"Earth is not an onion with layers that vary with depth. There are large-scale changes sideways."

University, Mitrovica showed that the western half of the North American tectonic plate had tilted downward, causing the ocean to inundate the interior. At the time, he declares, "I can assure you, I wasn't thinking of it as a sea-level problem. I was thinking of it as a plate-tectonics problem. It never dawned on me that I was entering into what is now called 'long-term sea-level research.'"

How Earth Shapes Its Climate

Mitrovica came to Harvard from Toronto in 2009 for opportunities to expand his interdisciplinary research. "In Toronto, for example, we did no work on ice-sheet stability, and we didn't look at the statistical analysis of climate signals." Since arriving in Cambridge, he and his students have "branched out in ways I would not have predicted, and each of them has really made an important contribution." At Harvard, he landed among people like professor of earth and planetary sciences Peter Huybers, with whom he and his students have collaborated on a number of important papers, and Adam Dziewonski, then Baird professor of science, who pioneered the use of seismic tomography—the measurement of waves propagating from earthquakes—to create images analogous to sonograms of the earth's interior.

"Earth is not an onion with layers that vary with depth," Mitrovica explains. "There are large-scale changes sideways." Imagine for the first time having a tool that "tells you how things vary laterally." Dziewonski's revolutionary work revealed the existence of two "large and deep vertical structures" with defined edges, one beneath the continent of Africa and the other under the Pacific Ocean, and thus changed the way geophysicists modeled everything from plate tectonics to deformations in the planet's shape.

His presence in the office next door also influenced the work of one of Mitrovica's current graduate students, Harriet Lau. Inspired by seismic tomography, Lau is attempting to develop a parallel technique, "tidal tomography," using the daily rise and fall in land elevations, like the eight-inch flux observed in Cambridge, to see whether these movements can enhance understanding of the planet's internal structure. Measured by GPS receivers on the earth's surface, such "body tides," which vary by geographic location, are caused by the same predictable forces that drive ocean tides (the gravitational pull of the sun and the moon). The goal of Lau's ambitious work is to determine whether the two large structures Dziewonski imaged are buoyant, energetically upwelling features, or dense anchors on the slow creep of rock within the earth's rocky mantle. Answering that question will shed light on the pace of the earth's evolution since its birth 4.5 billion years ago, a key unresolved issue in understanding how the atmosphere, ocean, geology, and climate have changed over time.

"When most people think of climate, they think of the atmosphere and things like that," Mitrovica says. "They don't imagine that the solid earth plays any role in the evolution of the climate system." In fact, "it plays a crucial role." For example, at the height of the last ice age, glaciers covered Canada, Scandinavia, and much of the northeastern United States. Twenty thousand years ago, the glaciers began melting; by 5,000 years ago, they were nearly gone. But how much ice was there at the glacial maximum? Scientists want to know because that will tell them something about ice-age climate and about how the ice sheets responded to cooling and warming.

One way to estimate the size of those ice sheets, which locked up a *lot* of water, is by reconstructing what happened to sea level as they melted. Scientists often use Barbados as a gauge to calculate ancient sea level because the island lies far from the polar ice sheets' maximum extent. Cliffs of fossilized coral, which grows only underwater, ring the island and record how sea level has changed in the past 20,000 years. But "the problem with that is that Barbados is not a magical meter stick," Mitrovica explains. "It is influenced by a number of solid-earth processes." Some of these geophysical processes cause the island to sink, others to rise. "There is no way to model

What Roman Ruins Reveal

Geophysical proofs are not the only kinds of evidence Mitrovica marshals to illuminate the history of sea-level rise. One of his favorite examples comes from a fellow researcher at the Australian National University, Canberra. Kurt Lambeck, a professor of geophysics, has used 2,000-year-old Roman fish tanks to illuminate changes in sea level. In an era long before refrigeration, wealthy Romans built holding tanks beside their coastal villas so they could eat fresh fish whenever they wished. Sluice gates positioned with their tops eight inches above the high-water mark let seawater in and out, flushing the tanks with the natural ebb and flow of the tides. To work, they had to be built at a precise level relative to high tide.

Lambeck, after correcting for known geophysical influences such as the ongoing changes in Earth's shape due to the ice age, showed that there has been virtually no change in sea level at these sites since the height of the Roman empire. The finding refutes climate skeptics' claim that sea level has been rising continuously for a long time. Had the water been rising at two millimeters per year for two millennia, these tanks would today be under four meters of water. Lambeck's work thus underscores the significance and implications of Mitrovica's recent finding that sea level rise has accelerated dramatically in the past two decades.

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Roman fish tanks in Cyprus, built at a precise level relative to high tide, show that sea level has barely changed in two millennia.