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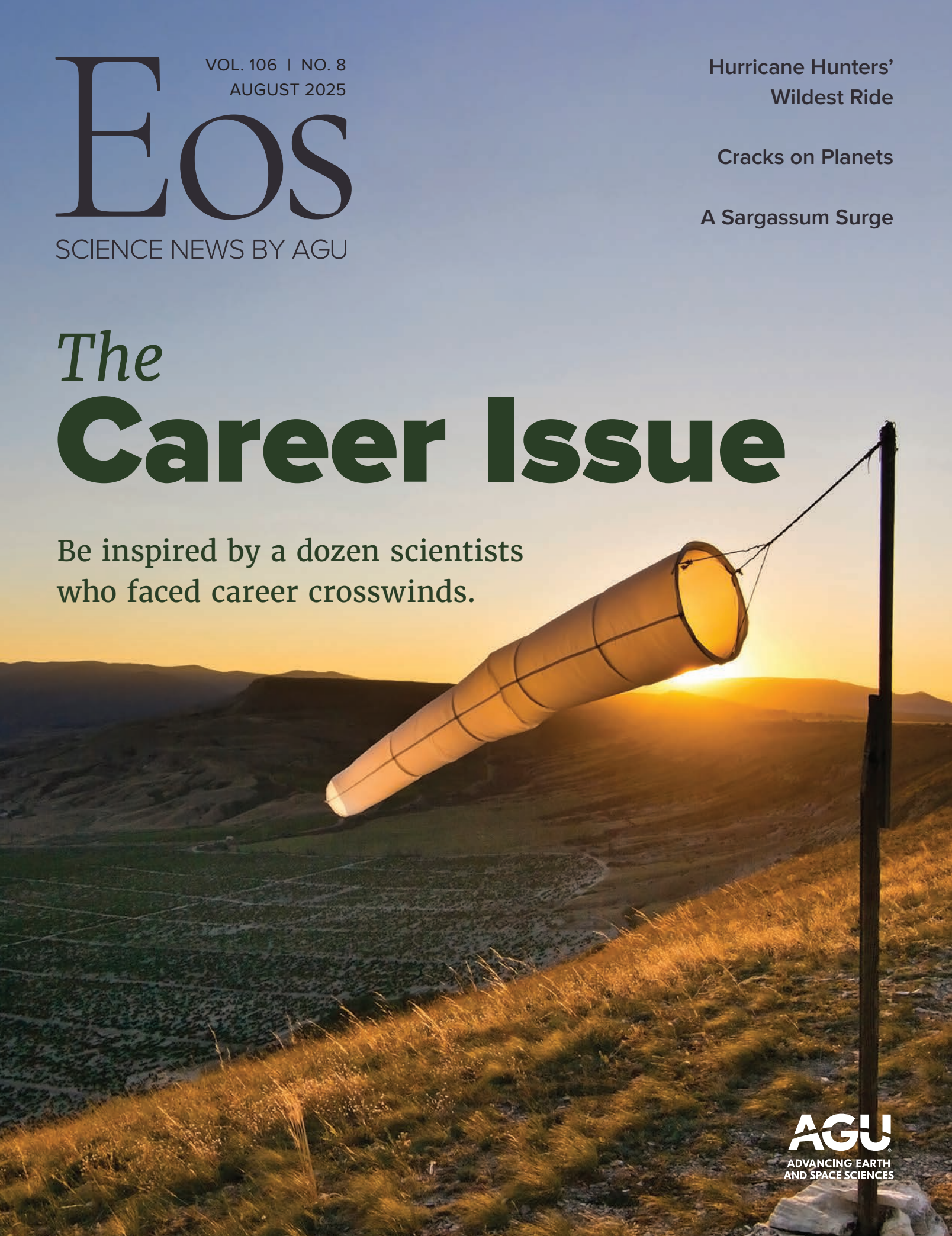

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# Cracks on Planetary Surfaces Hint at Water

*This cracks in this rock slab on Mars known as "Old Soaker" may have formed from the drying of a mud layer. Credit: NASA/JPL-Caltech/MSSS*

From cracking mud to thawing permafrost, fractured terrain is common on Earth and many planetary surfaces. The geometry of those fractures is influenced by the amount of water present and how long it's been around, according to researchers.

A team has now proposed a model to predict the evolution of fractured terrain through time. These new findings could be used to unravel the history of water on other worlds.

**"From the moment that materials solidify, they start falling apart."**

Since the 1960s, scientists have pored over hundreds of thousands of solar system images beamed back from spacecraft and landers. "The amount of data coming in is overwhelming, and it is mostly pictures," said Gábor Domokos, an applied mathematician at the Budapesti Műszaki és Gazdaságtudományi Egyetem in Hungary.

Many of those images show a process now known to be ubiquitous across the solar system: disintegration.

"From the moment that materials solidify, they start falling apart," said Doug Jerolmack, a geophysicist at the University of Pennsylvania in Philadelphia. The study that Domokos and Jerolmack and their respective graduate students Krisztina Regős and Sophie Silver recently published in the *Proceedings of the National Academy of Sciences of the United States of America* (bit.ly/planetary-cracks) reflects that sentiment in a poetic first line: "Things fall apart."

The researchers analyzed images of fractured terrain on Venus, Mars, and Jupiter's moon Europa and manually traced fractures visible in each. They focused on 15 images: 4 of Venus, 9 of Mars, and 2 of Europa.

From above, the fracture networks look like mosaics of convex polygons. Those polygons can be characterized by simple geometric properties, including their number of vertices and the number of cracks that meet at each of those vertices (or "nodes"). The team did just that, and there was nothing particularly complicated about that work, Domokos said. "We are just counting."

Of the more than 13,000 nodes that the researchers tabulated, more than 95% consisted of the meeting of two, three, or four cracks. Previous work in geomorphology has referred to those intersections as T, Y, and X junctions, respectively, on the basis of the letters that they often resemble.

## Three Letters, Three Processes

T junctions were the most prevalent in the imagery. That result is consistent with investigations of fractures on Earth and is not surprising, Jerolmack said, because these junctions form from a basic process in which a newer crack runs into an older crack and stops. "This is the most common pattern of something that just breaks and breaks and breaks," Jerolmack explained. A mud plain that was once wet and then dried over time would be dominated by T junctions.

Y junctions, on the other hand, were less common and tended to occur in landforms that had experienced alternating periods of drying and wetting, the team showed. Laboratory results support that finding: In 2010, another research group published time-lapse photography of clay undergoing repeated cycles of drying and wetting and uncovered T junctions evolving into Y junctions.

The propagation of a crack through partially, but not fully, healed T junctions tends to produce rounded corners, said Lucas Goehring, a physicist at Nottingham Trent University in the United Kingdom and the lead author of the 2010 study. "Over time, that corner will be dragged into a shape that is like a Y."

Although Y junctions do not necessarily imply the presence of water—these features also form in basalt columns, for instance—they hint that a landscape might have experienced a sustained presence of water, according to the researchers.

X junctions proved to be the rarest of the three. The team spotted X junctions—in which a newer crack runs right through an older crack—only on Europa. "Normally, a crack cleanly separates two surfaces," Goehring said. But an X junction is evidence that a previous crack healed, thereby allowing a younger crack to propagate across it largely unimpeded. "It's behaving as if that old crack isn't there," Jerolmack said.

Water ice is one such material that heals itself, and Europa is known to be covered in a shell of the stuff. The existence of X junctions implies the presence of frozen water, the researchers concluded.

## Making Movies

Domokos, Jerolmack, and their students next constructed a geometrical model of fracturing. The goal was to develop mathematical

expressions encoding the physical processes involved in forming T, Y, and X junctions and then, on the basis of a single image of a planetary surface, model how an ensemble of fractures would evolve over time.

Playing such a movie back might reveal something about the geological processes underlying crack formation, Domokos said. That's powerful for understanding not only our own planet but other worlds as well. "We don't have these kinds of movies, not even on Earth."

**"We don't have these kinds of movies, not even on Earth."**

The researchers showed that their model could accurately reproduce the entire range of fracture mosaics they observed. That's critical to verifying the utility of this model, Jerolmack said. "We built a toy model of the universe of fracturing. The actual universe of crack patterns seems happy to comply."

Testing this model will require more experimental data showing how real fractures evolve, however, Goehring said. Collecting such data isn't technically challenging, but it can be laborious: Goehring and his team spent several months observing how clay fractured in response to 25 cycles of drying and wetting. "It's quite a tedious experiment to do," he said.

But such a model could shed important light on the solar system's past, said Nina Lanza, a planetary scientist at Los Alamos National Laboratory in New Mexico who was not involved in the research. For instance, getting a handle on whether water persisted somewhere for a long time says something about the geological environment, she said. "Now we're getting a more complex picture of a planet over time."

Domokos, Jerolmack, and their students analyzed all of their fracture mosaics manually. However, future investigations could rely on artificial intelligence and machine learning, which would make it possible to probe thousands of fracture mosaics rather than just a handful.

By **Katherine Kornei** (@KatherineKornei), Science Writer

# Have We Finally Found the Source of the "*Sargassum* Surge"?

*A boat floats atop an inlet covered in brown Sargassum seaweed off the coast of Micoud, Saint Lucia. Credit: JD*

Since 2011, massive mats of golden-brown seaweed—pelagic Sargassum—have repeatedly swamped the shores of the Caribbean, West Africa, and parts of Central and South America. These sprawling blooms have suffocated coral reefs, crippled tourism, and disrupted coastal life.

What caused this sudden explosion of seaweed in regions that had rarely experienced it before?

A modeling study published earlier this year in *Nature Communications Earth & Environment* offers one possible explanation (bit.ly/Sargassum-surge-cause). It links the start of this phenomenon to the 2009–2010 North Atlantic Oscillation (NAO)—a rare climatic event involving stronger-than-usual Westerlies and altered ocean currents.

According to the study, NAO conditions transported *Sargassum* from its historic home in the Sargasso Sea in the western North Atlantic into tropical waters farther south, where nutrient-rich upwellings and warm temperatures triggered the algae's explosive growth.

### Migrating Macroalgae

Julien Jouanno, senior scientist at the Institut de Recherche pour le Développement and head of the Dynamics of Tropical Oceans team at Laboratoire d'Etudes en Géophysique et Océanographie Spatiales in Toulouse, France, led the modeling work behind the study.

"Our simulations, which combine satellite observations with a coupled ocean-biogeochemical model, suggest that ocean mixing—not river discharge—is the main nutrient source fueling this proliferation," Jouanno explained. The model incorporates both ocean circulation and biological processes like growth and decay, enabling the team to test various scenarios involving inputs such as ocean fertilization by rivers (such as the Amazon) or influxes of nutrients from the atmosphere (such as dust from the Sahara).

"Turning off river nutrients in the model only reduced biomass by around 15%," said Jouanno. "But eliminating deep-ocean mixing caused the blooms to collapse completely. That's a clear indicator of what's actually driving the system."

"When we exclude the ocean current anomaly linked to the NAO, *Sargassum* stays mostly confined to the Sargasso Sea," Jouanno said. "But once it's included, we start to see the early formation of what is now known as the Great Atlantic Sargassum Belt."

But not all scientists are convinced by the study. Some argue the truth is more complex, and more grounded in historical ecological patterns.

### Was the Seaweed Already There?

Amy N. S. Siuda, an associate professor of marine science at Eckerd College in Florida