is forced into the narrow gorge, the river has ploughed deeply into the adjacent wall of rock that blocked the river in 1999. As a result, the gorge entrance has been shifted downstream by nearly 90 metres. Not only has the gorge shortened, but the advancing braided channel is bevelling a new wide valley floor and erasing both gorge and terraces in the process. If this continues at the present rate, the entire valley floor could be reset in just 50 years.

Cook *et al.* name this process 'downstream sweep erosion', and propose that it is a general mechanism for gorge eradication and wide valley planation. Although they offer hints of similar valley evolution elsewhere, conditions at the Daan River site may be uniquely suited for this mechanism to occur: extremely weak bedrock, frequent typhoon floods, significant damming of the entire valley and the short longitudinal extent of the gorge relative to the pre-existing valley width. Where conditions differ, such as in the crystalline bedrock of the Swiss Alps[8], bedrock gorges are not so short-lived.

What determines whether a gorge persists or perishes is a question that remains to be answered. It is unclear which factors govern when, and how rapidly, rivers erode laterally into rock and what drives shifts between lateral and vertical incision. The relative influences of rock strength, uplift rate, sediment supply, river planform, and the frequency and magnitude of floods and earthquakes are yet to be determined. There are many unknowns regarding how the evolution of the Daan River gorge may apply elsewhere on Earth, let alone on the surfaces of other planetary bodies where fluvial terraces and bedrock gorges have formed[9,10] under vastly different conditions.

Cook *et al.*[1] find that downstream sweep erosion is rapidly erasing the Daan River gorge and suggest it will be eradicated well before the next big earthquake occurs. The vanishing Daan River gorge provides a rare portrait of a landscape evolving on a human timescale, and an unusual chance to read the fine print before the pages are eroded away and lost for all time. ❐

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SEAFLOOR METHANE

Atlantic bubble bath

The release of large quantities of methane from ocean sediments might affect global climate change. The discovery of expansive methane seeps along the US Atlantic margin provides an ideal test bed for such a marine methane–climate connection.

John Kessler

Sediments line the seafloor at continental margins and contain a massive and dynamic reservoir of the greenhouse gas methane. The global magnitude of this methane reservoir is staggering. It is estimated as one of the largest carbon reservoirs on Earth[1–3] and contains about ten times more carbon than the atmosphere. Direct transfer of even a small fraction of this methane to the atmosphere would have catastrophic effects on Earth's climate, a process that has been proposed as both an initial driver of and a positive feedback to climate change[4,5]. However, the methane–climate connection is difficult to test because the sources of methane are diverse and the processes controlling methane release, especially those modulated by climate, are varied and rarely found in one environment. Writing in *Nature Geoscience*, Skarke *et al.*[6] report the discovery of more than 500 methane seeps at various water depths and physical and geological conditions along the US Atlantic margin; this may well be one of the best locations to critically evaluate the interplay of changing climate and oceanic methane.

One of the most radical hypotheses involving global climate change is the waking of the sleeping giants — massive global carbon reservoirs that are currently disconnected from atmospheric greenhouse-gas dynamics, but that could awaken and connect with the atmosphere under changing environmental conditions. Sleeping giants include permafrost and methane clathrate hydrates, but the clathrate hydrates found in ocean sediments are considered the largest. These solid, ice-like structures are stable only under specific conditions (low temperature, high pressure, high methane concentration) and are estimated to contain a quantity of methane roughly equal in magnitude to the sum of all fossil fuel reservoirs on Earth[1,7]. If even a fraction of the clathrate hydrate reservoir is destabilized, for example, by warming ocean bottom waters[8], the influence on climate could therefore be profound. Once released to the ocean, methane can be dissolved in the water or emitted directly to the atmosphere as a bubble of gas[9] (Fig. 1). Dissolved methane is either emitted diffusively to the atmosphere[10] or consumed by microbes[11] in a process that produces carbon dioxide, also a greenhouse gas. It is therefore important to understand any connection between seafloor methane release and changing climate.

A significant roadblock to investigating the methane–climate connection has been the identification of regions where methane and climate are noticeably connected. Many known methane seeps are located along active continental margins and tectonic faults with a connection to a deeper geologic methane reservoir[11,12]. Additionally, geothermal heat flow, variations in the deeper source flux of methane and tectonically driven compression can all influence methane dynamics in a fashion that is unrelated to climatic feedbacks. Methane clathrate

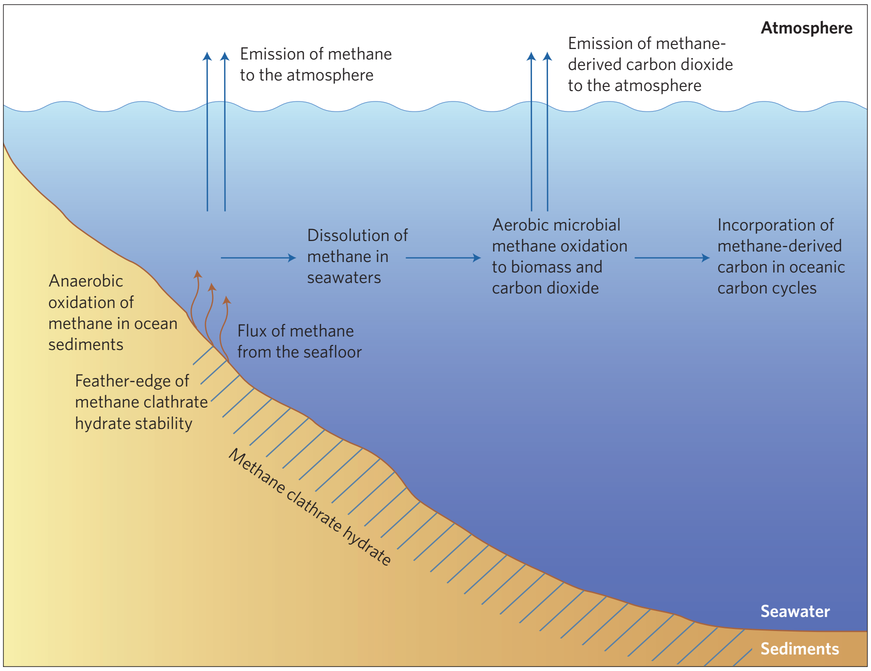

Figure 1 | Schematic of the seawater methane cycle. When methane is released from seafloor sediments, it can dissolve into the water to be emitted diffusively to the atmosphere, or be consumed by microbes, a process that generates carbon dioxide. Alternatively, the methane can be emitted directly to the atmosphere as a bubble of gas. Arrows represent fluxes that are all hypothesized to increase with increasing ocean water temperature. The extent to which methane released from the seafloor can influence the atmospheric fluxes of the greenhouse gases methane and carbon dioxide is currently unknown. Skarke and colleagues[6] have discovered over 500 methane seeps along the Atlantic margin of the northern United States, identifying an ideal test bed for many methane–climate connections.

hydrates are widespread in passive continental margins even without a connection to the deeper geosphere. Their stability at the shallowest depths is largely driven by changes in bottom-water temperature[13], yet the occurrence of equally widespread methane emissions from the seafloor has not been documented outside of Arctic regions[14,15]. This may lead to the false impression that methane clathrate hydrates are stable outside of the Arctic.

Skarke and colleagues[6] have discovered numerous methane seeps in a relatively accessible passive margin outside of the Arctic. They used water-column backscatter data, collected between September 2011 and August 2013 using multi-beam sonar instruments, to identify bubbles and methane seeps across the margin of the Atlantic Ocean between Cape Hatteras and Georges Bank in the northern United States. The seeps occur at a range of conditions. Shallow-water seeps, in water depths of less than 100 m, could be associated with groundwater discharge and most likely emit significant amounts of methane directly to the atmosphere. Deep-water seeps at water depths greater than 1,000 m, on the other hand, may source methane from deeper geologic reservoirs, supplied through fractures that exist even in this passive-margin setting. However, the majority of seeps were found on the upper continental slope, between water depths of 400 and 600 m. This depth is coincident with the upper limit of methane clathrate hydrate stability, implying that slight changes in ocean water temperature should influence methane emissions from the seafloor.

Extrapolating the density of seeps observed along the Atlantic margin of the United States to passive margins globally implies that tens of thousands of seeps could exist in similar settings. The study therefore implies that the decomposition of clathrate hydrates at mid-latitudes is ubiquitous. The extent to which changes in the decomposition of methane clathrate hydrate influences carbon cycling and climate will ultimately depend on the magnitude and timescales of change.

The discovery of these seeps does not directly inform our view of the marine methane–climate connection. However, the study does identify a region where we can investigate our most pressing questions, such as how substantial and sustained any variation in bottom-water temperature has to be to significantly affect the flux of methane from the seafloor and whether the position of currents, in this case the Gulf Stream, influences bottom-water temperature in such a way that changes in methane release from the seafloor are observed. Even after methane is released from ocean sediments, it is unknown what, if any, influence it may have on climate. Thus, this region can be used to further address questions as to how the emitted methane is partitioned between marine biological oxidation and atmospheric release, whether this partitioning changes with environmental conditions, and the significance of any downstream effects following conversion of methane by microbial alteration, including the influence on seawater biochemistry, dissolved oxygen content, ocean acidification and the sea–air flux of carbon dioxide (Fig. 1).

Skarke and colleagues'[6] discovery of numerous methane seeps on a passive continental margin, in mid-latitudes and at the edge of hydrate stability, highlights an ideal region where the methane–climate connection can be investigated. The study documents a location, outside of the Arctic, where methane is bubbling into the ocean at depths where clathrate stability is sensitive to changing ocean temperature. The accessibility of this region will surely draw a flurry of research investigating the influence of climate-dependent parameters, such as bottom-water temperature, on methane emissions and subsequent biogeochemical cycling. ❐

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