
MG
ES
SP
RJ
PR
SC
RS
1.300 km
Rio Grande
Rise

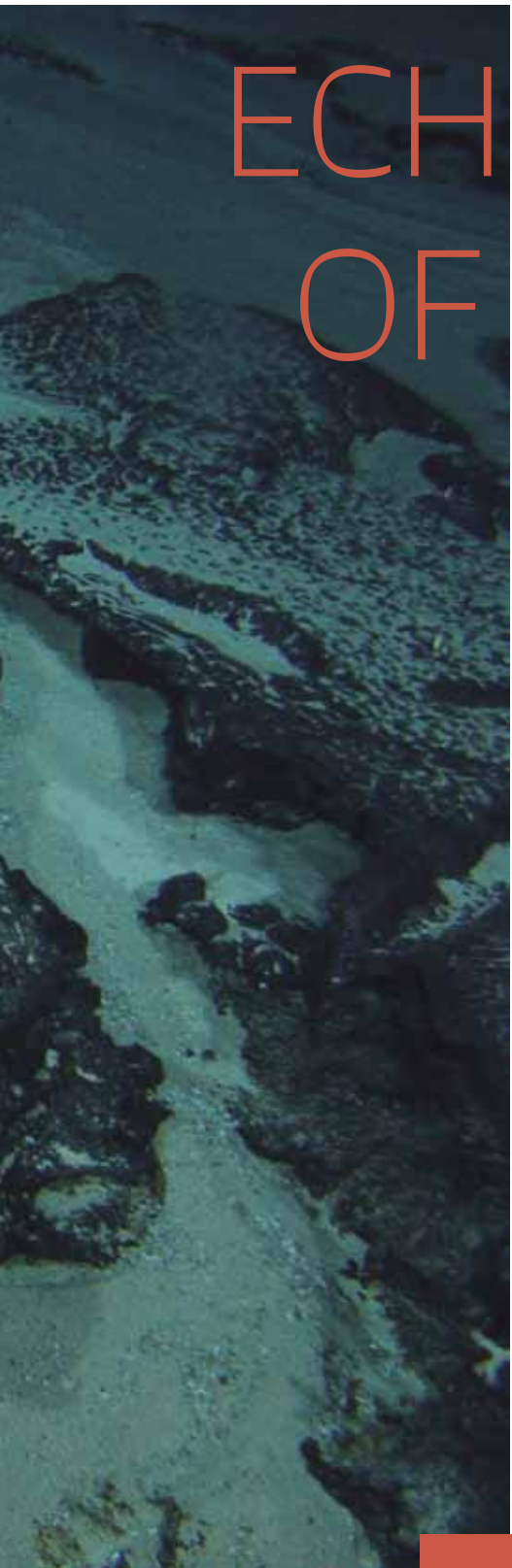


PHOTO JAMSTEC MAP SANDRO CASTELLI

The Rio Grande Rise: now, fragments of a continent

ECHOS OF SEPARATION

Great blocks of rock from different ages and origins combined to form the South Atlantic margins

Carlos Fioravanti

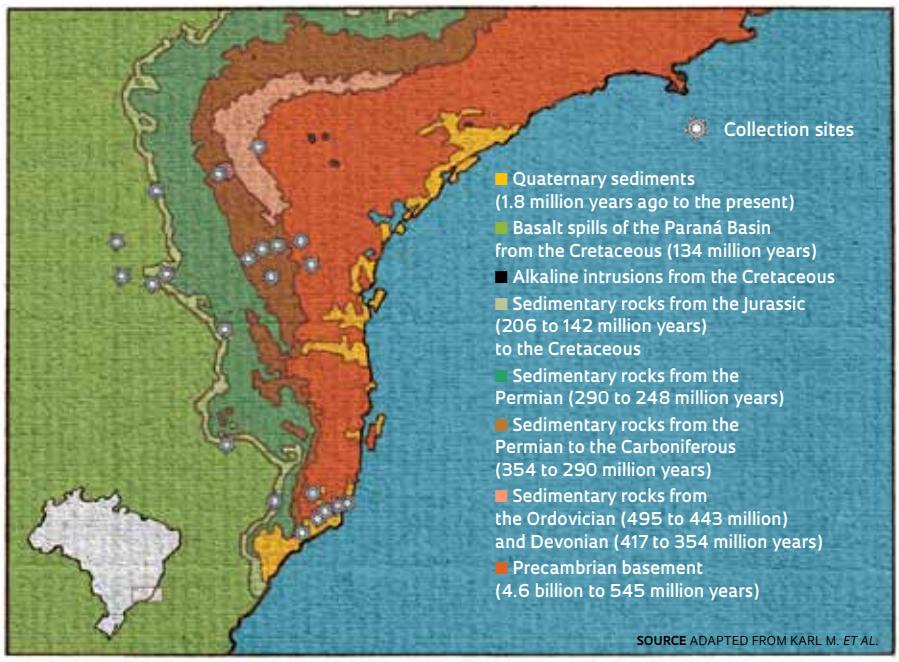
PUBLISHED IN OCTOBER 2014

No, it wasn't a mistake. In 2011, geologists collected samples of granite, a type of continental rock, from the Rio Grande Rise, a chain of submerged mountains approximately 1,300 kilometers (km) off the coast of the state of Rio Grande do Sul. Scientists had thought that these mountains were the result of formation of the ocean floor and volcanic eruptions and that they therefore were composed of a different type of rock. Two years later, using a submersible craft, researchers collected additional samples of continental rock, and the resulting analysis supported the hypothesis that this region of the South Atlantic was actually a piece of a continent submerged when South America and Africa separated—a process that began 120 million years ago.

This finding is economically valuable for the Rio Grande Rise. In July 2014, the Brazilian government received the green light to implement its plan to explore cobalt deposits in the region, which lie in international waters; hence, finding reserves of other minerals, such as nickel, manganese and rare earths, has become more likely. The scientific value of the formation has also increased inasmuch as it offers additional arguments supporting the hypothesis that the separation of South America from Africa is a more fascinating and complicated process than earlier thought. Geologists from Brazil, the United States, Germany and France met in Rio de Janeiro in April 2014 and concluded that the great blocks of rock, or microplates, that composed the two continents and seabed did not separate like two parts of a torn sheet of paper; rather, the continents stretched out, broke apart and were chaotically repositioned. Certain portions may have been repositioned in the middle and submerged, while others separated and combined, forming an immense mosaic that is now becoming clearer.

Researchers believe that rocks collected from the Rio Grande Rise—granites, granulites, gneisses and pegmatites—are 500 million to 2.2 billion years old, according to analyses conducted by teams from the University of Brasília and the Geological Survey of Brazil (CPRM). "The ages are not outside what we usually find in South America and Africa," says Roberto Ventura Santos, director of

Rocks of many ages



SOURCE ADAPTED FROM KARL M. *ET AL.*

geology at CPRM. Ventura says that the seismic uplifts indicate that the thickness of the crust in this area is nearly 30 km, "typical of continental rather than oceanic crust," further supporting the theory that it is a part of a continent.

This discovery, one of the most spectacular in Brazilian geology in recent times, has raised a number of questions. According to earlier thinking, the two mountain chains in the South Atlantic—the Rio Grande and the Mid-Atlantic Ridge—formed during the same period, but now scientists think that this may not be the case. In addition, what are the effects of the Rio Grande Rise? A chain of mountains 3,200 meters high at the bottom of the South Atlantic, the top of which is only 800 meters beneath the surface of the ocean, should create barriers to ocean circulation, but researchers do not understand the underlying mechanism. Ventura believes that analysis of a 70-meter column of sediment from the seabed will provide some answers, which he hopes will enable reconstruction of the climatic and geological phenomena of the past seven million years.

Effects of uplift after the opening of the Atlantic: valley of a river in West Central Angola with rocks formed 2 billion years ago...

"The identification of continental rocks from the Rio Grande Rise changes the evolutionary picture of the South Atlantic, which was formed by the break-up of the two continents," explains geologist Peter Christian Hackspacher, a professor at São Paulo State University (Unesp) in Rio Claro. Some 20 years ago, when doing field research in southeastern and southern Brazil, Namibia, and Angola, he studied signs of possible forces that led to the separation of South America and Africa. His findings support the traditional model, in which the coastlines of the two continents, representing the blocks of rock that formed them, fit together. The coastline of northeastern Brazil fits with that of West Africa, but in other regions, such as the coast of Rio de Janeiro State, parts appear to be missing from the jigsaw puzzle of rocks.

SERRA DO MAR REJUVENATED

The blocks of rock that once made up a single continent fragmented and aligned with older or newer blocks to form the mountainous region of southeastern Brazil and West Africa, concludes Hackspacher, whose research is carried out in collaboration with teams headed by Ulrich Glasmacher in Germany, Antonio Olímpio Gonçalves in Angola and Ana Olívia Magalhães at the Federal University of Alfenas in the state of Minas Gerais. Contrary to expectations, older blocks—such as the Mantiqueira and Bocaina mountain ranges, which were uplifted 120 million years ago—are in the continental interior, and more recent blocks that are 35 to 20 million years old are on the margins, such as the coastline between the states of Paraná and Rio Grande do Sul (*see map*).

"I'm not discovering the wheel, I'm just measuring by using other techniques," he says, acknowledging the conceptual baselines offered by professors at the University of São Paulo (USP), such as Fernando Almeida, Umberto Cordani and Benjamim Bley Brito Neves, who had already recognized that

South America was formed from microplates of rocks of different ages and varied origins (see Pesquisa FAPESP Issue No. 188). Claudio Ricommini, also from USP, challenged the customary view of the continent's formation somewhat further when he ascertained that the age of rocks from the Taubaté sedimentary basin was between 33 million and 55 million years—far from the 120 million years that had been hypothesized because of their proximity to the coastline.

Almost 10 years ago, with equipment on hand to measure the age and temperature variation of rocks according to depth—the lower the temperature, the closer to the surface and the more recent the rock is—Magalhães proposed to Hackspacher, her thesis advisor at the time, that they examine the ages of rocks distant from the coast in southern and southeastern Brazil. They started from the assumption that older and more recent blocks of rock rise and sink and become exposed on the surface in an alternating manner. From there, "It was possible to develop very good, geologically consistent findings with a reasonable degree of statistical reliability about the processes responsible for the crustal uplift of the Serra do Mar and Mantiqueira ranges," she says. In a series of "spectacular discoveries" (Hackspacher's description), they found blocks of rock, uplifted 60 to 90 million years ago, that did not fit the classic model of the formation of South America separation from Africa.

Hundreds of measurements led to conclusions that are helping scientists break down old notions. One example is the probable age of the Serra do Mar, a mountain chain that stretches for nearly 1,500 km along the Brazilian coast, between the states of Espírito Santo and Santa Catarina. "Until 10 years ago, when we began to zone in on the problem and challenge some of the assumptions about the geological evolution of the South Atlantic," Hackspacher says, "everyone understood that the Serra do Mar was formed 120 million years ago. But now we are seeing that the chain is only 35 million years old and is not a consequence of the continental separation."

The fact that the Tietê River flows westward is an indication of a more recent geological phenomena. According to Hackspacher, if the range had formed 120 million years ago, the river would probably flow toward the ocean rather than inland. Today, the most widely probed hypothesis is that this mountain chain resulted from the formation of the Andes, beginning about 60 million years ago, which may have generated large waves that affected the topography, creating depressions such as the Pantanal wetlands in the state of Mato Grosso and peaks such as the Mantiqueira and Serra do Mar. "I don't find it hard to accept that possibility, but there is not yet sufficient evidence," he says.

Hackspacher and his colleagues are seeing similar phenomena in Namibia and Angola. In research conducted in June 2014 that complements the land-based surveys, a German oceanographic vessel recorded signs of rock plates near the coast of Namibia that are similar in age to the Rio Grande Rise. ■

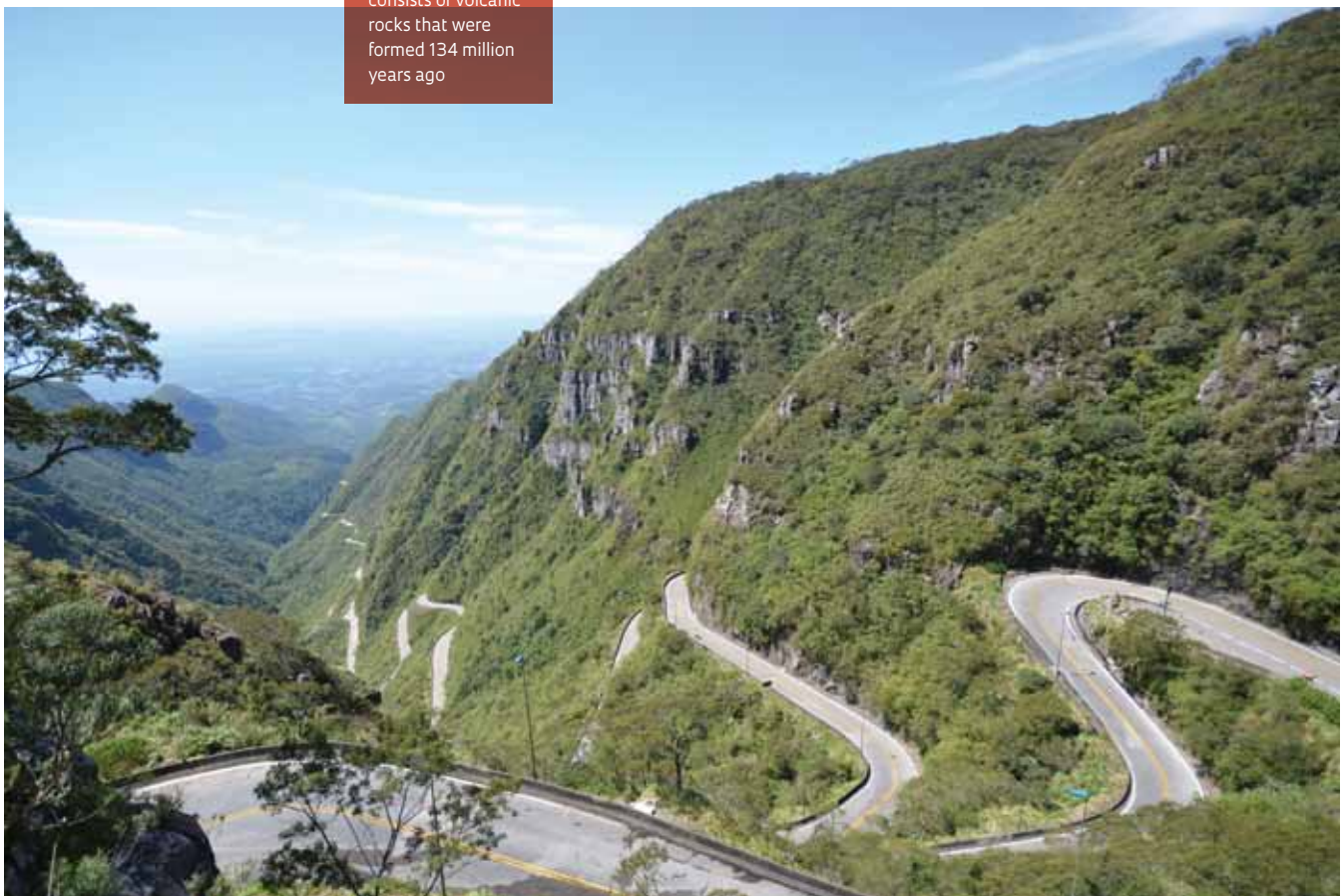
Project

History of exhumation of the South American platform in Southeastern Brazil: thermochronology by fission track analysis and ar/ar and sm/nd systematics (Nº. 2000/03960-5); **Grant mechanism** Thematic project; **Principal investigator** Peter C. Hackspacher (Unesp); **Investment** R$1,282,335.65 (FAPESP).

Scientific articles

KARL, M. *et al.* Evolution of the South Atlantic passive continental margin in southern Brazil derived from zircon and apatite (U–Th–Sm)/He and fission-track data. **Tectonophysics**. V. 604, pp. 224-44. 2013.

SALOMON, F. et al. Major paleostress field differences on complementary margins of the South Atlantic. **EGU** 13, p. 10894. 2013.



... and the Florianópolis-São Joaquim road, which crosses the Rio do Rastro mountain range in the state of Santa Catarina and consists of volcanic rocks that were formed 134 million years ago

PHOTOS PETER C. HACKSPACHER/UNESP **ILLUSTRATION** SANDRO CASTELLI