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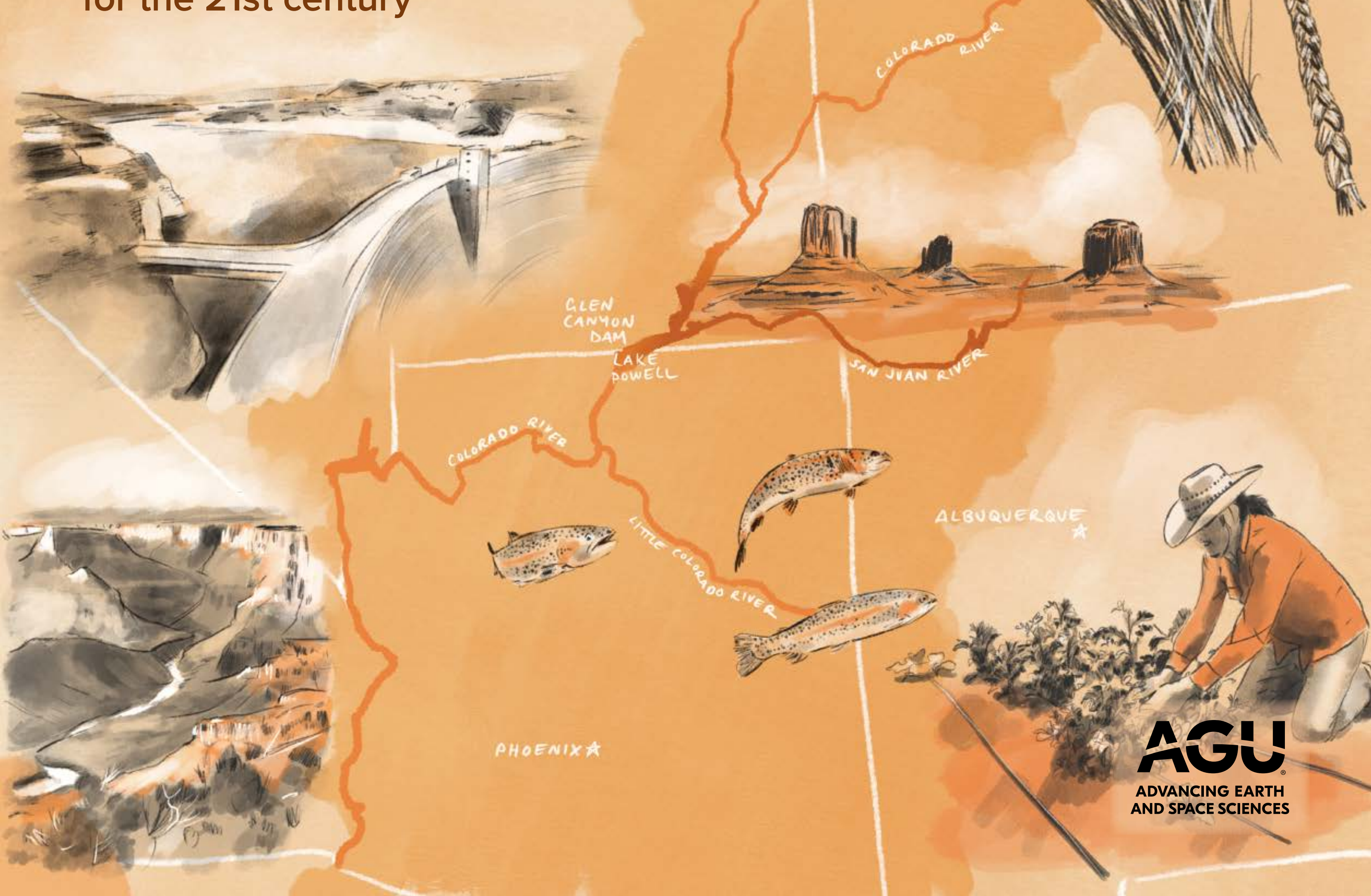

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Creating Crust

To dig into the past, researchers looked at data from thousands of TTG samples from locations around the world where the ancient crust is exposed—including in the Rocky Mountains in Canada. These data are detailed in the GEOROC (Geochemistry of Rocks of the Oceans and Continents) data repository at the University of Göttingen in Germany.

"This is a new idea and quite different from previous models."

Their analysis revealed that the TTGs had a distinctive signature of trace elements—a high ratio of the rare earth element lanthanum to samarium and high levels of europium—that indicated that gabbros were the source rocks, Smit said.

This new understanding enabled the researchers to determine that Archean TTGs had formed at the bases of areas of thickened oceanic plateaus above hot regions of the mantle.

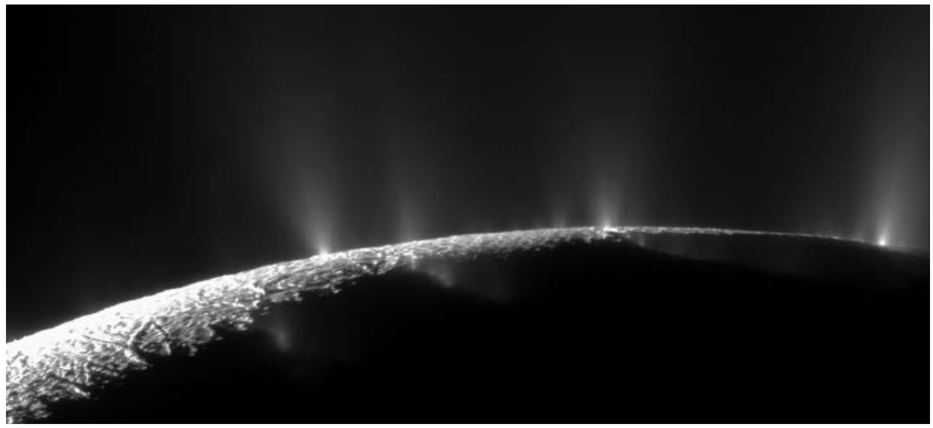
Earlier studies had suggested that Archean TTGs had formed from melting within oceanic plateaus, geochemist Balz Kamber of Queensland University of Technology in Australia wrote in an email. But the new study is the first to identify gabbros as the source.

"The idea had not previously been tested with such a thorough assessment of published geochemical data for TTGs," wrote Kamber, who was not involved in the new study.

Geologist Hugh Rollinson, a professor emeritus at the University of Derby in the United Kingdom who also was not involved in the study, added that he'd like to see a study of areas where such TTGs were exposed on the surface, rather than the latest study's statistical approach to all TTG samples in the GEOROC database. But he stressed that the specific geochemical mechanism proposed in the study was a novel approach to the issue of the formation of Archean TTGs: "This is a new idea and quite different from previous models," he said.

By **Tom Metcalfe** (@HHAspasia), Science Writer

Strike-Slip Faults Could Drive Enceladus's Jets



Jets along Enceladus's tiger stripes regularly eject water, ice, and organic compounds from the moon's subsurface ocean. Credit: NASA/JPL/Space Science Institute, Public Domain

Jets along Enceladus's famous tiger stripes may be punching through the moon's icy shell because strike-slip motion periodically tears the scablike fractures. New research explains how tides between the moon and Saturn force the edges of the stripes back and forth until they split (bit.ly/Enceladus-jets-faults).

Strike-slip motion regulated by tides could govern not just the timing and intensity of Enceladus's jets but also the geological evolution of its south polar terrain, explained Alexander Berne, a geophysics graduate student at the California Institute of Technology in Pasadena and first author on the study.

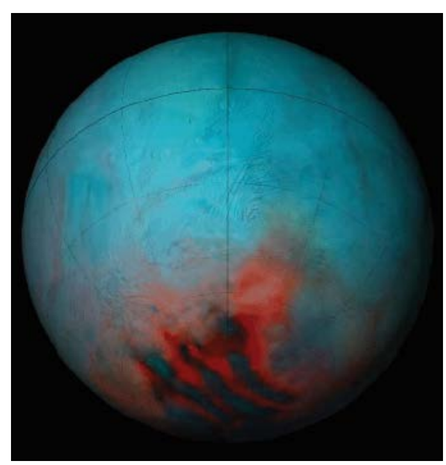
Enceladus's four tiger stripes—named Alexandria, Cairo, Baghdad, and Damascus after locations in *The Arabian Nights*—are roughly 135-kilometer-long fractures in the moon's south polar terrain. Infrared measurements have shown that the stripes are much hotter than their surrounding areas, suggesting the presence of thinner or broken crust or an unknown heating mechanism at those spots.

Images from NASA's Cassini mission revealed intermittent plumes of water, ice, and organic compounds venting from the stripes. The jets are thought to be tapping material from a subsurface ocean.

From Tides to Jets

"Tidal processes have played an important role in Enceladus' evolution, the current presence of a subsurface liquid water ocean, and the spectacular plume activity," explained Sarah Fagents, a planetary scientist at the University of Hawai'i at Mānoa in Honolulu who was not involved with the research. But it has been difficult to explain how tides influence the timing and brightness of Enceladus's jets, she said.

The moon's eccentric 33-hour orbit contracts and stretches the icy crust, but between times of maximum crust stress and when a plume's outflow (and thus its brightness)



This global thermal map of Enceladus shows how the four tiger stripes in the south polar terrain are anomalously hot compared with the surrounding crust. Credit: NASA/JPL-Caltech/University of Arizona/LPG/CNRS/University of Nantes/Space Science Institute, Public Domain intensifies is a 6- to 7-hour lag. Moreover, past simulations have shown that if tidal stress were opening the tiger stripes straight apart, like divergent plate boundaries on Earth, peak jet brightness would occur only once per orbit, but the jets instead peak twice.

To unriddle the mystery, the researchers simulated the tidal forces experienced at Enceladus's south pole, inspired by newer earthquake models. "In the last 20 years, very sophisticated numerical models have been developed to model earthquake sequences on Earth along the San Andreas Fault and other places to try to understand the structure of the crust," Berne said. "We adapted that [approach] for Enceladus."

This work is "exactly the type of tricky modeling work we need to understand a body like Enceladus."

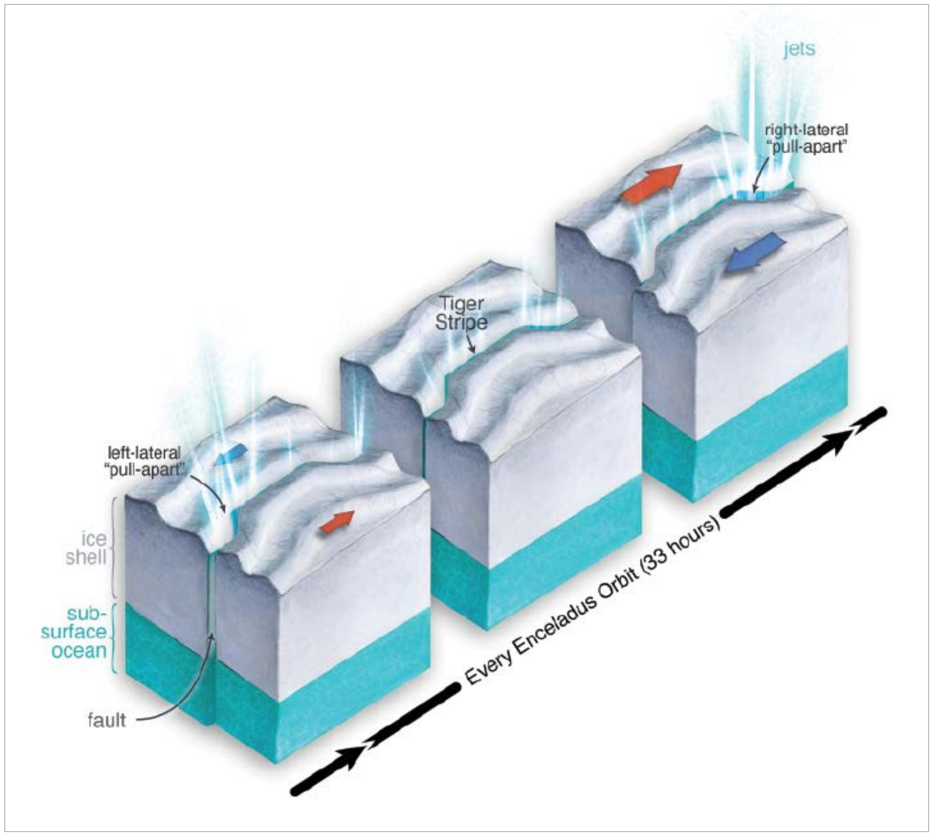
The simulations revealed that for every orbit Enceladus makes around Saturn, the tiger stripes experience two periods of high shear stress from tides. The stress drives strike-slip motion along the two edges of each tiger stripe: Tectonic movement causes blocks of ice to slide past each other, rather than separate or crash together.

Strike-slip motion happened roughly 6–7 hours after the peak tidal stress, matching the lag in observed jet activity. What's more, strike-slip motion occurred twice per orbit, a characteristic of jet activity that other tidal simulations had not been able to replicate.

Fagents found the research "persuasive," adding that "the model elegantly explains a key and puzzling aspect of Enceladus' plume dynamics."

"The work made a compelling case that tidally driven strike-slip motion is broadly consistent with the plume activity," said Miki Nakajima, a planetary scientist at the University of Rochester in New York who was not involved with the research.

The simulation showed that areas that slip more match observed hot spots. "This may be indicating that the strike-slip motion helps open the tiger stripes and encourage heat production," Nakajima said.



Strike-slip motion along faults could be linked to jet activity at Enceladus's tiger stripes. Orbital tides between the moon and Saturn pull the faults back and forth, stressing them and causing strike-slip motion. The regular tension along pull-apart zones allows water to rise and feed material to cryovolcanic jets. Credit: James Tuttle Keane

Geologic Evolution

One curious feature of Enceladus's jets is that one of the outflow peaks is brighter than the other. The new simulation reproduced the asymmetry and suggested that the edges of the tiger stripes tend to slip more in one direction than the other during each orbit. More slipping leads to jets that are more intense.

Berne cautioned that the team has not yet pinned down a mechanism that links the strike-slip activity to jet brightness. The study authors propose that strike-slip motion weakens areas along the stripes that have already been stretched and morphed by tides until they eventually pull apart. They plan to explore this possible mechanism more fully in future work.

This work is "exactly the type of tricky modeling work we need to understand a body like Enceladus," said Hamish Hay, a planetary scientist at the University of Oxford in the United Kingdom who was not involved with the study. "The correlation the authors find between fault activity and plume brightness is very intriguing."

Features such as chasmata, rift zones that radiate like bicycle wheel spokes from the south polar terrain, could also have been created by this asymmetrical motion (bit.ly/Enceladus-south-pole).

"This is how geology is created around tectonic faults, like the San Andreas Fault," Berne said. "Our models, even though they only treat the short-term deformation problem, have implications for the long-term evolution of the south polar terrain."

By **Kimberly M. S. Cartier** (@AstroKimCartier), Staff Writer