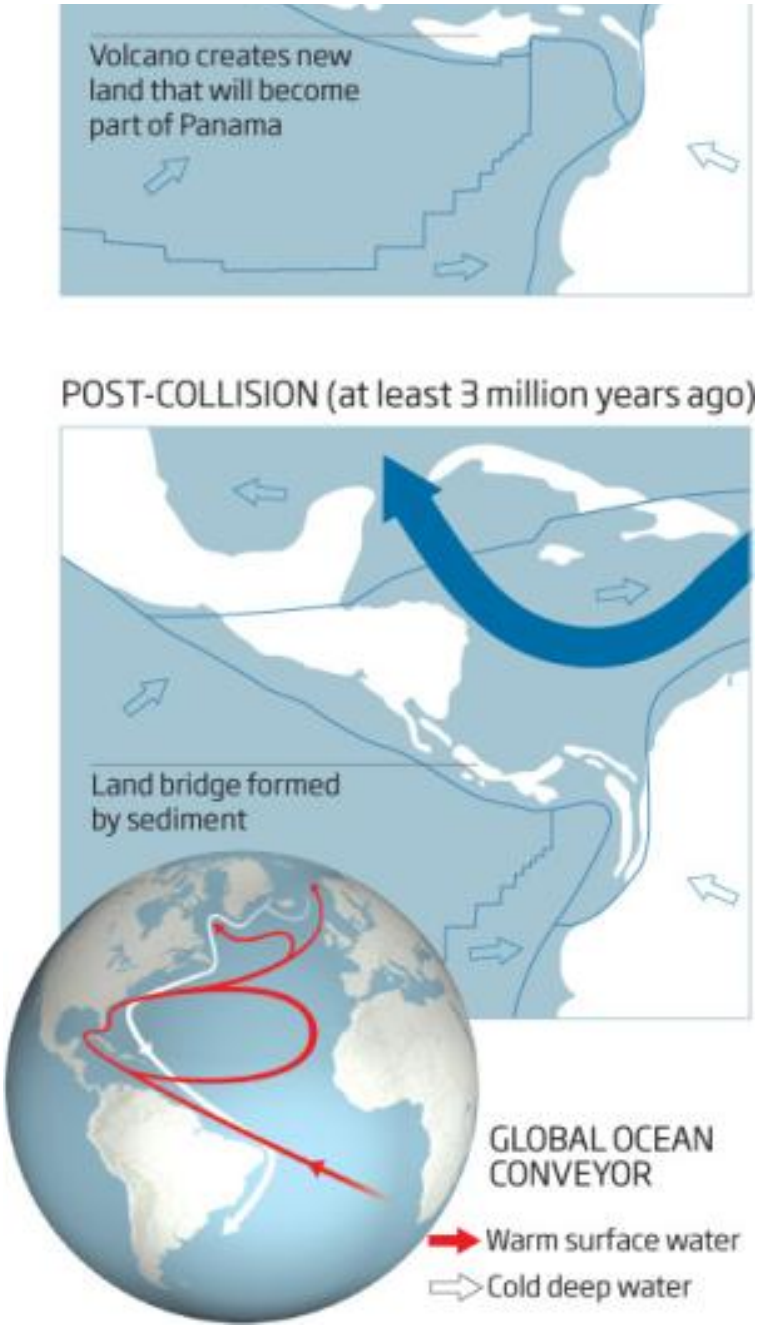
# United plates of America: The making of a new world

08 June 2011 by **Gaia Vince**
Magazine issue 2816. **Subscribe and save**




Closing the gap

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*The collision of North and South America changed the Earth's climate dramatically – and may have happened far earlier than we thought*

THERE'S something rather impressive, and a little surreal, about watching a container ship glide through a mountain, but here in Panama it's an everyday sight. Around 15,000 ships pass through the famous canal each year, slicing through an isthmus that changed the world.

It took the builders of the Panama canal more than 10 years to blast their way across Central America, but their efforts were worth it. Before the canal was opened in 1914, ships passing between the Atlantic and Pacific had to make the treacherous journey around Cape Horn. The canal cut journey times in half, saved countless lives and helped establish the global system of trade that underpins the modern world.

A few million years earlier in the same area, an event of even more lasting significance took place - this time driven by the closing, rather than the opening, of a waterway.

Go back 20 million years and the world was a very different place. Though plate tectonics had arranged the continents pretty much as they are now, there was one crucial difference: North America and South America were separated by a deep ocean channel, the Central American Seaway.

The closure of that channel by the land bridge we know as Panama was one of the most important geological events of the past 65 million years. It had major effects on the world's oceans, climate and biology, and perhaps even triggered the evolution of humans. Now, palaeontologists working close to the canal have found evidence that dramatically changes our understanding of that continental collision. If confirmed, it will do more than upset geologists: it alters our understanding of what drives the world's climate, with important implications for predictions of global warming and its consequences.

The orthodox account of the rise of Panama was pieced together in the 1980s by geologist Tony Coates of the Smithsonian Tropical Research Institute (STRI) in Panama City. It begins with a series of volcanic eruptions that formed an archipelago to the south-west of the Central American Seaway, on a small tectonic plate called the Caribbean plate. As this plate drifted north and east, the archipelago entered the seaway, partially closing the gap. That was about 4 million years ago, and by 3 million years ago, following tectonic uplift and an accumulation of sediments, the two great continents had become linked by a land bridge - what we now know as Panama (see map). It changed the world.

This closure of the Central American Seaway separated the Pacific and Atlantic Oceans, completely changing ocean circulation patterns. With the seaway closed, the waters of the two oceans could no longer mix and their salinity began to diverge. Water evaporating from the Atlantic was carried west by trade winds and fell as rain into the Pacific, making the Atlantic saltier and the Pacific more dilute. This salinity gradient set in motion the giant oceanic loop that drives our modern climate system.

At the same time, warm Atlantic currents that previously flowed through the gap were deflected north, creating the Gulf Stream. This is thought to have tipped the world into the current glacial period - 23 ice ages and counting - and led directly to the formation of the Arctic ice cap. It also "reset" rainfall patterns, creating the African savannah that is credited with attracting our ancestors down from the trees. Quite a lot for a little spit of land.

Locally, it was a crazy time. Weird and wonderful creatures that had evolved in isolation in South America - sloths, marsupials, porcupines, anteaters and armadillos - were able to

spread into North America. At the same time, North American animals - pigs, dogs, sabretooth cats, camelids, horses and elephants - went the opposite way. Their migration was far more successful. Much of South America's native fauna was wiped out and animals of North American origin can still be found all the way down to Patagonia.

### Dig for your life

Every land animal that made the transcontinental journey had to traverse an isthmus that in parts is just 80 kilometres wide. That makes Panama a palaeontologist's dream - and now is the perfect time to explore it because the Panama Canal Authority is midway through a widening project that is exposing new deposits rich with fossils. For the first time, sites older than the established 3-million-year collision date can be explored, right down to the volcanic bedrock. But time is short: the researchers have got about a year left before canal water drowns the past forever.

Taking full advantage of this opportunity to delve into the deep past of Central America is Carlos Jaramillo, a Colombian scientist with unusual energy and drive. Based on the evidence he and his team at the STRI have unearthed in the past couple of years, they conclude that the Americas crashed into each other not 3 million years ago, but up to 22 million years ago - some 19 million years before the birth of the Arctic ice cap.

To say that this is controversial is an understatement. "Jaramillo will run his flag up the pole and some will salute it and some will burn it," says Coates. "It's a fascinating finding, if he's right, but it's going to cause a furore."

First, Jaramillo has to confront several lines of evidence that point to the conventional closure date of around 3 million years ago. For example, sloth bones and droppings are seen in the North American fossil record from that time, but not before. Fossil evidence from the Caribbean points the same way.

One effect of the gap closing was to cut the Atlantic off from a huge upwelling of cold, nutrient-rich deep waters along the Pacific coast of the Americas. This created the warm, clear and nutrient-poor Caribbean we now know, and marine palaeontologists see a massive crash in biodiversity around the Caribbean 3 million years ago. Around the same time, coral diversity changed, with species favouring clear, warm waters increasing and those that prefer churned-up nutrients declining.

"Caribbean biodiversity is now remarkably poor for a tropical ocean. There were twice as many coral species before the isthmus formed," says marine palaeoclimatologist Aaron O'Dea, also at STRI. "What we are seeing, I think, are the effects of a mass extinction."

Perhaps the most compelling piece of evidence for the conventional date is provided by the glaciation of the Arctic around 3 million years ago, which is generally believed to have been triggered by the emergence of the Gulf Stream. Though it seems counter-intuitive that warm water surging north could have led to the formation of ice sheets in the Arctic, the logic is clear. The Gulf Stream delivers an otherwise missing ingredient for ice-cap

formation: moisture. Warm water evaporates and falls as rain or snow, either directly into the Arctic Ocean or indirectly via Siberia's great rivers, diluting the sea water and allowing ice to form at relatively mild temperatures. Once the ice cap grew, it reflected heat back into the atmosphere, further cooling the polar zone.

That's the accepted theory. But if Jaramillo is right then the Arctic freeze may be unconnected to the Gulf Stream and we may have to work out an entirely new scenario for how the ice cap formed. That raises important questions about the future as well as the past. How the current melting of the glaciers in Greenland will affect the Gulf Stream - and vice versa - becomes even less predictable.

Such ifs and maybes hinge on Jaramillo being right. So what's the evidence? "When Tony Coates did his study, he didn't have the fantastic site exposures or the technologies we have now. He was really starting from scratch," Jaramillo says. "Tony was only able to look at sediments on top of the volcanic bedrocks and date them from remains found there. But we are now able to look at the volcanic rocks themselves."

Using a tool called thermochronology, Jaramillo's geologist colleague Camilo Montes has been able to date the major uplift created by the collision between the Caribbean plate, carrying the beginnings of Panama, and the South American plate. "We can see that signal, dated at 22 to 25 million years ago, everywhere from our canal site to Colombia." says Montes.

### Magma rising

The technique relies on the fact that volcanic rock is created by magma rising from a chamber and then cooling, causing crystals to form and then crack. Once you know at what temperature a particular crystal, say zircon, cracks, it is possible to use the cracks to calculate how many years ago it was raised by an eruption or continental collision.

Another new technique also places Panama and South America in close proximity 20 million years ago. Sediments can now be dated and traced back to the mountains from which they eroded, sometimes hundreds of kilometres away. Using this "provenance" technique - which relies on measuring ratios of elements such as uranium and lead - the team has traced 20-million-year-old sediments found near Cartagena, on Colombia's Caribbean coast, back to their roots. "It is clearly from a mountain in Panama being weathered 20 million years ago," Jaramillo says. "The sediment could only have reached Cartagena if the Panamanian rock was close enough - less than 150 kilometres away."

Perhaps the most persuasive evidence for the earlier collision comes from the canal excavations: remains of distinctly South American animals and plants dating from 22 million years ago. "We've found many animals, including freshwater crocodiles, river turtles and snakes," Jaramillo says. "We are still cleaning up enormous amounts of sediments, looking for tiny bones, seeds and fruits. It's like panning for gold."

But even if Jaramillo is right and Panama struck South America around 20 million years

ago, that doesn't necessarily mean that this was when the Central American Seaway closed. The key question is the location of North America at the time of the collision. Was Panama already connected to it, or was it just a series of islands? If the latter, then the collision would not have closed the gap.

Jaramillo again found his answer at the Panama canal site: fossilised remains from 22 to 23 million years ago revealing a mature forest containing large mammals. "We found everything from horses to camels to bear-dogs, as well as large tree trunks," Jaramillo says, which strongly suggest that Panama was already joined to North America by the time of the collision. "If it was an island, we would expect to see different animals to those on the mainland. But they are all typical fauna of the rest of North America."

Jaramillo is now convinced that the continental closure happened long before the conventional date of 3 million years ago. He accepts, however, that it may have taken another 15 million years after the plates collided to create an unbroken land bridge. That may be why he sees crocodiles and turtles but not other large animals: the shallow channel would have prevented the latter from bridging the divide.

### Jungle clearance

He also concedes that there is no evidence for North American animals moving south around 20 million years ago, but points out that this may be because there are no accessible sites in the South American tropics that date back that far. "We are just starting to dig at the collision zone site in Colombia, but we have to clear jungle first," he says - not to mention the risks of working in an area controlled by the guerrillas of the Revolutionary Armed Forces of Colombia.

As for the Caribbean coral extinction 2 to 3 million years ago, Jaramillo says: "There have been many coral extinctions, including one that occurred 22 million years ago, perhaps related to the isthmus forming." He cites recent evidence that suggests the extinction 3 million years ago may have been caused by a change in ocean chemistry unrelated to the closure of the seaway.

Further supporting evidence for Jaramillo's early date may come later this year. An international ocean-drilling project working off the coast of New Jersey, where the Gulf Stream passes, is bringing up core samples extending as far as 3 kilometres below the seabed to probe ocean currents going back 40 million years. Meanwhile, Jaramillo has asked researchers at the Laboratory of Climate Science and the Environment, run by the French National Centre for Scientific Research in Gif-sur-Yvette, to model ocean circulation through the Central American Seaway as it became narrower and shallower, to see when the Gulf Stream could have started up.

Perhaps his biggest challenge, though, is to explain how the Arctic iced up independently of the Gulf Stream. "Maybe plate tectonic configurations elsewhere, or a drop in carbon dioxide made the Arctic colder," he guesses. Another possibility is that the tilt of Earth's axis altered slightly around 3 million years ago, reducing the amount of sunlight hitting the

northern hemisphere.

Jaramillo can take encouragement from the fact that he isn't alone in challenging the orthodoxy. Climatologist Gerald Haug of the Swiss Federal Institute of Technology in Zurich also suspects that the continents collided much earlier. "Certainly, there is evidence of a proto-Gulf Stream - far weaker than today's - 20 million years ago," he says. Despite that, he says he has "compelling evidence" that the salinity of the Atlantic and the Pacific didn't diverge until 4.5 million years ago, suggesting that the Central American Seaway remained at least partially open until then. "The shallow channel provided sufficient interchange until that date. And it is the salinity imbalance that drives the strong Gulf Stream we see today."

To add to the confusion, Haug has yet another take on the glaciation question. He thinks the Gulf Stream played no part in provoking the Arctic big freeze - in fact, it did the reverse. "I call it the Panama paradox," he says. "The Earth had been cooling for millennia and had reached the threshold conditions for glaciation around 4.5 million years ago. But then the strong Gulf Stream caused by Panama closing brought warmth to the area and delayed glaciation until 2.7 million years ago."

Who is right? Did the rise of Panama trigger the glaciation of the Arctic, delay it, or have no effect? The answer matters enormously as we try to model the consequences of climate change. The isthmus that changed the world is as relevant as ever.

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From issue 2816 of New Scientist magazine, page 44-47.

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