Times Standard

Not My Fault: Exploring the Josephine Ophiolite

Lori Dengler for the Times-Standard
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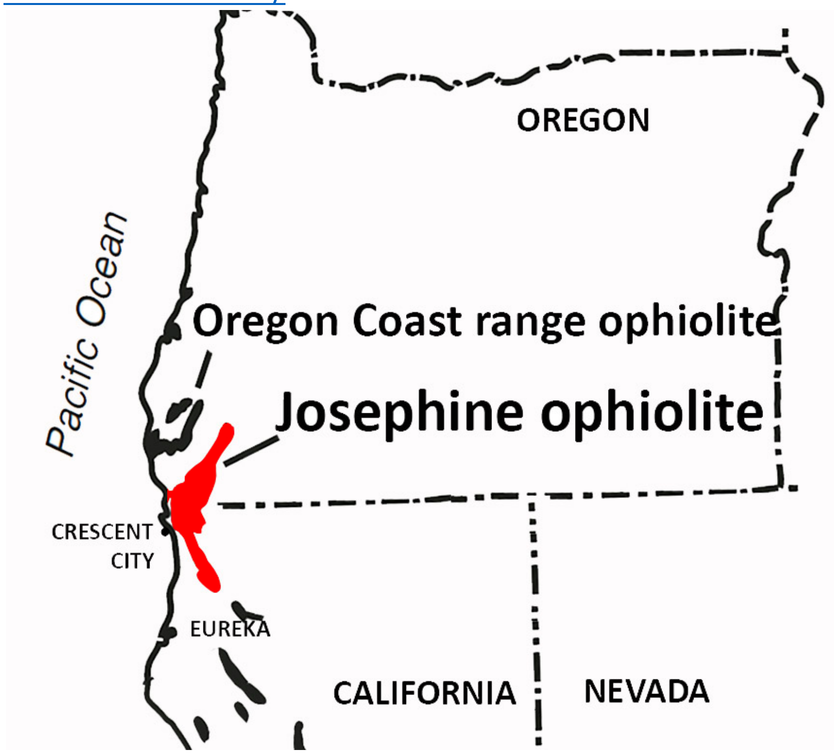

Simplified location map of the Josephine Ophiolite (in red) and other ophiolites (black) in the Pacific Northwest.

What are mantle rocks like? Now that the JOIDES Resolution expedition has recovered cores from the mantle (last week's column) information will be pouring in over the coming months and years. But we have had glimpses of mantle rocks before, in areas where geologic processes have thrust up these rocks from the depths. California features a number of places where one doesn't need a drill rig to find exposed bits of the mantle and one of the best examples is nearby. It's called the Josephine Ophiolite and every time you drive on 199 to Grants Pass, you have been on top of it.

Ophiolite means snake stone (from the Greek ophos = snake and lithos = stone). The term was first used in the early nineteenth century by French mineralogist Alexandre Brongniart who applied it to unusual rocks he found in Italy. The units were distinctive packages of ocean sediment, igneous rocks that had both erupted on the surface and crystalized more slowly at depth, and very dense serpentines whose scaly green appearance gave rise to the name.

For more nearly a century and a half, ophiolites were an enigma to geologists. How they formed and why the different rock types were associated together was beyond the understanding of geologic thinking of the time. I remember the great lengths my early 60s introductory geology course went to explain them.

Plate tectonics to the rescue. With the recognition of our planet's mobile surface and that ocean basins are the result of plate motion; ophiolites finally had a reasonable explanation. It all came down to the new understanding of how oceans are formed.

Before I go further, it's important to state that the mantle is solid and rocky. It's not metallic like the core and certainly not molten like the outer core. We know this from seismic waves that, like CAT scans of the human body, tell us about general characteristics. I still occasionally see popular media describe the mantle as a molten pool of lava with the crust floating on top. Please erase that image from your mind.

The mantle is very hot and gets hotter as you go deeper. It is easily hot enough to melt rocks if they were at the surface. But pressure also increases with depth, inhibiting melting. The upper part of the mantle is caught in an intricate dance between temperature and pressure and small variations can tip an area just over the melting line producing molten rock (magma).

Oceans are born when heat pools up beneath continents causing them to buckle and split. The two sides of the rift move away from each other sliding "downhill" from gravity's pull, eventually forming a new ocean basin. The uplift changes the temperature – pressure balance enough to produce some melt and trigger volcanic activity. We are witnessing this process today in Africa's Rift Valley.

Spreading continues and a new ocean basin is formed. The rift zone becomes a sea floor ridge where volcanic activity is nearly continuous. The eruptions are small scale, unnoticeable without sensitive instruments to detect accompanying earthquake activity. Over time this volcanic activity creates most of the oceanic crust.

The result is a relatively uniform structure of the ocean sea floor. On the top is a thin layer of sediments. Beneath the sediment is basalt or lava rock, the product of millions of years of eruptive activity. Eruptions along the ridge keep adding new basalt to the edge of the plate that is continuously moving further away.

Beneath basalt is gabbro, identical to basalt in composition, but different in texture. When magma erupts to the surface, it cools quickly, and crystals are small. Most basalt looks uniformly black to the naked eye, and it takes a hand lens to see crystals. But much of the magma along the ridge doesn't erupt. Insulated by the overlying rock, it cools slowly allowing crystals to grow larger.

Basalt and gabbro are crustal rocks, but denser than most of the rocks that make up continents. Geologists use the term mafic (magnesium and iron) to describe them. Mafic rocks have comparatively less silica (like quartz-rich rock) and more heavy minerals. When I taught intro labs, I would tell students to close their eyes and hand them chunks of granite and gabbro. No one had any problem distinguishing the denser mafic rock.

Now for the interesting part. Drum roll please. Beneath the gabbro is peridotite. You may have heard of peridot, beautiful olive-green gemstones, and the traditional August birthstone. Peridots are large crystals of olivine highly enriched in magnesium. Peridotite owes its name to peridot – it's a rock containing a large amount of olivine.

Peridotite is an ultramafic rock, roughly 10% denser than gabbro and makes up much of the upper mantle. The ophiolite package of sediment – basalt – gabbro – peridotite is a cross section of the oceanic crust and mantle, and until the recent JOIDES Resolution cores, the only way to put your hand on mantle rock.

Ophiolites end up on land with the assistance from plate tectonics. When oceans become large enough, the oldest seafloor becomes heavy enough to founder and sink, pulled by gravity back into the mantle creating a subduction zone. Subduction zones are complex places and sometimes bits of the oceanic plate get scraped off and slapped onto the land. More rarely, the scraped off chunks include the whole ophiolite package from sediment to upper mantle.

The North American west coast has spent most of the last 100 plus million years as a subduction zone, collecting remnants of ancient terrains rafted across the oceans and occasional ophiolites. John McPhee gives a generally accurate account in Assembling California. The Josephine Ophiolite is one of the largest and most complete ophiolite assemblages in North America. I first became aware of it when fellow Berkeley grad student Greg Harper was working on his PhD in the late 1970s.

It doesn't take a technical background to realize the landscape is unusual when you drive through Josephine Ophiolite territory. The trees are sparse and look stunted. Soils have high concentrations of nickel and chromium; large enough to support mining in the past. The Darlingtonia Trail off of HW 199 is an easy introduction to some of the unique plant species.

Why bother to core into the mantle is so much of it is exposed on land? The Josephine Ophiolite and other ophiolites on land have been altered by the experience. Contact with water converts minerals in peridotite to serpentine and other alterations have occurred over the millennia of surface exposure. I am very interested to see how in pristine in-situ cores recently recovered compare to ophiolite geology.

Note: More on ophiolites of the world at https://blogs.agu.org/georneys/2011/02/10/geology-word-of-the-week-o-is-for-ophiolite/. Dave Bazard of College of the Redwoods has posted phtos of the the Josephine Ophiolite, at https://photos.app.goo.gl/aUjAXabn7oBPKTmY6.

Lori Dengler is an emeritus professor of geology at Humboldt State University, an expert in tsunami and earthquake hazards. The opinions expressed are hers and not the Times--Standard's. All Not My Fault columns are archived online at https://kamome.humboldt.edu/taxonomy/term/5 and may be reused for educational purposes. Leave a message at (707) 826-6019 or email Kamome@humboldt.edu for questions and comments about this column. Downloadable copies of the North Coast preparedness magazine "Living on Shaky Ground" are posted at https://rctwg.humboldt.edu/prepare/shaky-ground.