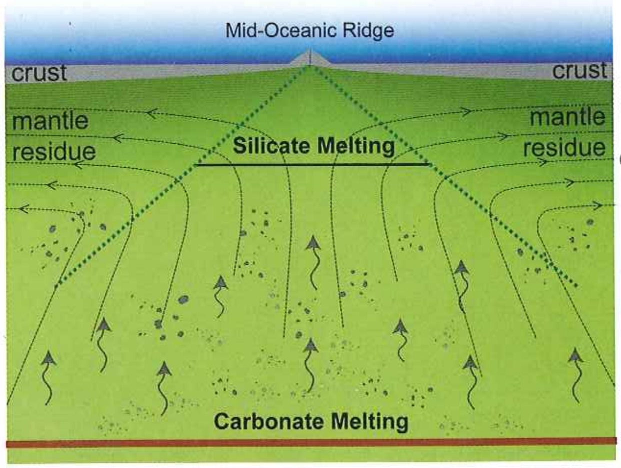
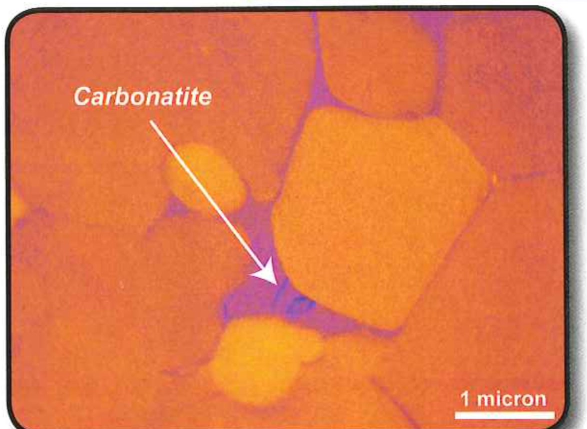
CARBON'S CONDUCTIVITY CONUNDRUM

Are carbonates responsible for high electrical conductivity in the mantle?

Scientists think they may have solved a long-held mystery about why Earth's mantle suddenly becomes highly electrically conductive at about 60 to 80 kilometers below the ocean basin and remains conductive as far down as 300 kilometers deep: The answer is carbon-rich melted rocks.

Lab experiments have shown that olivine and pyroxene, the dominant minerals that make up the upper mantle at those depths, are highly resistive to electrical current. So scientists have been left wondering where the electrical conductivity comes from. For years, the mystery has had two main suspects: water and partial melting.





New experimental evidence points to carbon-rich melts (carbonatite) as the source of electrical conductivity within Earth's mantle, even though carbon-rich melts form less than 1 percent of the mantle.

Researchers have hypothesized that trace amounts of water in the form of hydrogen and hydroxyl ions within mantle minerals produced the conductivity. On the other hand, some scientists have also suspected that carbon melts could be the answer because vast amounts of carbon exist in the mantle: During subduction, carbonates in the crust get sucked beneath the continents and into the mantle, where they melt and churn about, later returning to the surface through mid-ocean ridges and volcanoes. Small amounts of carbon-rich melt can also originate from as deep as 300 kilometers, as data from the East Pacific Rise — the mid-ocean ridge that separates the Pacific Plate from the North American and other eastern Pacific plates — suggest.

But one problem haunted the melt argument: Many scientists remained unconvinced that mantle temperatures are high enough between 60 and 300 kilometers deep to produce significant melting. Therefore, there would not be enough melt to produce the observed levels of electrical conductivity. In fact, experiments show that carbon (a volatile element in the mantle present only in a few tens to hundreds parts per million by weight) would only account for less than 1 percent of the mantle, says Rajdeep Dasgupta, an experimental petrologist at Rice University in Houston, Texas, who was not involved in the new research. Surely, scientists thought, such small amounts of melt could not account for so much of the observed conductivity, Dasgupta says.

But a new study published in Science suggests otherwise. Through lab experiments, Fabrice Gaillard of the National Center of Scientific Research in France and colleagues found that the conductivity of carbon-rich melt, called carbonatite, is three orders of magnitude greater than that of the silicate melt that inhabits the upper 60 kilometers of the mantle — and up to five orders of magnitude greater than mantle minerals containing trace amounts of water.

That's a key point for melt supporters. "Because the conductivity [of carbon-rich melt] is so much higher," Dasgupta says, "it is possible to attain the high observed electrical conductivity in the mantle even with this very small volume" of melt. The finding by no means rules out water as a contributing conductor, Gaillard and his colleagues wrote, but melt has a larger role.

Still, new questions surround the melt argument: Molten carbonate has a very low density and viscosity. How is it then, Dasgupta asks, that these melted carbonatites have not already floated up through the mantle and out of mid-ocean ridges? And even though the melt is highly conductive as a substance, he adds, its low concentrations in the mantle make it harder for melt pockets to stick together and make a pathway for the observed electrical currents throughout the mantle. "If you have a rock in which there is some amount of melt, but the melt pockets are isolated," he says, "then the circuit is broken."

Even if geologists solve these questions, it is unlikely that the water argument will fade, says geophysicist Rob Evans of the Woods Hole Oceanographic Institution in Massachusetts, who wrote an accompanying article in Science on the study's implications. For example, some geologists think that water plays a role in driving the mantle that fuels plate tectonics, Evans says, so assuming all conductivity is largely melt-driven and without a detectable water component might limit further investigation of Earth's interior. "There's somewhat of a vested interest in keeping the debate open."

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