WORKING TOGETHER TO BUILD THE ANDES

Ask geoscientists what shapes the Andes, and you might be reminded of the story about blind men trying to identify an elephant based on the feel of its trunk, tail or feet: A tectonic geologist might tell you about varying rates of plate convergence throughout South America; a geomorphologist might talk about erosion; a geophysicist might describe dense rock being formed and lost at the bottom of the crust. Now, for the first time, researchers examining the whole Andean system have quantified each process's relative importance.

Formed by the subduction of the Nazca Plate beneath the South American Plate, the Andes Mountains extend the length of South America. In the relatively wet north and south parts of the mountain range, the range is narrow, and the peaks are relatively low. At the arid middle of the range, around Bolivia, the mountains are taller and span a broader region.

There's no dispute that tectonic forces are the primary builders of the mountains, says Jon Pelletier, a geomorphologist at the University of Arizona in Tucson and lead author of the new study, published in Geology. The uplift of the mountains is affected by changes in the crustal dynamics due to the partial melting of the Nazca Plate as it slides under the South American Plate. For example, the effective convergence of the two plates varies throughout the mountain range, and is fastest at the center of the range, where the mountains are most substantial.

Meanwhile, two processes act to bring down the mountains: Erosion accounts for much of the range's demolition, and geomorphologists argue that the mountains are highest around the Bolivian desert because that's where there's the least rainfall to erode the mountains and wash material into the ocean. The second force is the formation of the dense metamorphic rock, eclogite, at the bottom of the crust. Eclogite forms under the high pressure of the massive mountains and colliding plates, and its weight has the effect of sinking the crust lower into the mantle. However, eclogite also builds up the mountains: It is so dense that once enough is formed over the course of millions of years, it can break off from the crust and fall into the mantle, Pelletier says. This process, known as delamination, causes the suddenly lighter crust to rise up, and can add thousands of meters to the height of the mountains over a few million years. Delamination has happened twice in the 60-million-year-history of the Andes, he says.

But exactly how much does each process contribute to shaping the Andes? Pelletier and colleagues turned to modeling for the answer to that question. "We wanted to try to come up with a model that brought these things together, and did the best job of predicting both the current state of the Andes, which we know to high precision, and also the rates of erosion and eclogite production that we've been able to infer for the last few tens of millions of years," Pelletier says. He worked with tectonic specialist Peter DeCelles and geophysicist George Zandt, both at the University of Arizona, to create a simple model that takes into account the varying shortening rates, erosion rates and eclogite production rates in the Andes. They largely borrowed data from already existing models that hadn't been previously coupled together, Pelletier says.

New research quantifies how much erosion, plate convergence and delamination each played a role in shaping the Andes.

The results showed that in the central arid region, eclogite production and delamination account for five times more crustal mass removal than surface erosion, and that in the wetter regions to the north and south, erosion was the primary mover of rock. Although this was apparent before, this study was the first to quantify it, Pelletier says.

The study also found a series of feedbacks between the various processes. Where there is little erosion, the topography can grow higher, which results in greater eclogite production and quicker delamination — which ultimately allows the mountains to grow even taller. The higher mountains also create a rain shadow effect, which further prevents erosion, allowing the mountains to grow even higher. "It's not an earth-shattering conclusion," Pelletier says, "but it hadn't really been described before."

According to Lindsay Schoenbohm, a tectonic geomorphologist at the University of Toronto Mississauga in Canada, this is interesting because recent studies had suggested that differing rates of eclogite production could be a result of changes in the atmospheric circulation patterns that create deserts and humid areas, rather than changes in elevation. "It's a nice controversy," she says. "It's like two camps facing off against each other. And this paper addresses that."

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