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Back to basics

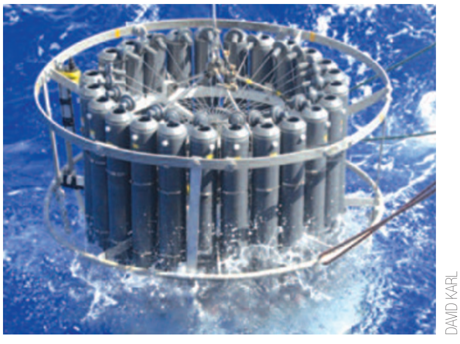
The discovery that biogenic methane production may not be limited to oxygen-free environments throws conventional thinking into turmoil, and calls into question basic assumptions regarding the global methane budget.

Mechanisms of biogenic methane production have fallen under scrutiny. Until recently methane, a greenhouse gas second only to CO_2 in its climatic importance, was thought to be produced exclusively by anaerobic bacteria living in oxygen-free environments like swamps, rice paddies and more curiously, the insides of termites. The discovery that methane may be produced in the oxygen-rich interior of plants, without the aid of bacteria, shattered this understanding (*Nature* **365,** 187–191; 2006), and set in motion a fierce debate regarding the possibility of aerobic methane production (*New Phytol.* **175,** 29–35; 2007, *Environ. Sci. Technol.* **42,** 62–68; 2008).

On page 473 of this issue, Karl and colleagues add more fuel to the fire, suggesting that marine bacteria might produce significant amounts of methane in the oxygen-rich surface waters of the world's oceans. Their findings not only add to the debate on alternative aerobic pathways of methane production, but may help to resolve the long-lived 'oceanic methane paradox': the conundrum of persistent, inexplicably high methane concentrations in the oxic upper oceans.

Doubts about the fundamentals of methane production started to emerge in 2005, when a group of researchers used satellite data to chart tropospheric concentrations of this greenhouse gas on a global scale (*Science* **308,** 1010–1014; 2005). The methane distribution map they created captured the biogenic plumes of methane rising up from paddy fields in China and the fossil-fuel derived methane pouring out of coal mines in the United States. This was the world's methane emissions laid bare.

From this vantage point something striking emerged: levels of methane above the broadleaved evergreen forests of the tropics were significantly higher than expected. The origins of these methane emissions, which exceeded predictions by 4%, were a mystery, and suggested the presence of an as yet unidentified source.


DAVID KARL

Seawater sampler used by Karl and colleagues.

Only a year later, the suggestion by Keppler and colleagues that terrestrial plants emit methane under aerobic physiological conditions (*Nature* **365,** 187–191; 2006) presented a possible solution to this puzzle. Although the amount of methane emitted from individual plants was small, when scaled up to the global level emissions from plants were disconcertingly large, constituting approximately 10–30% of annual source strength. This astonishing proposal marked the beginning of a split between conventional wisdom and current thought.

Unsurprisingly, these findings shook the plant and climatic scientific communities and unleashed a throng of commentaries and rebuttals. If true, we will have to revise our understanding of methane production, reassess the palaeoclimatic records, redesign our climate models and try to understand how we could have missed such a potentially massive source. But before rushing into all this, one crucial question awaits an answer: what is the mechanism? Without a good idea of how plants actually produce methane, the findings stand on shaky ground.

Now, with the possibility of land-based aerobic methane emissions still hanging in the air, the debate is spreading to the oceans. But here, the suggestion of aerobic methane production comes with a mechanism: Karl and his group suggest that bacterial degradation of the phosphate-containing compound methylphosphonate generates methane as a by-product. The abundance of this compound in the surface waters of the world's oceans has yet to be determined, but the findings offer an explanation for the curiously high levels of methane in these oxygen-rich waters. Furthermore, a tentative link between climate warming, ocean stratification, nutrient availability and the activity of this marine methane production pathway suggests a potential positive feedback between ocean and climate.

It seems astonishing that up until two years ago even the most basic mechanisms of methane production were not understood. Had it not been for the work of Keppler, Karl and their groups we might still be in the dark as to the possibility of aerobic methane production on land and in the sea. Both studies highlight the tremendous importance of probing those curious anomalies that appear to defy explanation, such as the unexpectedly high methane concentrations above the world's tropical forests and in the oxic upper oceans.

The latest report from the Intergovernmental Panel on Climate Change stressed that we need a better understanding of the relationship between climate and today's industrially perturbed biogeochemical cycles. Understanding the significance of natural methane emissions for the world's methane budget is a first step in that direction and thus a matter of global concern.