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Scientists Have a New Explanation for Mysterious Sand Spikes

New research links the geological oddities to intense ground shaking from earthquakes or asteroid impacts.

The sand spike occurrence near Mount Signal in southern California, USA. Credit: Mila Zinkova

By Katherine Kornei
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With their bulbous heads and tapered tails, sand spikes resemble miniature mushroom clouds. But the origin of these rare geological formations has remained enigmatic since their discovery in underground deposits nearly 200 years ago. Are they petrified seaweed? Sand-filled animal burrows? Or perhaps even objects created by prehistoric human populations?

Researchers studying sand spikes found in California and Germany have now proposed that these geological oddities form rapidly during intense ground shaking. Powerful seismic waves — triggered by either earthquakes or asteroid impacts — ripple through sand and create these features in mere seconds, the team suggests. When sand spikes are found, they say, they can be used to pinpoint both the timing and location of long-ago seismic cataclysms.

Despite the striking appearance of sand spikes — which have "the shape and proportions of an ancient mace," a researcher wrote in 1906 — they aren't well known, even among scientists who study rocks.

"I would define them as geological curiosities," said Lidia Lonergan, a geologist at Imperial College London, who was not involved in the research. "They're very unusual." Sand spikes were first discovered in the 1820s in southern Germany near the Nördlinger Ries impact crater, which formed 14.8 million years ago when an asteroid struck the region. The impact triggered ground shaking equivalent to that of a magnitude 8.5 earthquake, previous research has suggested:
https://onlinelibrary.wiley.com/doi/abs/10.1111/j.1945-5100.2005.tb00157.x

Sand spikes from the former Liebherr outcrop in Ochsenhausen. Credit: Volker J. Sach

Over the last three decades, Elmar Buchner, a geologist at the Neu-Ulm University of Applied Sciences in Germany, and his colleagues have collected thousands of sand spikes around the Ries crater. The hardy sandstone structures, the largest of which have been found to top three feet in length, are only located in sediments dating to the time of the impact. And curiously there's a pattern to how they're oriented in the ground.

"The bulbous heads of the sand spikes point toward the seismic source," Dr. Buchner said.

That was an unexpected finding, but it reminded Dr. Buchner and his collaborators of similar looking sand spikes found thousands of miles away in the Imperial Valley of Southern California. Over 95 percent of those sand spikes, mostly found clustered near Mount Signal, have heads pointing east. That is directly facing the nearby San Andreas Fault, the earthquake-prone intersection of the Pacific and North American plates.

Ground shaking therefore appears to play an important role in the formation of sand spikes, Dr. Buchner and his colleagues concluded. Furthermore, the structures themselves reveal not only that ground shaking occurred, but they also indicate the direction from which it originated, the team suggests.

Museum-quality sand spikes from the former Liebherr outcrop in Ochsenhausen. Typical sand spike aggregate with roundish to cauliflower-like heads and uniformly orientated tails. Credit: Volker J. Sach

In a study published last month in Nature Communications, Dr. Buchner and his collaborators proposed a recipe for how sand spikes form. The necessary ingredients, the researchers suggest, include powerful ground shaking, loose sand, water and calcite, which functions like a glue. [https://www.nature.com/articles/s41467-021-27061-6]

The process starts when the fastest-moving seismic waves, or primary waves, pass through sand and compress it, the researchers suggest. That sends most, but not all, of the moisture within it to the surface, Dr. Buchner said. “The sediments are basically dry but there are still a few pockets of water.”

A few seconds later, slower seismic waves, called secondary waves, ripple through the sand again. Those waves trigger dramatic increases in pressure, which cause remaining reservoirs of water to rapidly heat and then vaporize explosively. Each explosion excavates a hollow structure that sprouts a tail pointing away from the source of the pressure. The surrounding sand rapidly flows back into the void, and calcite, the primary mineral in limestone, cements the structure together.

Sand spikes probably form in a matter of seconds, the researchers suggest. That’s unlike most other geological structures, said Franek Hasiuk, a geologist at the Kansas Geological Survey who was not involved in the research. “A lot of our rocks take at least millions to tens of millions of years to form. This happens in a geologic blink of an eye.”

Besides Germany and California, sand spikes have been spotted only in a few other places. Given their relative scarcity, particularly powerful ground shaking must be necessary to form them, Dr. Buchner and his colleagues propose.

Because sand spikes are markers of intense, potentially destructive ground shaking, they’re valuable indicators of hazardous conditions, Dr. Hasiuk said. It’d be a bad idea to build a school or a nuclear power plant where sand spikes have been found, he said. “Understanding ancient seismicity can really help us more intelligently plan our infrastructure.”