Methane: Promise and Peril of the Arctic

The author accompanies a Norwegian research vessel to the edge of the continental shelf off Svalbard to study methane seepage from the seabed.

Text and photographs by
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This steel carousel, called a rosette, is winched aboard after being lowered to the seafloor to collect water samples at various depths for testing related to methane bubbling.

At 78° north latitude, the snowy mountains of Prins Karls Forlandet loom over the dark waters of CAGE institute's methane study site off the west coast of the Svalbard archipelago.

The University of Tromsø's research ship, R/V *Helmer Hanssen,* moors in Isfjorden at the end of a week investigating seafloor methane.

CLINGING TO MY BUNK ALL NIGHT IN GUT-WRENCHING seas, I wistfully thought back to terra firma on mainland Norway a few days earlier. Before boarding the University of Tromsø's research ship, R/V *Helmer Hanssen*, I had watched a team of engineers put finishing touches on two golf-cart-sized crafts brimming with scientific instruments. Now the so-called landers were lashed to our aft deck looking like NASA probes bound for planetary exploration, except these were headed for our own planet's continental shelf in the Svalbard archipelago, Norway's northernmost territory, 800 miles from the North Pole.

The landers would be monitoring chemistry, particularly methane, for an entire year to glean a better understanding of how that substance, 25 times more potent than carbon dioxide as a greenhouse gas, might affect Earth's future climate. At nearly half a million dollars each, the new landers represented the single most ambitious effort by Norway's CAGE institute (Center for Arctic Gas Hydrate, Environment and Climate) to advance seafloor methane research.

CAGE scientists already have evidence that oceans can absorb some of the methane that naturally bubbles up from the seafloor, but knowing how much is too much is crucial to predicting climate change. A much bigger threat than methane is its cousin, an ice-like substance called methane hydrate. Trapped semi-frozen beneath seafloors worldwide, methane hydrate is a sleeping giant that can expand 160 times when changed to gas. That's exciting news for oil companies, but terrifying for climate scientists. Some of Norway's largest reservoirs lie right along the continental shelf where a slight rise in temperature could thaw and unleash a methane hydrate monster.

"Methane hydrates serve as a kind of cement of the sediments," Dr. Peter Linke told me the next morning. As a scientist at Germany's GEOMAR Helmholtz Centre for Ocean Research, Linke works closely with CAGE and was on our cruise to supervise deployment of the German-built landers. "Our fear is that if this cement gets dissolved, sediment might slide down the slope. If a large volume of sediment is moving, this might cause a tsunami, which has happened before."

Where climatologists see great peril, oil companies see great promise. While its economy is based largely on oil, Norway is looking at all other possibilities, especially since global reserves of hydrate-bound methane have been estimated at as high as 10,000 gigatonnes—twice the world's total petroleum,

> *Geothermal and bacterial methane emanate from the seafloor in features called seeps.*

natural gas and coal reserves combined.

Norway is not alone in putting a lot of effort and money into researching these seemingly innocuous bubbles at the bottom of the ocean. In recent years, methane has become the subject of intense international scrutiny, both as an environmental threat and as an energy windfall. The Japanese have shown it is possible to extract methane from seafloor hydrates, but an uncontrolled, quick increase of methane from a meltdown could produce a vicious cycle: the more methane emitted into the atmosphere, the more the oceans warm and the more hydrates continue to destabilize.

Like oil and coal, natural gas forms deep beneath the seafloor under great pressure and heat where ancient organic matter decomposes without oxygen. Bacteria also produce such gas through anaerobic decomposition, similar to what they do in bogs and swamps on land. Both geothermal and bacterial methane emanate from the seafloor in features called seeps, but gaseous seeps are just a small part of the story. On the way up through the seabed where cold temperatures and pressure often converge in the perfect combination, lots of methane gets trapped as solid hydrates.

RESEARCH ON SEEPS AND HYDRATES BEGAN IN THE 1980S, around the time scientists noticed natural carbonate chimneys displayed as curios in the yards of fishermen in Corvallis, Oregon. Trawlers had accidentally dredged the chimneys from the seafloor, but this serendipitous discovery helped launch a new field of science. Like many budding disciplines, research on marine methane attracted scientists of all kinds, from biologists to geochemists to geologists to physicists.

"We were all trying to construct explanations for the who, what and why," Linke told me. A few years later, he and his boss, one of the first to stumble across the fishermen's curios, took a crude methane sniffer aboard a German research vessel in the Barents Sea. Right away they found seeps everywhere, but their good luck ran out when a massive storm hit.

"We thought we'd never make it back," Linke recalled. "It was a surprise October gale. For three days we had these huge waves and the boat swinging back and forth at a 42-degree tilt. It was crazy. We had heavy icing and smashed windows and labs filling with water."

His description made my "gut-wrenching seas" look like a splash in the kiddie pool, but whatever weather was yet to come, the week-long schedule promised to be grueling. Sampling water and air within a 400-square-kilometer sector known for methane seeps, 16 scientists would be measuring microbial and chemical activity at 65 stations plus launching the two landers. Adjacent to our survey site, under the seabed at the very edge of the

A deck hand pulls the rosette aboard at one of 65 methane sampling stations.

continental shelf, sat large hydrate reservoirs. Should those hydrates ever begin bubbling off, CAGE research findings could be crucial in predicting the consequences.

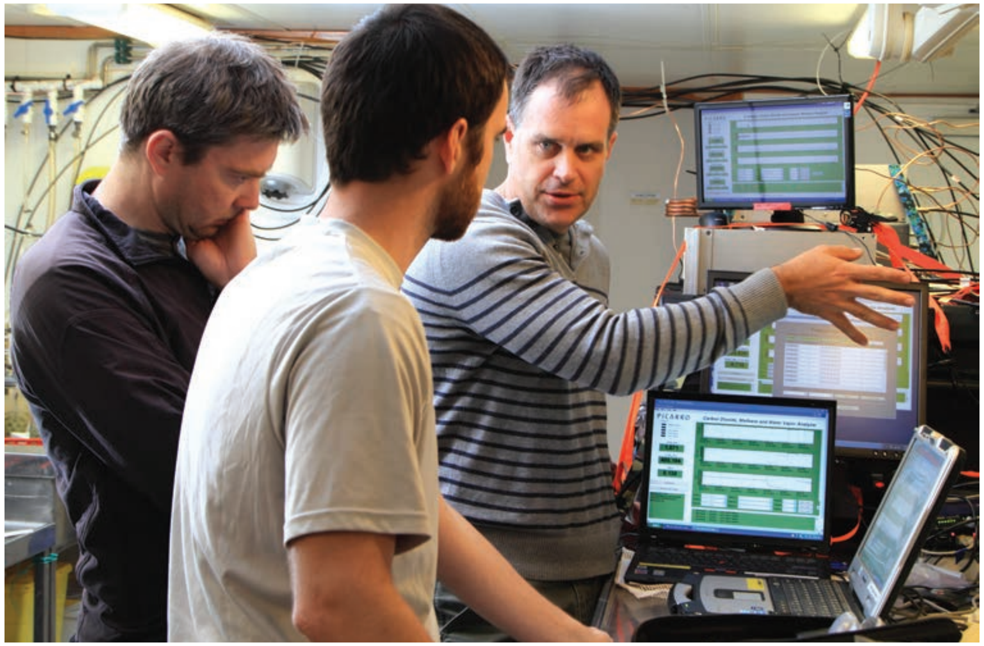
In methane hydrates, the gas molecule is actually trapped in a "cage" of water molecules, hence the name of Norway's CAGE institute. Hydrates look and feel like ice, but are not a frozen gas. In fact, they are more akin to minerals because they have a geometric architecture rather than a random structure like true ice. Another distinction: unlike frozen water, a lump of methane hydrate can be set on fire.

Hydrates require low temperatures and high pressure to remain intact. There are normally plenty of both in the Arctic Ocean—lots of cold and tons of pressure beneath the sea floor. Along Svalbard's continental shelf, however, hydrates reside in relatively shallow waters near the top of the seabed where required pressure is marginal. Such that even a small change in water temperature can initiate a meltdown.

It's not all bad news, though. According to Dr. John Pohlman, a U.S. Geological Survey scientist working with CAGE, methane seeps might actually help reduce greenhouse gas.

"I call it the Seep Fertilization Hypothesis," Pohlman explained as he set up the cruise's main experiment. "On this same survey last year I noticed that where methane content was highest at the surface, there was also a depletion of carbon dioxide in the water. We don't yet understand why, but the release

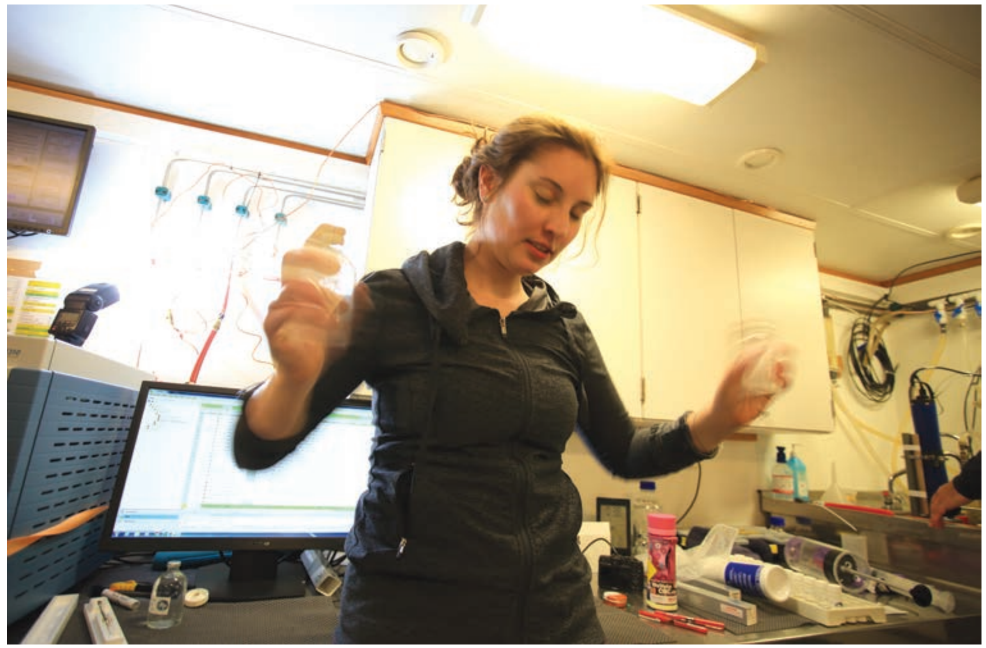
Pohlman and two colleagues were busy rigging machines to measure methane and carbon dioxide.



Biogeochemist John Pohlman discusses the set up of equipment for measuring methane and carbon dioxide with two of his colleagues.

Biogeochemist Helge Niemann drains water from a rosette canister for radioactive testing of methane-loving bacteria called methanotrophs.

Microbiologist Friederike Gründger sets a microfilter into a test tube to strain water samples and check the identity of the methanotrophs with the aid of fluoresence microscopy.



Doctoral student Carolyn Graves vigorously shakes water samples to create gas bubbles for extraction and testing of methane and carbon dioxide content.

The roster of high-tech devices . . . read like a Christmas toy list for oceanographers.

of methane bubbles from the seafloor seems to stimulate uptake of CO2 from the water, which leads to uptake of CO2 from the overlying atmosphere."

In Pohlman's model, the water above methane seeps is like a garden full of algae and methane-loving bacteria called methanotrophs. As methane bubbles upward, it carries nutrient-rich deep water with it that fertilizes algae at the surface. The CO2 that methanotrophs produce may also fertilize the algae since, like all plants, algae consume carbon dioxide and produce oxygen. The concept of methane seeps as sponges of greenhouse gases is new for oceanographers.

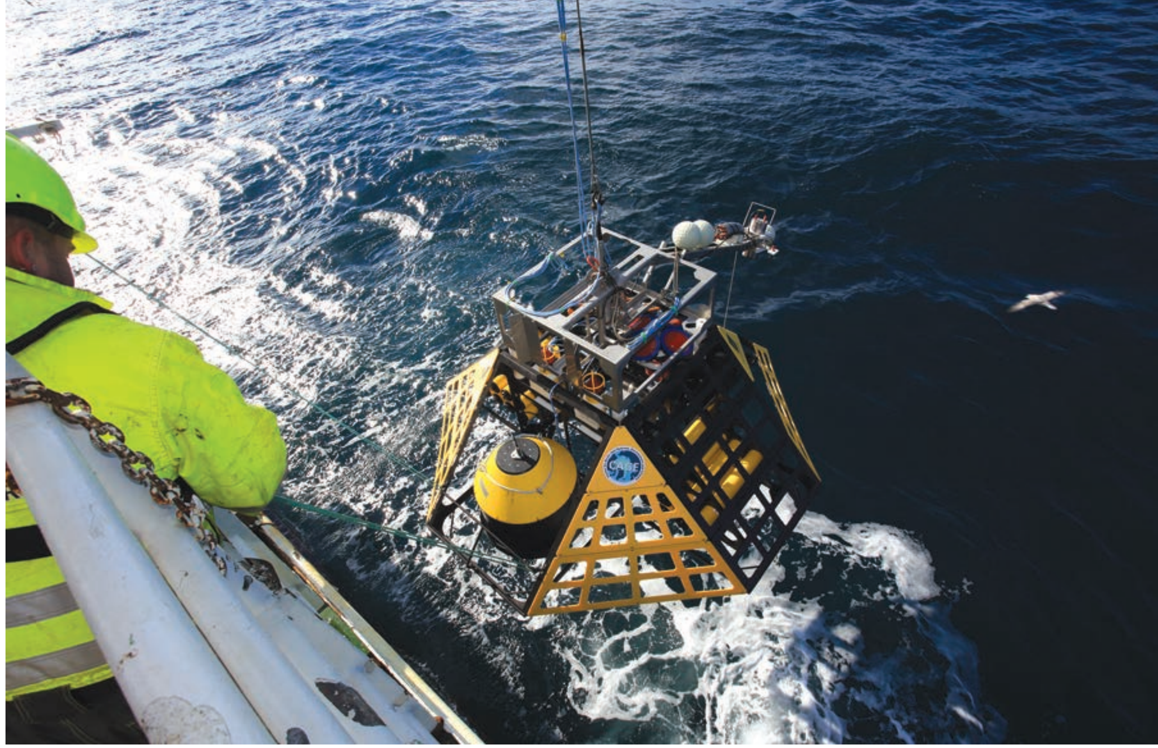
TO DUPLICATE THE PREVIOUS YEAR'S OBSERVATIONS, Pohlman and two colleagues were busy below deck rigging three machines to measure methane and carbon dioxide, as collected outside the ship through funnels and tubing. Two more experiments were crucial in order to see how active methanotrophs are and to determine what happens to excess carbon dioxide. A big question is the capacity of algae to get rid of excess carbon dioxide and prevent it from becoming carbonic acid, which acidifies the ocean. Dying coral reefs around the world are proof that even slight acidification can be devastating.

Biochemist Dr. Helge Niemann of the University of Basel in Switzerland was preparing to measure methanotrophs in a lab above Pohlman's. The afternoon we arrived off the coast of Svalbard, I found him mixing radioactive cocktails.

"Think of it like a dinner table and our guests are methanotrophs," Niemann explained as his assistant carefully worked under a chemical hood. "We want to know how hungry they are, how many they are and who they are."

To measure hunger, Niemann and his assistant were preparing vials of radioactive hydrogen called tritium to add into water samples throughout the week. When they "eat," methanotrophs produce carbon dioxide and water. The amount of radioactive water produced would reveal how much they ate. Other special procedures would allow him to actually count the active bacteria as well as identify their species. Throughout the cruise, another colleague would be sampling seawater acidity and dissolved carbon content at different depths to measure the impact of excess carbon dioxide. All was ready, but the first order of business was deployment of one of the landers.

Linke and others were already on deck in hard hats and life vests gently maneuvering the 1.6-ton unit with a cargo crane. After a year of preparation, the pyramidal lander dangled above cobalt seas, attached to a detachable launch module equipped with a video camera. The roster of high-tech devices aboard the lander read like a Christmas toy list for oceanographers, with half



A CAGE lander is lowered into the sea for a one-year stint on seafloor collecting data on methane bubbling, carbon dioxide, acidity, algal blooms, temperature and ocean currents.

a ton of lithium batteries included to run the package for a full year.

In minutes, the team lowered the lander to the sea. As the cable began winding out, Linke ditched his safety gear and rushed inside to the instrument room to flip on the video feed from the lander's detachable launch frame. Amid an array of computer screens, a grainy blue scene appeared as the craft descended 240 meters (787 feet) toward the seafloor.

Scientists and engineers anxiously clustered together in the darkened room to watch, with only quiet murmurs and the throb of the ship's engines filling the silence. It felt like an Apollo moon landing. Suddenly the seafloor came into view and the cable was brought to full stop. As the ship slowly edged toward the predesignated landing site, occasional rocks appeared and a shark sashayed by.

Then the moment of truth: bubbles. As expected, methane seeps were plentiful here, but the challenge was to position the lander among them, not on top of them, where optimal observations could be made. CAGE's cruise leader sat nervously beside Linke. When the critical moment arrived, he gave her the honor of releasing the lander. With a click of the computer keyboard, the video image careened wildly as remotely-fired explosives shot the launcher off its payload and allowed the lander to set down.

Applause and handshakes filled the room, but the celebration was brief. Now began days of water sampling using a cluster of canisters fixed to a circular steel carousel called a rosette. At each measuring station on our map,

Biogeochemist Peter Linke and CAGE team leader Anna Silyakova gather with colleagues in the instrument room to watch the video link of a lander descending down to the seafloor.

the crew lowered the rosette to just above the seafloor and then retrieved it, snapping open ports on successive canisters to fill them at specific depths.

Over the next 96 hours, with a short pause for launching the second lander, scientists gathered around the rosette every hour after it was pulled aboard, draining canisters into dozens of glass vials for each experiment. They worked continuously in rotating shifts, catching what sleep they could.

By the end of the week, exhausted and bleary-eyed, Pohlman had documented several clear examples of carbon dioxide levels mysteriously dropping above methane seeps, just as he had done one year earlier. Careful analysis and cross-referencing of data from the other experiments would be necessary after the trip to confirm his Seep Fertilization Hypothesis.

ON OUR LAST DAY, THE TEAM TREATED ITSELF TO A BIT OF tourism in a Russian ghost town of Pyramiden, nestled deep in a fjord. It was a perfect conclusion to our trip. Pyramiden is an abandoned coal mining village and a reminder that, although there is plenty of coal, gas and oil in the Arctic, harvesting any of it is difficult.

Founded by Swedes in 1910 and sold to the Soviet Union in 1927, Pyramiden once boasted a population of over 1,000 and was heavily subsidized as a model communist village. As a 1924 signatory of the Svalbard Treaty, which recognizes Norway's sovereignty but allows treaty members to engage in commercial activity there, the Soviet Union maintained Pyramiden

The abandoned Russian coal mining town of Pyramiden remains as a silent testimony to the vagaries of extracting fossil fuels in the high north.

for much of the 20th century until the empire's fall. Dwindling profits and a devastating plane crash that killed 141 miners and their families in 1996 led to the last residents leaving in 1998.

Walking from the dock past mounds of coal and scrap metal, we came to a monolithic town sign (at left) with a small rail car parked beneath identifying the contents as the last ton of coal mined at Pyramiden. In the town's heyday, no extravagance had been spared to lure miners from their meager lives in Russia and Ukraine to this remote Soviet paradise. Frost-resistant grasses imported from Ukraine stretched along broad boulevards lined with modern brick buildings. An expansive basketball gymnasium, natatorium and movie theater graced the sports complex, but dresses, musical instruments and other sundries lay about as if everyone had suddenly vanished. In the ghostly main square, a lonely statue of Lenin stared toward the massive, ancient glacier

As Arctic coal and oil lose their glow . . . natural gas grows ever more attractive.

An opulent staircase in the company canteen is a reminder of the extravagant measures Soviets took to attract Russian and Ukrainian miners to a better life at the end of the earth.

that presided over Pyramiden's meteoric rise and fall, underlining humanity's fleeting presence in this harsh land of ice, storm and darkness.

AS ARCTIC COAL AND OIL LOSE THEIR GLOW AND PETROLEUM giants like Royal Dutch Shell walk away from billions of dollars of investment, natural gas grows ever more attractive. It is a cleaner fossil fuel increasingly used in power plants, home heating and vehicles. If extracting methane hydrates on an industrial scale becomes viable, many nations will have access to substantial reserves. At the Arctic Frontiers conference in Tromsø last January, Norwegian Prime Minister Erna Solberg declared that gas would play a crucial role in oil-rich Norway's transition from fossil fuels to renewables. With the Arctic warming twice as fast as the global average, Norwegian research on methane hydrates is very much on the front burner.

Randall Hyman has covered cultural and environmental topics from the Arctic to the tropics for over 30 years for *Smithsonian*, *National Wildlife*, *American History*, *British Heritage*, *Discover* and various *National Geographic* publications. As the Alicia Patterson Foundation's 2015 Josephine Patterson Albright Fellow, he is covering science, technology, culture and geopolitics in the Norwegian Arctic throughout this year.