

## **Not My Fault: The Clear Lake Volcanic Field enigma**

Lori Dengler/For the Times-Standard  
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After last week's Geysers article I got two excellent questions: what causes volcanic activity in the Clear Lake area and how does waste fluid injection at The Geysers differ from what happens in Oklahoma with fracking.

First a correction. I errantly called Mount Konocti a cinder cone. It is a composite volcano, mostly composed of dacite, with cinders only covering the top. Why it is there is an interesting plate tectonics story.

You may be aware of the three places on earth where volcanic activity is concentrated: ocean ridges, subduction zones and hot spots. Most of the world's volcanic activity occurs along mid-ocean spreading centers where the crust is thin, heat flow is high and submarine volcanic flows ooze out at a nearly continuous rate.

We have such a ridge near by. The Gorda ridge is 180 miles west of Eureka and 150 miles offshore of Crescent City. Gorda ridge eruptions were documented in 1996, 1998, 2005 and 2011. They were quiet affairs far below the ocean surface and barely made the news. We only know about them because of offshore acoustic cables. The cables, originally deployed as part of the SOSUS array to detect Soviet submarines, can sense the tiny earthquakes that accompany submarine eruptions. Spreading center eruptions are geologically important but pose no hazard to us.

Most hazardous eruptions are associated with subduction zones where pressure, chemical reactions and friction fuel melting as crustal material is pulled deep beneath the surface. All of the great explosive eruptions of the 20th century can be traced to this cause including 1980 Mt. St. Helens. Unlike ridge volcanism, subduction zone volcanoes spend most of their time asleep, with decades or centuries elapsing between successive eruptions.

Hot spots, concentrated zones of high heat flow perhaps extending to the core mantle boundary, provide an explanation for most of the volcanic activity not on plate boundaries. I'll leave them for another time, with the note that there is no hot spot in Clear Lake.

The Clear Lake Volcanic Field is not on a spreading center or within a subduction zone. It lies just west of the San Andreas transform system that forms the boundary between the Pacific and North American plate. Any chance this plate boundary plays a role in the volcanic activity? The answer is an ambiguous No and Yes. No because transform boundaries involve horizontal motion of the two plates and don't provide a heat source for volcanic activity. Yes because the evolution of the San Andreas has provided a gap in the plate structure that, in this case, allowed for magma bodies to form and eruptions to occur.

It's complicated and you need to visualize in space and time to understand. It helps to view Professor Tanya Atwater's great animation at <https://www.youtube.com/watch?v=9F8AcDJq2QU>. The first step is to understand the normal layering of the upper part of the earth. We live on the crust, with all the soil and rock that is familiar. Beneath the crust is the upper mantle, denser and more iron and magnesium rich, it is still hard and rocky. But as you go deeper into the mantle the rock gets warmer. It doesn't melt but becomes somewhat soft and is capable of slowly moving. This is the asthenosphere, a warm zone within the mantle, that allows the relatively rigid packet of the upper mantle and crust above it (the plate) to move.

Turn the clock back about 120 million years. The entire west coast of what was to become North and South America was a subduction zone where a once giant plate that geologists call the Farallon was pulled beneath the continental edge. That subduction process generated the heat that uplifted the Rocky Mountains and the Sierras and is still fueling Andean volcanism today. At that time, a spreading center far offshore in what is now the Pacific generated the Farallon plate and the Pacific plate further to the west. But subduction was consuming the Farallon plate faster than the ridge could make it, and slowly it was getting closer to the coast.

About 30 million years ago, the ridge bumped into proto-California roughly at the latitude of Los Angeles. Ridges are very weak zones with nothing binding the Farallon and the Pacific. So subduction ceased and a new boundary, the San Andreas, was born.

The Mendocino triple junction marks the northern end of the growing San Andreas fault. About ten to 12 million years ago, it had made it north to the San Francisco Bay area and by 3 million years ago was near the latitude of Clear Lake.

The San Andreas is not the only thing that is changing as more and more of the ridge hits the coast. The remnant of the Farallon plate continued to be pulled down into the mantle, creating a gap or window in the zone between the ridge and the subducting slab. The hot asthenosphere below slowly filled the gap causing heat flow to increase and, in some cases, stretching and thinning of the coast. As the San Andreas grew to the north, a slab window trailed it behind.

About a million years after subduction had ceased near Clear Lake, widespread volcanic activity began in the area where Clear Lake is located today. It continues intermittently to the present. The most recent activity was about 10,000 years ago. USGS geologists at the California Volcano Observatory put the Clear Lake area in the high risk category for future eruptions, below Mt. Shasta and Lassen, but above Mono Lake and Mammoth.

I'm surprised by the lack of media attention to the Clear Lake volcanic threat. The biggest concern is a phreatic or phreatomagmatic eruption – where water in Clear Lake could become superheated by the magma body and flash to steam creating an explosion. The good news is that thanks in part to the urging of my friend and colleague Julie Donnelly-Nolan, a new USGS Clear Lake project has been launched to better understand the dynamics of the field and the risk it poses not only to Lake County, but regionally.

I'll tackle the fracking question next week.

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