When continents try, and fail, to break apart

February 4 2026, by Jorge Salazar

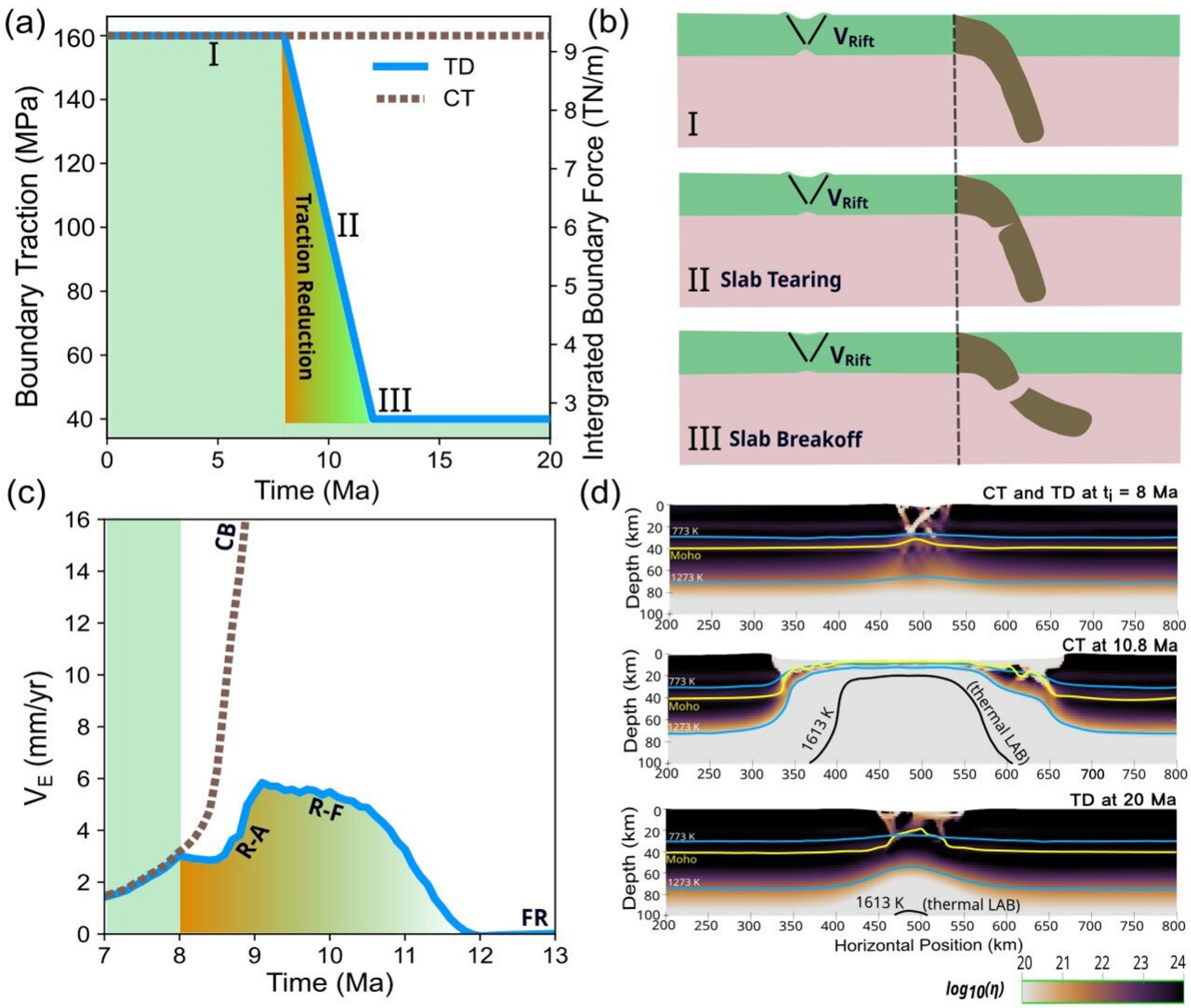


Figure (a) Designed time dependent boundary traction depth integrated tractions for model. (b) Modeled slab dynamics. (c) Half extensional velocities for two models; CT model accelerates towards continental breakup (CB). (d) Model evolution at different time stamps. Credit: *Scientific Reports* (2025). DOI: 10.1038/s41598-025-19691-3

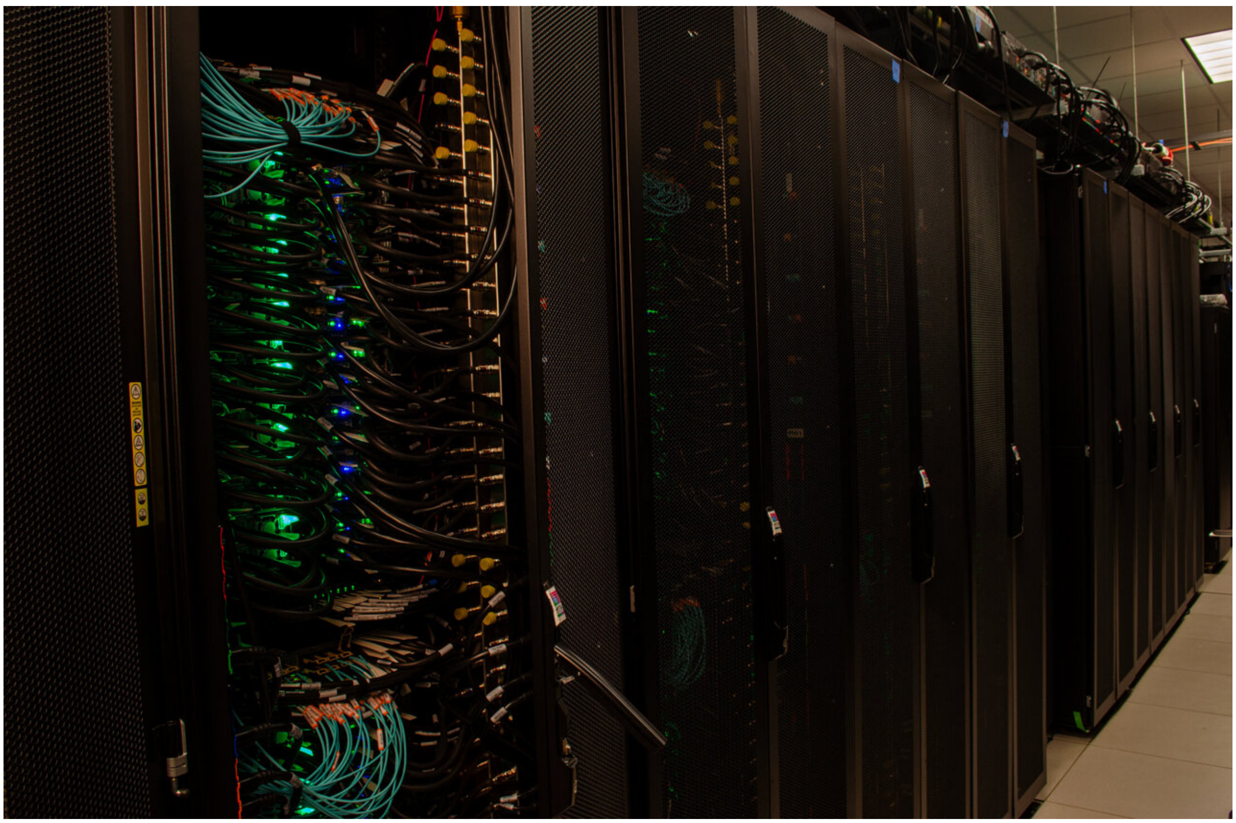
Great things can come from failure when it comes to geology. The Midcontinent rift formed about 1.1 billion years ago and runs smack in the middle of the United States at the Great Lakes. The rift failed to completely rupture, and had it succeeded it would have torn North America apart. Under immense pressure from receding tectonic plates, the weakened lithosphere instead created a basin in the crust eventually filled by Lake Superior, and it also exposed a 3000-km-long band of deeply buried igneous and sedimentary rocks.

Long a mystery, the details of rift failure are becoming clearer thanks to U.S. National Science Foundation (NSF) ACCESS-allocated supercomputer simulations on the Texas Advanced Computer Center's (TACC) Stampede3 system by a pair of University of Memphis scientists. Their findings could help understand rift failure in other parts of the world with applications in renewable geothermal energy, rare earth minerals, and more.

"Our main finding is that we can understand the rift systems losing driving forces in terms of three parameters: how much the driving force is reduced, how fast it is reduced, and how mature the rift is when it starts losing its driving force," said Kuruvitage Chameera Silva, a Ph.D. student at The University of Memphis. He co-published a study in *Scientific Reports* with his advisor Eunseo Choi, who leads the Geodynamics Research Group at the Center for Earthquake Research and Information.

"By running numerous numerical models while varying those three parameters, we could map out exactly when continental extension continues to full breakup, and when it fails," Choi added.

"The NSF ACCESS program plays a vital role in making supercomputing resources broadly available to researchers across the United States," Silva said. "These supercomputer allocations provided me, as a student researcher, with the high-performance computing resources necessary to conduct the high-resolution continental rifting simulations central to this study, work that would have been impossible on local machines."



TACC's Stampede3 supercomputer is an NSF-funded ACCESS-allocated national strategic resource utilized by thousands of scientists. Credit: TACC

Supercomputing continental rifts

The scientists used TACC's Stampede3 supercomputer to simulate what happens when a tectonic plate is pulled from the sides. Rather than prescribing a fixed velocity, they applied more realistic force boundary conditions that evolve over the millions of years modeled. They also used HPC resources at The University of Memphis Computational Infrastructure for Geodynamics.

The numerical models were made using the geodynamic code ASPECT that accounted for both the driving forces of the pulling that stretches the rift zone and the gravitational energy gradient, and the resisting forces of lithospheric cooling, rift strength, and mantle drag.

"This is the first study that successfully implemented the force-boundary-driven continental extension models in the ASPECT code," Silva said.

ASPECT developers helped the team simulate the tensional tectonic settings, where each 2D model needed 128 cores or about three nodes to run over a period of two days to get a model simulation time of 20 million years. The published manuscript has 23 models.

"The Stampede3 supercomputer proved to be an excellent platform for this work, and ASPECT is well tested on its architecture. The installation was straightforward, and the system delivered strong parallel performance with reasonable queue times," Silva said. "This allowed me to run model suites, parameter sweeps, and complex rheology efficiently, greatly accelerating the pace of the research."

Beyond raw computing power, the NSF ACCESS initiative also helped Silva develop essential HPC skills including writing SLURM scripts, managing parallel workloads, and optimizing large-scale simulations. "The clear documentation and user support ensured I could focus on scientific objectives rather than technical obstacles," he added.

Below the surface

As a tectonic plate stretches, it becomes thinner and weaker. If the driving force is not enough to stretch the lithosphere, it cools and thickens. Whether a rift keeps spreading, eventually splitting a continent apart, or stops in the middle of making one main valley depends on the competition between the weakening forces and strengthening forces. The rift's fate is determined by how quickly the plate weakens compared to how strongly it's still being pulled apart.

A significant reduction in driving force stops rifting and results in no continental breakup, and with a small reduction, rifting is affected little, proceeding to continental breakup. A surprise in the study results, however, was that when the driving force decreases very slowly, it will have enough time to mature the rift, promoting continental breakup. Also, the more mature a rift gets, the weaker it becomes. Thus, a continental rift is more likely to complete breakup if it starts losing the driving force at a sufficiently late stage of shifting.

This new research helps the larger scientific community by connecting deep Earth dynamics with surface evolution in a quantitative, testable way. It shows how changes in stress, heat, and lithospheric structure lead to the diverse rift behaviors we see around the world—from successful ocean-forming rifts to long-lived failed rifts.

"Supercomputers let us 'see' processes inside Earth that we can never observe directly, deep underground and over millions of years," Silva said. "By recreating them in high-resolution simulations, we can test ideas, explore what-if scenarios, and better understand natural hazards and how continents evolve."

More information: Kuruvitage Chameera Chathuranga Silva et al, Continental rifts losing driving forces can still complete breakup, *Scientific Reports* (2025). DOI: 10.1038/s41598-025-19691-3

Provided by University of Texas at Austin