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Old methane and modern climate change

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Old methane is less important for our immediate future than contemporary sources

Carbon is stored over thousands of years in many natural reservoirs in land and ocean ecosystems. This is vital for regulating global climate. These old carbon stores are vulnerable to climate change, which can cause this carbon to be released in the form of greenhouse gases such as methane. If these gases reach the atmosphere, they can drive further warming, which has implications for all life on Earth (see the figure) (*1*). But such positive feedback loops are a major uncertainty when predicting future climate change (*2*). On page 907 of this issue, Dyonisius *et al*. describe their search for signals of old methane released to the atmosphere during the last deglaciation about 18,000 to 8000 years ago. This was when Earth last showed warming similar to what is predicted for our immediate future. They found that methane emissions from old carbon sources during this time were small, suggesting that substantial emissions of old methane may not be triggered in response to current and near-future climate change.

Methane is about 86 times more powerful as a greenhouse gas than carbon dioxide over a 20-year time period—the time scale in which global action is needed to reduce carbon emissions from human activities and limit catastrophic climate change. The two main sources of potential methane release to the atmosphere from destabilization of old carbon stores are methane hydrates and permafrost regions of the Arctic, taiga forests, and Tibetan Plateau (*3*). During the last deglaciation period, Earth shed much of its vast glacial ice sheets as the global climate warmed by around 4°C. If old methane was an important driver of that period of warming, it will likely be important in modern climate change.

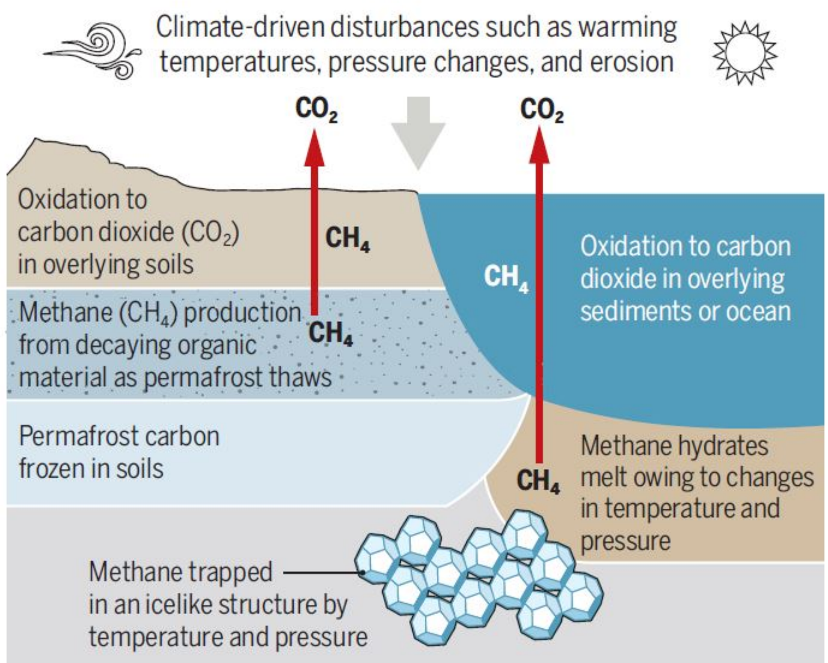
Dyonisius *et al*. extracted methane from ice cores in the Antarctic for radiocarbon (^{14}C) dating in the same way an archaeologist radiocarbon dates cultural artefacts. Contemporary methane will have a radiocarbon age close to the year of its release; old methane will be so old it will have no radiocarbon in it at all, known as "radiocarbon-dead." Ice core records trap bubbles of air during formation, and these bubbles represent an archive of atmospheric composition that spans up to a million years. However, large amounts of ice on the order of 1,000 kg are needed for a single radiocarbon date of this methane. This study presents an impressive 11 such dates spanning 15,000 to 8,000 years ago.

Dyonisius e*t al*. found no evidence for substantial releases of methane from old carbon sources. The methane they found was overwhelmingly contemporary relative to the time period that each sample represented, indicating that the vast majority of methane in the atmosphere during the period under study was derived from the decomposition of recently formed organic carbon, such as plants and soil, and not from the destabilization of old carbon stores. Given the substantial size of these old carbon reservoirs and their theorized sensitivity to climate change, why don't we see evidence for their release as methane?

Methane hydrates contain between 500 and 4000 giga–metric tons of old carbon, roughly one to five times the amount of carbon currently in the atmosphere (including carbon dioxide). This old carbon is mostly biologically produced methane that has been trapped in a crystalline water (icelike) structure as the result of low temperatures and high pressures. Methane hydrates are found deep in the ocean and also trapped under permafrost and glacial ice sheets. Regions of permanently frozen ground, or permafrost, contain around 1300 giga–metric tons of carbon in frozen soils, almost a quarter of which is at least as old as the last glacial maximum (*4*). Both methane hydrates and permafrost are carbon reservoirs that are vulnerable to climate warming because their storage capabilities are temperature controlled. Methane hydrates are also vulnerable to pressure changes owing to sea level fluctuations and disappearing permafrost and ice sheets.

Most old methane is oxidized before it can reach the atmosphere

Whether released from melting methane hydrates or produced from thawing permafrost, to reach the atmosphere, old methane must avoid being oxidized to carbon dioxide by microorganisms.



However, old methane release occurs much slower than the pace of modern climate change. This is because methane is a rich source of energy within ecosystem food webs, particularly for microorganisms that consume this methane and release carbon dioxide. Thus, old methane is often rapidly consumed by microorganisms living in sediments, soils, and water, which convert it to carbon dioxide before it can be released to the atmosphere (*5, 6*). Some methane will escape this process and, along with the carbon dioxide produced from these microorganisms, will still have the potential to influence global climate (*7*).

How important will old methane be to modern climate change? Old methane release may have been important in the geological past because of the long time scales involved (*8*). Hundreds or even thousands of years of warming may be required to generate sustained methane release from old carbon stores that can then outpace methane consumption (*3, 7*). Old methane release therefore does not occur fast enough nor at magnitudes that will be important in the immediate future when compared with methane release from contemporary sources such as wetlands and half of all methane currently in the atmosphere, respectively (*2, 9, 10*). And despite the potency of methane as a greenhouse gas, it is still second in importance to carbon dioxide, which is a much more abundant climate pollutant from human industrial activity and a product of natural ecosystem carbon cycling.

Slowing modern climate change is important to decrease the chance of old methane adding substantially to an already overloaded atmospheric carbon pool (*10*). Reduction of methane as a product of human activity, such as agriculture and the fossil-fuel industry, remains an important component of climate change mitigation efforts (*2, 11*). Although methane hydrates and permafrost carbon are unlikely to be major sources of methane to the atmosphere in the immediate future, unrestrained climate change over the coming century could lead to their destabilization. This could drive sustained emissions of old methane to the atmosphere over the following centuries, causing further warming.

How much methane would be released, at what rates, and for how long are important unanswered questions. In the geological past before the time span of ice cores, the full importance of methane to global climate fluctuations is a mystery. To better explore this geological time span, the development of a useful proxy for past atmospheric methane concentrations, parallel to what is used as a proxy for carbon dioxide (*12*), remains an elusive goal (*13*). It will also be important to search for evidence of old methane release as an indicator of destabilization of current old carbon reservoirs and to serve as a baseline for the future. Methane hydrates and permafrost regions are large potential sources of old methane to the atmosphere in the long term but are less important for our immediate future than contemporary sources.

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