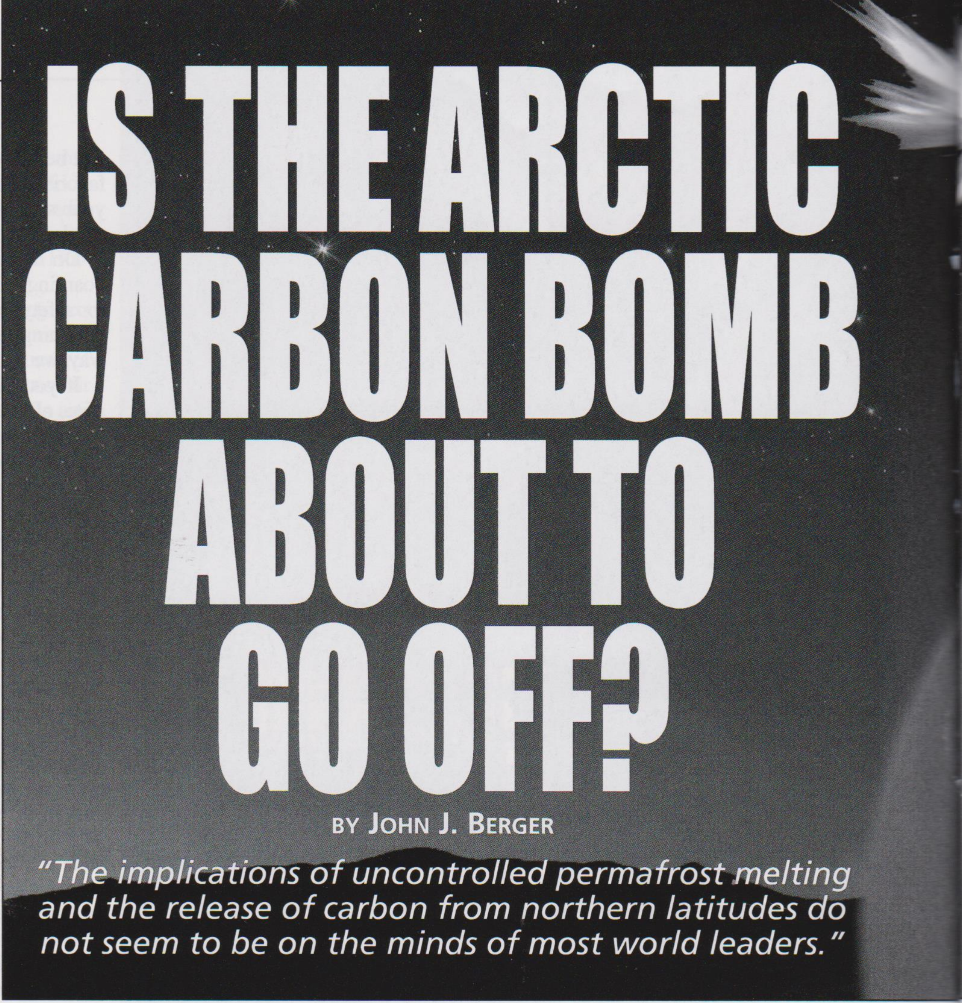

IS THE ARCTIC CARBON BOMB ABOUT TO GO OFF?

BY JOHN J. BERGER

"The implications of uncontrolled permafrost melting and the release of carbon from northern latitudes do not seem to be on the minds of most world leaders."

THE GLOBAL CLIMATE system is comprised of major components or elements. At the largest scale, these include the atmosphere (vapor), cryosphere (snow and ice), hydrosphere (oceans and freshwater), geosphere (soil and rocks), and biosphere (living things). On a smaller scale, each of the major climate elements has key components that themselves can exert powerful impacts on global climate. For example, permafrost—thick subsurface layer of soil that remains frozen year-round—and frozen methane deposits in the seabed, known as methane hydrates or clathrates, are critically important parts of the cryosphere and hence the climate system.

When an element becomes unstable, it not only can accelerate climate change, but potentially can cause a chain reaction consisting of an irreversible, self-intensifying cycle. A global climate element close to one of these dangerously unstable conditions is said to be at a tipping point. At that juncture, an incremental change in climate conditions can provoke a disproportionately large and dramatic feedback response that permanently could disrupt the world's climate. If the feedback is a warming, that warming will cause additional warming in a continuous, positive feedback cycle. A polar icecap or region of permafrost close to its melting point is at a tipping point.

Tipping points are not reversible on time scales of interest to current generations. A climate threshold leading to a tipping point thus is a little like the spring-loaded steel spikes at a parking lot exit. You can roll forward over them, but you cannot back up. Similarly, passing that threshold is a one-way journey that leaves our climate at the mercy of self-reinforcing natural processes.

When the Arctic permafrost tipping point or climate threshold has been passed, the permafrost begins to deliver ever-increasing amounts of heat-trapping gases to the atmosphere in response to global warming. The additional heat-trapping gas then generates additional warming in a vicious, self-amplifying cycle. Eventually this significantly could reduce the planet's ability to support human life.

By 2100, average global temperatures will be warmer than at any time in the past 5,000,000 years, if current emissions trends continue. However, as global temperatures rise, more and more extensive areas of permafrost and methane hydrates will begin thawing, as average increases in global temperature are magnified in the Arctic.

When we warm the planet, we do likewise to the oceans. Warming the oceans is a risky proposition, even if only by a few degrees. In many undersea areas, methane-containing ice lies frozen in undersea permafrost, but at temperatures close to its melting point. Slight warming of the water above these deposits is all it takes to melt the methane ice and release the stored methane—a powerful greenhouse gas with 82 times the global warming impact of carbon dioxide over a 25-year period. In a worst-case scenario, billions of tons of this methane could be released along with whatever also vaporizes from the thawing permafrost of the Arctic tundra—with devastating impacts on Earth's climate.

Permafrost covers one-quarter of the Earth's land area, including 60% of Russia, geographically the world's largest country. The release of carbon dioxide and methane from permafrost and the ocean seabed is a classic tipping-point risk. When permafrost thaws, the organic matter in it can be converted by bacterial action either to carbon dioxide or, in oxygen-poor environments, to the more-potent methane. For thousands of years—and, in some cases, about 1,000,000 years—huge caches of methane have lain frozen and isolated from the atmosphere, both in the northern latitude permafrost and in the frozen seafloor methane clathrate deposits, in which gas is trapped in a crystal lattice cage of frozen water.

The Arctic now has warmed to such an extent, however, that some permafrost and methane hydrate deposits already are beginning to thaw. In fact, methane hydrates in some shallow seafloor areas are bubbling up to the ocean surface—and into the atmosphere.

In deeper ocean areas, however, cold temperatures, high pressure, masses of overlying water, and low oxygen concentration hold the hydrates harmlessly in the icy ocean sediments but, as global surface temperatures rise and gradually penetrate to the seafloor, frozen methane can thaw and form bubbles. If the thawing occurs in the bottom of the deep ocean, the methane can be dissolved in the overlying seawater and oxidized to carbon dioxide by bacteria. While preferable to having the methane released to the atmosphere, the dissolved carbon dioxide further acidifies the ocean.

Modeling studies of methane bubble behavior indicate that, in the deep ocean, the depths of the overlying seawater do provide effective barriers against the transfer of methane bubbles to the atmosphere. The ocean's depth also delays the release of methane and carbon dioxide from frozen storage because of the length of time required for heat to reach the deep ocean sediments. However, in seas of less than 328 feet in depth, a large proportion of methane bubbles that emerge from once-frozen sediments are able to percolate up to the ocean surface without being dissolved and oxidized. It therefore escapes to the atmosphere, much as bubbles from a bottle of soda water escape when the cap is removed.

Substantial amounts of methane also may reach the atmosphere from thawing hydrates in shallow freshwater lakes, wetlands, and reservoirs. About one-third of the Arctic region is covered by millions of freshwater lakes, and their numbers are increasing as higher Arctic temperatures melt more and more permafrost. Ecologist Katey Walter Anthony from the University of Alaska, Fairbanks, has

studied lakes from Alaska to Greenland and Siberia. Her measurements of gas releases from northern lakes and soils show that fossil deposits of methane that were sealed away for thousands of years are escaping and entering the atmosphere. Bubbles of long-dormant methane gas already clearly are visible as they break on the surface of these far northern lakes. In some areas, the surface looks as if it were boiling.

As Arctic seas, lakes, and tundra continue to warm, and more and more permafrost melts, scientists are not certain precisely how quickly methane and carbon dioxide from permafrost and clathrates will reach dangerous levels. Some methane specialists affiliated with the U.S. Geological Survey view global oceanic methane releases as insignificant on a planetary scale, and project that the releases only will cause significant warming in 1,000 to 100,000 years.

If they are in error and the permafrost and shallow seas release more methane than anticipated, it would be too late to stop the process. Ocean sediments contain huge amounts of carbon—1.8 to 2.2 trillion tons—in methane hydrates. If these as-yet imprecise estimates of the methane deposits' magnitude are roughly correct, the deposits would hold two to two-and-one-half times the amount of carbon in the Earth's atmosphere, and several times as much as all the carbon in all the oil, gas, and coal ever burned to date. Thus, were significant fractions of these hydrates to thaw and reach the atmosphere, they would—without question—superheat the climate.

In addition to the ocean methane deposits, roughly 2.1 trillion additional tons of carbon are stored on land in permafrost in the Northern Hemisphere. Most of it lies in the upper, more vulnerable layers of the permafrost. Some of this is much more susceptible to thawing than the carbon in the deep ocean and, as noted, already has started melting.

Researcher Natalia Shakova, who leads the Russia-U.S. Methane Study at the International Arctic Research Center, and her colleagues are finding that the water in the East Siberian Sea perennially is supersaturated with methane from top to bottom from all of the gas already bubbling out of the seafloor. Methane concentrations above the sea surface are 10 times normal open-ocean levels. The East Siberian Sea alone is venting an estimated 7,000,000 metric tons of carbon dioxide per year to the air—a process that, until recently, largely was ignored in climate models.

Research by Shakova and others reveals that, in effect, the "lid" holding methane in the permafrost of shallow seas has opened and that frozen undersea methane—which, until recently, was thought stable—is leaking. The quantities of methane potentially at risk are substantial, as the East Siberian Arctic Sea has an amount of carbon comparable to that of the Siberian tundra. At the moment, these releases are not "alarmingly altering the contemporary global [methane] budget," according to the researchers, but need to be monitored closely to determine whether they might be signaling the start of a period of massive releases.

Clearly, much still needs to be learned about the release of methane from the seafloor. Contemporary models of the process only can provide educated guesses about how methane hydrates will behave when the oceans get warmer. Studies by David Archer, professor in the Department of Geophysical Sciences at the University of Chicago, and colleagues, however, suggest that a warming of 5.4°F could result in the release of half the gargantuan amount of methane stored in seabeds.

Even if these releases did not accelerate, the Arctic has been warming much faster than predicted and twice as fast as anywhere else on the planet, putting its permafrost at risk. Not surprisingly, release of methane from Arctic wetlands (still a relatively small source) increased by one-third from 2003-07. Longer-term measurements are needed to better assess the risk from vast areas of tundra permafrost, Arctic lakes, and wetlands with billions of tons of additional carbon.

More research also is needed to track the destabilization of methane hydrate by shifting ocean currents. A study in *Nature* found that rising temperatures in the Gulf Stream at "intermediate depths" off the East Coast of the U.S. already had destabilized 2,500,000,000 tons of frozen methane hydrate under 4,000 square miles of the seafloor. "A changing Gulf Stream," the authors wrote, "has the potential to thaw and convert hundreds of gigatonnes of frozen methane hydrate trapped below the sea floor into methane gas, increasing the risk of slope failure and methane release."

At present, concentrations of atmospheric carbon dioxide are above any concentrations for the past 2,000,000 to 4,000,000 years. If we persist in continuously adding more and more greenhouse gas to the atmosphere, we will, at some point, reach Arctic temperatures that will cause thousands of square miles of permafrost and shallow clathrates to thaw. This would, in effect, set off the "carbon bombs" lying quietly in the permafrost and the marine clathrate deposits. Earth then would begin a progressive planetary overheating from which civilization as we know it would not recover.

The implications of uncontrolled permafrost melting and the release of carbon from northern latitudes do not seem to be on the minds of most world leaders. They, in turn, are not helping to raise public awareness of this danger. Until leaders comprehend its implications and begin factoring it into their decision-making, scientists need to be much more assertive in bringing it to their attention. ★

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