fix carbon—to plants that gobble a lot of nitrogen when storing carbon, especially quack grass, a weedy Eurasian import.

In this latest study, Wedin and Tilman have quantified how these changes in a grassland's resident species affect the carbon-absorbing power not just of the plants themselves, but the overall ecosystem. The researchers collected soil, root, and plant samples and analyzed their elemental composition. The results confirmed their earlier findings that as weedier species took over the nitrogen-fed plots, they absorbed less carbon for a given nitrogen input. And when they looked belowground, they found that the weedier plots had stored less carbon in soils.

The researchers explain that because their tissues contain more nitrogen, invading species decompose more quickly than do native plants and thus contribute less organic matter—and less sequestered carbon—to soils. "Although the weedier species grow well with added nitrogen, they simply can't build the soil carbon the way the [native] prairie species could," says Wedin. "So, in the long term, the higher growth rates observed aboveground are not reflected in greater ecosystem storage."

The added nitrogen also had another adverse environmental effect: As weedy species overran plots, the plots began to leak soluble forms of nitrogen, mainly nitrate, into soils. The reason: Soil microbes convert nitrogen in dead plants into nitrate, and the high-nitrogen tissues of weedier plants cause the microbes to put out more nitrate. As Wedin points out, this nitrate can wind up in aquifers and runoff and may contribute to harmful algal blooms and water-quality problems.

Ecologist David Schimel of the National Center for Atmospheric Research in Boulder, Colorado, says the study underscores that climate modelers need to take into account the shifts in species, and resulting changes in how much ecosystems store carbon, when modeling the impact of nitrogen on global climate. "This is a very, very nice demonstration of the tight coupling between species composition and a biogeochemical change," Schimel says. He adds that the shifts Tilman demonstrated are likely to take place in other ecosystems, such as forests, which are an even more important carbon sink than grasslands: "This process may be occurring over very large areas of the world."

"On balance," says Schimel, this study suggests that "the addition of nitrogen to these systems is quite damaging" to biodiversity and water quality. And the payoff in slowing global warming isn't what some have predicted either, Wedin says: "The ecosystems that do a good job of storing carbon are the very same ones we're losing because of the added nitrogen."

–Jocelyn Kaiser

GEOPHYSICS

Did a Plate Tectonic Surge Flood Earth?

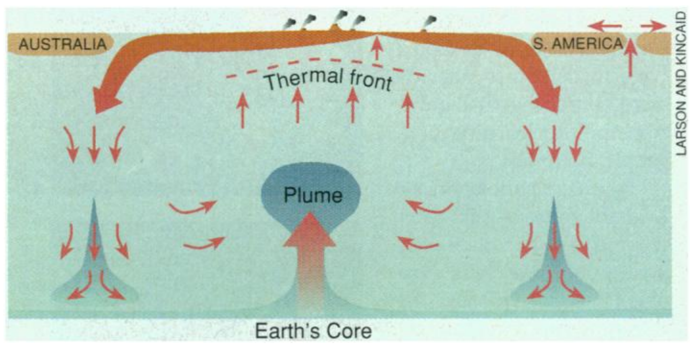
One hundred million years ago, the oceans ruled the planet. Sea level was perhaps 200 meters higher than today, flooding the world's coastal plains and pushing the seas into the hearts of the continents. What drove these surging seas? One theory, proposed 5 years ago by marine geophysicist Roger Larson of the University of Rhode Island, suggests that a huge plume of nearly molten rock beneath the Pacific Ocean raised the sea floor and so pushed the waters onto the land (*Science*, 15 February 1991, p. 746). Larson's idea garnered much attention and won some converts, in part because he suggested that this deep-seated convulsion also drove other unexplained Cretaceous events: a massive gush of volcanism, an overheated climate, and a stabilization of the flip-flopping magnetic field.

But now, other geologists are throwing some cold water on Larson's theory. In a new analysis of the geologic record presented at October's meeting of the Geological Society of America in Denver, Paul Heller and Charles Angevine of the University of Wyoming and Don L. Anderson of the California Institute of Technology argue that the superplume, if it existed at all, had only a modest effect on sea level. Instead, they cite other, more superficial forces, such as the plate motions involved in the breakup of the supercontinent Pangea. Other geophysicists agree that the sea level aspect of Larson's scheme has grown weaker, but they aren't ready to give up on the superplume entirely.

In Larson's view, as the plume neared the surface, it speeded the volcanic creation of new ocean crust at midocean ridges, to the point that new Pacific crust was produced at twice the rate it is today. The abundance of young, warm, and therefore buoyant ocean crust would have raised the sea floor by as much as 2.5 kilometers and pushed seawater onto the continents, Larson concludes. And between ridges, the plume would have sent lava spewing onto the sea floor to form great volcanic plateaus, jacking up sea level even more. Meanwhile, the carbon dioxide released in the volcanism may have increased the greenhouse effect and warmed the climate, while the cooling effect of the plume on Earth's core temporarily stabilized the magnetic field.

But Heller and colleagues find little sign of an increase in crustal spreading rates in the Pacific. By including newly recognized shifts in ocean plate boundaries during the Cretaceous and using the most recent geologic time scale to set the pace of spreading, Heller and his colleagues slice some previous estimates of the rate of Cretaceous sea-floor creation by 40%, so that it was not much faster than today's 19 cubic kilometers per year. They also question Larson's estimates of the magnitude of the volcanic plateaus, something even Larson concedes is debatable.

What's more, Heller points out that there is a string of mechanisms unrelated to a plume that could have changed sea level by the amount he suspects it rose, perhaps 100 to 200 meters. In particular, he notes that the supercontinent Pangea began to break up about 200 million years ago, when new oceans—and new spreading ridges—formed. The hot, young crust produced by these new ridges could have helped raise sea level, says Heller—without any effects from a plume.



Ocean rising? Larson theorized that a rising plume from deep within the Earth spurred undersea volcanism, creating buoyant new oceanic crust and raising Cretaceous sea level.

Other researchers working on Pacific crustal generation take the middle ground. Heller's criticisms are "a bit heavy-handed," says plateau specialist William Sager of Texas A&M University, although he agrees that the "early papers with high spreading rates are probably overestimates." Still, something unusual seems to have struck the Pacific in the mid-Cretaceous, he says, whether it was a superplume or not.

And Larson's theory still has the appeal of uniting many other aspects of global change, notes Tanya Atwater, a marine geologist at the University of California, Santa Barbara. His scenario "solves a lot of my problems," she says. Even if a superplume is not needed to explain sea level, she says, it might still explain the coincidence of a burst of volcanic plateau formation, an abrupt reorganization of plate motions, and an overheated climate. Still not bad for one volcanic burp.

–Richard A. Kerr