



The Udachny kimberlite pipe in Siberia is one of the world's largest open pit diamond mines.

Although Earth is dotted with thousands of known kimberlite pipes, not one has been known to erupt in recorded human history. The vast majority are hundreds of millions of years old. “All of us volcanologists would be willing to chip in and have a new eruption of kimberlites,” Russell says.

During COVID-19 lockdowns, Gernon found himself returning to the question of why these eruptions only occur in cratons—the old, cold interiors of continents. Although some researchers believed mantle plumes could be the source, many kimberlite deposits don't match known hot spot tracks. In addition, geochemical analysis of isotopes in mantle plume rocks suggest they originate in the lower mantle, whereas recent analyses of kimberlites point to a shallower origin.

Gernon and his co-authors noticed how the timing of kimberlite eruptions did seem to match up with landmark events in plate tectonics. They reconstructed the movement of the continental plates over the past 500 million years, comparing the rate of continental rifting with the bursts of kimberlite formation. The analysis showed kimberlite eruptions seemed to peak, on average, 26 million years after a continental breakup. “That was curious and jaw dropping,” Gernon says.

They then zoomed in on the geologic history of kimberlite deposits in southern Africa

and South America, which formed after the breakup of the Gondwana supercontinent 120 million years ago, and those that formed in North America after the earlier crack up of Pangaea. The kimberlite volcanoes popped off progressively farther from the rift over time, the clusters shifting some 20 kilometers every million years.

Gernon and his colleagues think they know what drives this migration. As continents split apart, hot mantle rocks well up to fill the gap. But they cool off and sink as they rub up against the cold continental sides of the gap, creating whirling convective patterns. Computer modeling shows these vortices travel along the keels of the continents, stripping their mushy roots and creating a rock mix perfect for melting into kimberlite. The simulations show the waves crawling along at a pace that matches the propagation of kimberlites: about one-millionth of a snail's pace. “It's a really clever idea,” says Jeroen van Hunen, a geodynamicist at Durham University. “It makes perfect sense.”

It's also a big claim, as the powerful waves would strip some 40 kilometers of rock from the base of continents. But some other evidence seems to support it. For example, not only do kimberlites migrate out from rifts over time, but their mix of isotopes also shifts, from patterns that resemble a mantle-crust mix where the wave first breaks to a more uniform upper mantle composition as the wave dies out. And in the Kaapvaal craton of southern Africa, for example, the continent saw several kilometers of uplift around the same time as the kimberlite eruptions. The uplift suggests the wave was underfoot at the time, stripping off the continent's undercarriage and allowing it to rise like a hot air balloon shedding its ballast. “Combined, this evidence is really compelling,” Gernon says.

It's unlikely the team has found the single cause for kimberlites, given how noisy the data are, and how much Earth's quirks vary from place to place, says Karen Smit, a geochemist at the University of the Witwatersrand. “It's a model that makes sense. I just don't know if that correlation exists globally.” But Kolawole says the study is likely to prompt a surge of work in regions such as the Gulf of California or the Red Sea, where incipient rifting might be creating the deep waves, which seismic observations could reveal. The theory might also explain some volcanic deposits that were previously attributed to plumes, he adds.

The greatest interest in the study may come from commercial diamond miners, Gernon says. In theory, it could help predict the location of undiscovered kimberlites, he says. “You should be able to pinpoint, roughly, the sweet spot for diamonds.” ■

ETHICS

Famously creepy museum reckons with its past

Mütter Museum launches an ethical review of its anatomical curiosities—and sets off a firestorm

By **Rodrigo Pérez Ortega**

Many regular visitors to the Mütter Museum in Philadelphia have their favorite specimen. There's the megacolon—a 2.4-meter-long brown organ, the result of Hirschsprung disease in a 29-year-old man who performed at a freak show as Balloon Man and died in 1892 with 18 kilograms of poop in his bowels. There's the Soap Lady, whose remains are covered with adipocere, or “corpse wax,” a fatty substance that forms in warm, alkaline, and airless environments. And there are the skeletons of Carol Orzel and Harry Eastlack, two Philadelphians who lived with fibrodysplasia ossificans progressiva, in which connective tissue slowly turns into bone.

For decades, the 35,000 objects and specimens in the storied museum, which just completed a \$3.2 million renovation of its storage and lab facilities, have attracted legions of fans, including some members of the disability community who see themselves represented in its exhibits. But in February, members noticed that most of the museum's images and videos had disappeared from its website and YouTube channel without explanation, although the objects themselves remained on display. After a public outcry, the leadership of the museum and the College of Physicians of Philadelphia, which owns the Mütter, revealed the reason: They have launched a thorough ethical review of the museum's handling and display of its 6500 specimens of human remains.

Although turnoffs for some, the Mütter's skeletons, skulls, and body parts, displayed in a 19th century cabinet of curiosities style, are a source of knowledge as well as fascination. Bioarchaeologist Molly Zuckerman still remembers her first visit to the Mütter, when

she was 21. “I [found out] how much I really enjoyed learning about health and disease,” recalls Zuckerman, now at Mississippi State University. By displaying extreme examples of human anatomy, she says the Mütter “really shows us, in a way that other resources don’t, the capabilities of the body.”

But ethical standards for collecting and displaying human specimens have changed over the years. When Kate Quinn, executive director of the Mütter, took over leadership in September 2022, she was surprised to find the museum didn’t have specific ethics policies. “That makes it all the more important for us to move forward together to create an ethics policy for all aspects of [our] work,” she says.

“I see it as taking the right path for those individuals who cannot speak for themselves

Thomas Dent Mütter, a 19th century Philadelphia surgeon who operated on hundreds of patients with unusual anatomy. Physicians of the time often kept body parts excised during surgery and collected unclaimed bodies, practices legal at the time but unethical today. Around 1875, for example, anatomist Joseph Leidy became aware that bodies from the cemetery where the Soap Lady was buried were being relocated. He lied to the grave digger, stating she was his grandmother, and obtained the saponified body, which he later donated to the Mütter. The museum also displays slides of Albert Einstein’s brain, which was dissected without his or his family’s consent. “[Physicians back then] collected people like kids collect Pokémon,” de la Cova says.

These days, she says, “Scholars who work with the dead think about better ways of en-

The plan is to finish the review by early September, Quinn says.

Staff began to audit every human specimen in May, reviewing how it was acquired and how it is displayed—a process that will take up to 48 months. For each human specimen, “we need to become much more aware of the circumstances of their lives and the times in which they lived,” Quinn says.

Take the Soap Lady. “We know she was taken from her grave,” Quinn says. But the museum doesn’t have information on her identity or records of her or her family’s consent for donation—let alone display. “Personally, do I believe she should go back into the ground? Yeah, probably.” But that decision will be up to the college’s Board of Trustees, after hearing the community’s perspectives and discussing whether there’s a strong medical reason to keep the remains on display. “That’s one case,” Quinn says. “There’s 6500 of them.”

For some specimens, such as the megacolon, what is missing is contextual information. “It’s a little bit like a circus,” says Sabine Hildebrandt, an anatomy educator and researcher on the history and ethics of anatomy at Boston Children’s Hospital and Harvard Medical School. The specimen is currently displayed as an “object of curiosity,” she says, rather than what it really is: “witness to the suffering of a person.”

The museum’s new direction irks Robert Pendarvis. In 2021, he donated his enlarged heart, the result of a condition called acromegaly, to the Mütter after getting a transplant at Duke University Medical Center. He wanted his information public and was upset when a video of his heart was taken down, according to a report by a Philadelphia radio station. (His heart is still on display.)

Others have broader complaints. Although Ezra Eisenstein, an organizer of the Protect the Mütter campaign, agrees with the need for the ethical review, “What are the review criteria? Who’s doing the reviews?” he asks. “There’s just a complete lack of transparency or accountability.”

“We are being as transparent as we can,” Quinn says. “We’re open to all conversations.” The museum is now providing updates to the public in a dedicated page on its website.

She and other experts stress the value of the displays. Zuckerman notes that the Mütter houses bones bearing scars from the late stages of syphilis, rare in patients today. Seeing the early examples helps clinicians recognize the full expression of the untreated disease, she says. “They’ve never seen congenital syphilis before.”

But, Quinn promises, “Everything that we will be doing moving forward is out of respect for the humans involved in this conversation, both living and dead.” ■



The Mütter Museum in Philadelphia, shown in 2013, displays specimens in a cabinet of curiosities style.

[and] did not know that they were going to end up in this museum,” says Carlina de la Cova, a biological anthropologist at the University of South Carolina.

But some are unhappy with how the review is being done. An online petition called Protect the Integrity of the Mütter Museum, led by museum members and members of the public, has amassed more than 31,000 signatures demanding the reinstatement of all online content, as well as more transparency from leaders about their decisions. The controversy illuminates the thicket of ethical issues faced by museums, especially those focused on human anatomy and disease, as they reckon with the history behind their collections. “You end up reexamining yourself,” says Mira Irons, president and CEO of the College of Physicians. “It’s painful.”

The Mütter started with a donation of 1700 objects from the private collection of

gaging with [them].” In Philadelphia, an impetus came in 2021 when antiracism activists protested the news that the Penn Museum—blocks away from the Mütter—had retained, for teaching and research, the remains of victims of the 1985 MOVE bombing, in which the police killed members of a Black separatist group.

The Mütter is now returning the remains of seven Native Americans to communities in New Jersey and California, as required by federal law. And it launched the ethical review of all of its 450 YouTube videos and website images in January. Quinn gathered a multidisciplinary group of about 20 experts that includes members of the museum, college fellows, and the disability community to be sure the human remains shown are treated with respect. In one video that is likely to be dropped or edited, former staff jokingly pretend to brush the teeth of skulls.



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