Researchers unravel the mystery of marine methane oxidation

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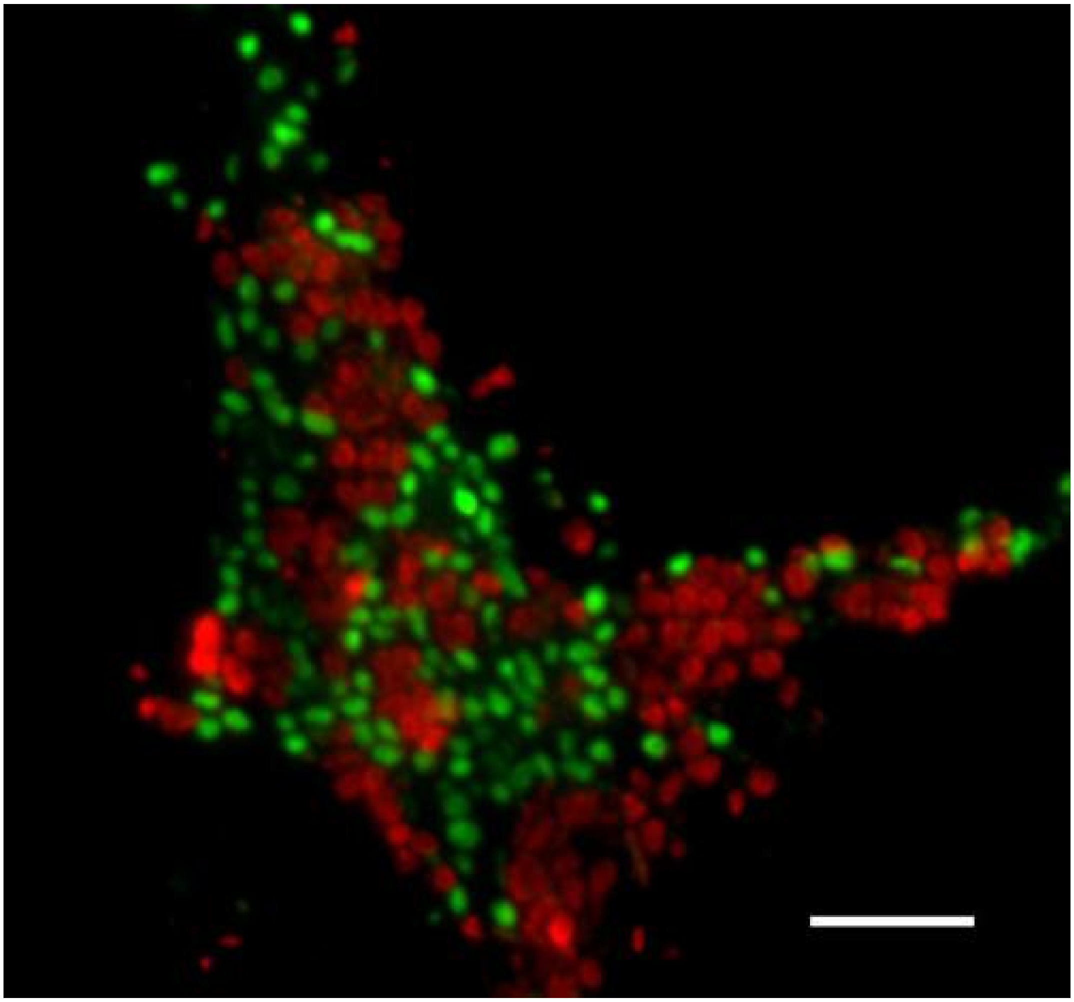
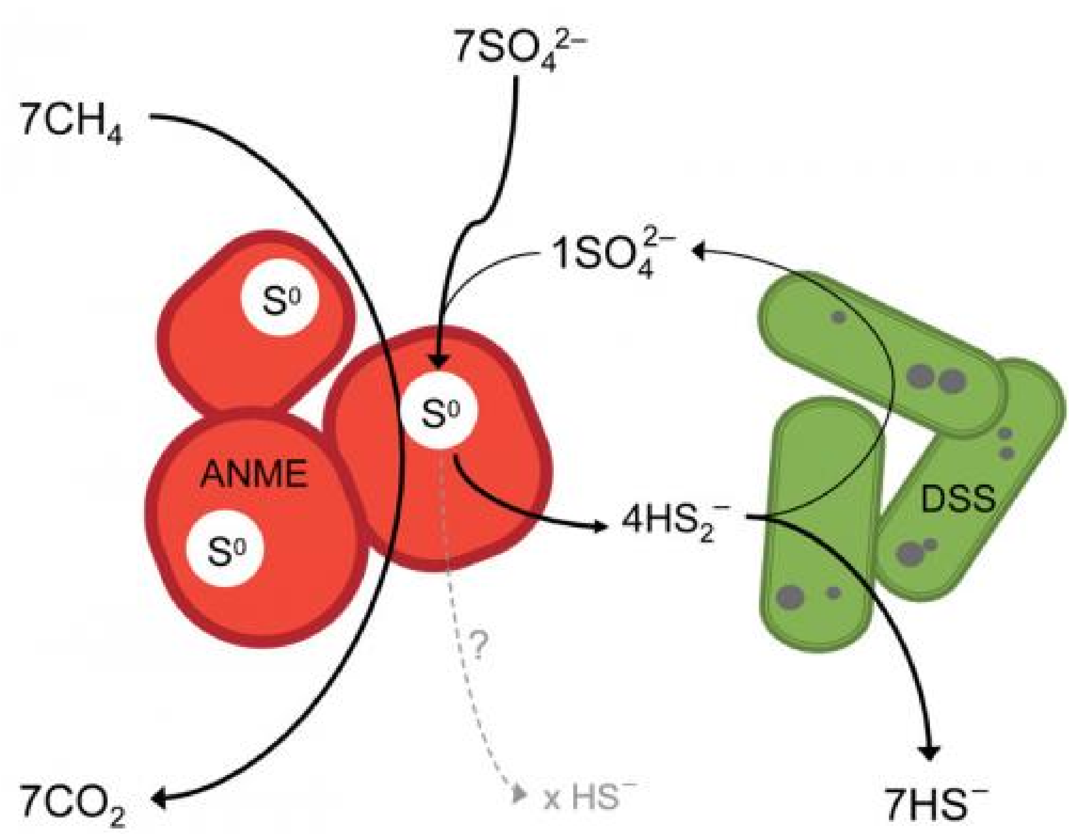


The enrichment of the microorganisms responsible for marine AOM, archaea in red and bacteria in green from the Isis Mud Volcano in the Mediterranean Sea has taken eight years of continuous incubation. Without these cultures it would not have been possible to trace down the complex sulfur cycling involved in AOM. Credit: Jana Milucka, MPI f. Marine Microbiology

(Phys.org)—Microbiologists and geochemists from the Max Planck Institute for Marine Microbiology, along with their colleagues from Vienna and Mainz, show that marine methane oxidation coupled to sulfate respiration can be performed by a single microorganism, a member of the ancient kingdom of the Archaea, and does not need to be carried out in collaboration with a bacterium, as previously thought. They published their discovery as an article in the renowned scientific journal *Nature*.

Vast amounts of methane are stored under the ocean floor. Anaerobic oxidation of methane coupled to sulfate respiration (AOM) prevents the release of this potent greenhouse gas into the atmosphere. Although the process was discovered 35 years ago it has remained a long standing mystery as to how microorganisms perform this reaction. A decade ago, an important discovery was made which showed that two different microorganisms are often associated with AOM. It was proposed that these two microorganisms perform different parts of the AOM reaction. One, an archaeon, was supposed to oxidize methane and the other, a bacterium, was supposed to respire sulfate. This implied the existence of an intermediate compound to be shuttled from the methane oxidizer to the sulfate respirer.

Now, the team around Professor Kuypers has turned this whole model on its head. They show that the archaeon not only oxidizes methane but can also respire sulfate and does not necessarily need the bacterial partner. It appears that the archaeon does not employ the common enzyme toolbox that other known sulfate-respiring microorganisms use, but relies on a different, unknown pathway.



In this model, methane oxidation and sulfate respiration to elemental sulfur (or all the way to sulfide) is performed by the methanotrophic archaea. The associated bacteria are disproportionators (sulfur fermentors), which take up produced elemental sulfur in the form of disulfide and turn it into sulfate and sulfide. Dark circles represent iron- and phosphorus-rich precipitates found in the bacteria. Credit: Jana Milucka, MPI f. Marine Microbiology

The basis for this dramatic shift in thinking is the observation that elemental sulfur is formed and accumulates in the methane-oxidizing archaeon. "Using chromatographic and state-of-the-art spectroscopic techniques we found surprisingly high concentrations of elemental sulfur in our cultures", says Professor Marcel Kuypers and adds: "The single-cell techniques showed that the sulfur content in the methane-degrading archaeon was much higher than in the bacterium. Our experiments show that this sulfur is formed during sulfate respiration."

This finding begs the question: What does the bacterium do if the archaeon does both sulfate respiration and methane oxidation? "The bacteria actually make a living off of the elemental sulfur produced by the archaea," explains Jana Milucka, first author of the study. "The bacteria grow by splitting the elemental sulfur into sulfate and hydrogen sulfide. This is a form of fermentation, like the process that produces alcohol."

"Until now we have always had trouble explaining the occurrence of elemental sulfur in oxygen-free sediments," notes Tim Ferdelman, scientist at the MPI Bremen and coauthor on the publication. "Our discoveries not only provide a mechanism for marine methane oxidation but also cast a new light on the carbon and sulfur cycling in marine, methane-rich sediments."

More information: Jana Milucka, Timothy G. Ferdelman, Lubos Polerecky, Daniela Franzke, Gunter Wegener, Markus Schmid, Ingo Lieberwirth, Michael Wagner, Friedrich Widdel, Marcel M. M. Kuypers, Zerovalent sulfur is a key intermediate in marine methane oxidation, *Nature*, 2012. 8 November, 2012. Doi: 10.1038/nature11656

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