colleagues[1]. Both the linear relationship between seepage and growth rate, and the proportional relationship between branching rate and contributing area, are based on model assumptions that require verification. Simulation modelling indicates that the degree of branching in seepage valleys may depend on the functional relationship between seepage flux and the rate of valley extension[8]. Measurements of water and sediment fluxes in the Florida drainage network, estimation of erosion rates and history (using cosmogenic isotopes and other methods), and detailed study of the geologic context should help with testing these relationships. ❐

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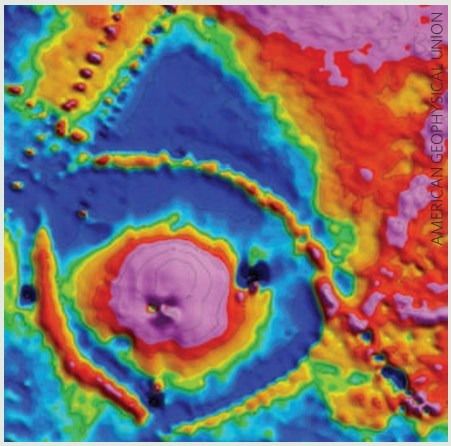
GEOMORPHOLOGY

Crater or not?

Chance physical phenomena can intersect with human civilization in unexpected ways. One such phenomenon is a putative meteorite impact in Italy's Sirente region dated to around AD 400: it has been speculated that the fiery arc traced by the meteorite fragments in the sky was instrumental in triggering a chain of events that eventually led to Christianity displacing pagan beliefs in the Roman Empire.

The primary evidence for an impact in this region is the presence of an approximately 100-metre-wide sag or depression, accompanied by other smaller sags. The morphological attributes and distribution of these features have been considered consistent with crater formation due to a meteorite shower. However, this interpretation is by no means unique. Several features typical of impacts, such as shocked minerals and high concentrations of certain metals, have not been found, and the craters have alternatively been proposed to be mud volcanoes, pits dug by humans or sink holes, that is pit-like features that commonly form when water dissolves lime.

Resolution of the craters' origins requires detailed information about the subsurface structure of the sags, which is now presented by Speranza and colleagues (*J. Geophys. Res.* doi: 10.1029/2008JB005759; 2009).



According to the team, the electrical and magnetic properties of the area's sediments and rocks show unambiguously that none of the crater-like structures were formed by an impact. Furthermore, geological and geochemical data — such as the absence of methane or carbon dioxide reservoirs at depth — rule out a mud volcano origin.

The survey shows that the sags are underlain by a thin sedimentary package that rests on a series of ridges and valleys cut into a limestone substrate. Sediment-filled depressions in the subsurface ridges, indicative of sink holes, underlie many of the smaller sags. The researchers conclude that water seeping through the sediments led to the formation of sinkholes at depth, which ultimately caused the surface to cave in.

The main crater-like feature is now occupied by a lake. Layers of sediments within and underlying this lake show no sign of being disturbed and are more or less horizontal, which is inconsistent with an impact. The properties of these sediments and those surrounding this sag are rather similar and it is therefore unlikely that sediments in the structure represent impact crater fill. Moreover, the magnetic signature of the material at the bottom of the main sag is quite the opposite of what would have been expected for a buried meteorite.

Depressions with a size similar to the main Sirente sag are also found in nearby hill ranges; the researchers have previously proposed that these are man-made. The region's economy has depended on sheep rearing for thousands of years: water flowed from springs and accumulated in these sags, which served as a drinking trough. Speranza and colleagues suggest that the Sirente crater served a similar purpose and is in fact a water reservoir made by humans.

The Sirente sags appear to have been emplaced under far calmer circumstances than a meteoritic impact. Their birth is unlikely to have swung Roman history, but probably helped satisfy many a thirsty lamb.

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