Phantom

FROM THE DEEP

Hidden in flame, a clathrate of methane hydrate illuminates Scripps geophysicist Neal Driscoll and second-year student Elizabeth Johnstone.

Burning Questions Abound Over Methane Hydrates

BY ROBERT MONROE

One day in November 2000, the trawler *Ocean Selector* took a fateful detour in its search for groundfish.

Captain Brian Dickens had charted a course to a location south of Vancouver Island, British Columbia. He strayed beyond the fishing grounds inhabited by his competitors to try someplace new. Trawling an undersea valley called Barkley Canyon, he dragged his net at a depth of 500 fathoms (3,000 feet), almost twice the depth anyone else usually went.

He had hoped to find a bonanza of perch and rougheye. What the ship netted that day instead would be the single biggest haul on record of a substance like something out of Jules Verne's *20,000 Leagues Under the Sea* and known only to those familiar with the deep ocean.

Selector's net snapped off a chunk of mysterious ice from the seafloor. The mass strained the trawl net's 150,000-pound capacity. However, by the time it came to the surface, it weighed only 15,000 pounds. The block was the size of a school bus.

Dickens recalls that when he first saw it bobbing on the water, it looked like a yellowed piece of iceberg but behaved like an Alka Seltzer, well on its way to seething into nothingness.

His perplexed crew hauled the chunk into the fish hold. By this time it weighed only two tons.

Dickens was relieved that the ice didn't smell of rotting eggs, the calling card of poisonous hydrogen sulfide, a killer of fishermen. Only later, after talking to geophysicists, would he find out that the ice was flammable, a fact the smokers among *Selector*'s crew were lucky enough not to discover, though Dickens swears several of them lit up as they stood over the weird find.

On board *Selector* that day, the nearest thing to a geoscientist was a Canadian government fisheries observer named Chris Cleary, who was there to ensure that the crew adhered to fish catch quotas. While the biologist was searching for a sealable plastic sandwich bag in which to save a piece, the substance was breaking down to the size of snowballs. These were about the size of the biggest samples scientists had retrieved to date in sediment cores. Now the fishermen were throwing chunks off the deck by the hundreds to ready the boat for another trawl.

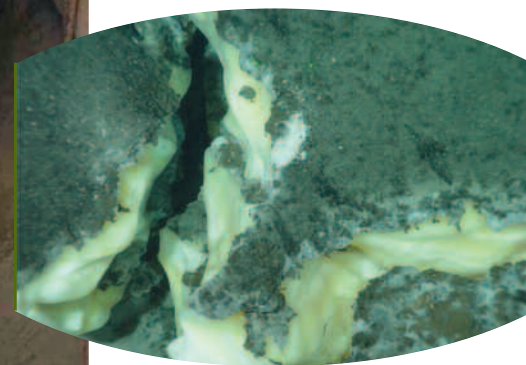
The gas released by the ice kept popping the bag open as Cleary tried to seal it. By the time a small sample stayed put, the entire mini iceberg was gone, the final pieces dissolving like ice cubes in a cup of coffee. What had been a 75-ton mass 90 minutes before would later be identified from a few shaved-ice-sized flecks in the sandwich bag that had survived the journey to *Selector*'s freezer.

OIL AND WATER

The "ice" found off Canada's coast that day was actually a clathrate of the gas methane, trapped inside a lattice of frozen water. It was created in the cold temperature and high pressure of the deep ocean.

In that form it is called methane hydrate. It was first noticed in the 1930s, at the advent of gas transmission, when oil companies began seeing clumps of icelike material clog their pipelines.

Only four decades later did researchers begin to appreciate hydrates as a product of nature with an important function. They can act as a storage facility for gas, the geologic equivalent of the lamp containing a genie. A melted cubic foot of methane hydrate yields a puddle containing 0.8 cubic feet of water and a cloud containing 170 cubic feet of methane gas.



Left, *The strange haul in the hold of* Ocean Selector *in November 2000.* **Above,** *Two years later, a University of Victoria-led team returned to Barkley Canyon and found methane hydrate outcrops on the seafloor. The yellow hydrate pictured measures one meter (3.3 feet) across.*

But in order to perform this function, hydrates must be kept under intense pressure and cold temperatures. To remain intact at 1.8 °C (35 °F), methane hydrates require pressures equivalent to water depths of more than 350 meters (1,150 feet). At sea level, they are as fragile as a fish out of water.

"One of the most remarkable things about gas hydrates is that they and humans are incompatible," said Charlie Paull, a marine geologist at Monterey Bay Aquarium Research Institute and a Scripps Institution of Oceanography alumnus. "They decompose very rapidly under the conditions in which humans observe them and yet the conditions in which hydrates form are common on Earth."

For conflicting reasons, hydrates are remarkable in other ways. They are believed to exist in vast quantities in polar regions and along continental margins in every ocean. Though current estimates may eventually prove them wrong, some researchers have suggested, in fact, that hydrates sequester more carbon than all oil, gas, and coal deposits on Earth combined, spurring interest in them as a potential panacea for an energy-hungry planet.

Yet hydrates may also constitute a sizeable natural hazard. Scientists suspect that the decomposition of hydrates may be behind certain undersea landslides that have occurred throughout history, of the kind that take place when a major component of an undersea land mass suddenly isn't there anymore. At

Opposite page, top, *Protection of investments like the $5-billion* Thunder Horse *platform, seen here in tow in 2004, helps drive oil industry interest in Gulf of Mexico hydrates.* **Bottom,** *Stages of core collection aboard* Uncle John.

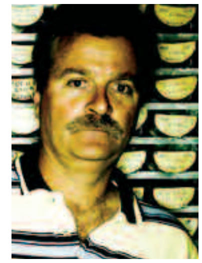
least one such past landslide may have produced a tsunami on the scale of the devastating wave that struck several Indian Ocean countries in December 2004. Researchers at Scripps are studying continental margins in the United States to define areas that might be susceptible to slope failure and consequent tsunami generation.

Trouble also follows hydrate decomposition as catastrophically released methane gas makes its way to the ocean surface. Some scientists suspect that a grand-scale version of the melt-off witnessed by *Selector* would cause an outgassing into the atmosphere large enough to set in motion a dangerous acceleration of global warming. This, too, has happened before. Some researchers suggest that the final act of the Paleocene epoch started 55 million years ago with a methane release from displaced hydrates. The event caused a sharp warming trend that precipitated a reordering of life on Earth that included the first appearances of many modern land mammal species.

With methane hydrate's potential to act as an energy resource, landslide trigger, or climate destabilizer, how will society first come to know it? Speculation still outpaces fact within this young research field. Scientists, for example, are still trying to find ways to pinpoint the whereabouts of hydrates in the ocean basins. In search of answers, Scripps has joined forces with the industry that most frequently encounters them.

SYNERGY FOR ENERGY

A helicopter ride over the Gulf of Mexico showcases some of the world's most expensive machinery. From the air, new oil and gas



"Tsunamis are rare events but their risk is finite. We need to conduct the research on the events that trigger them. We just can't take the risk of not being informed." —Neal Driscoll

megaplatforms look like postage stamps affixed to a rippling blue backdrop. In fact, they are minicities representing leapfrogging exploratory firsts and the regard oil companies have for the gulf's production future. More than 240 kilometers (150 miles) southeast of New Orleans is the newly completed *Thunder Horse*, the world's largest semisubmersible oil and gas rig. The $5 billion platform will enable a consortium led by British Petroleum to extract as much as 250,000 barrels of oil per day from a seafloor more than 1,800 meters (6,000 feet) deep. It is one of several new billion-dollar monster structures in the gulf, tethering to seafloor expanses once considered unreachably deep.

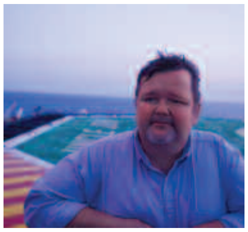
In April 2005, a smaller mobile drilling platform called the *Uncle John* took on an unusual collection of guests. Petroleum exploration firms, service companies, and academics had pooled their resources into a mission four years in the making to characterize the location and quantity of hydrates under the seafloor. The $15-million effort culminated in this cruise. The research party included Scripps geochemist Miriam Kastner, U.S. Geological Survey geologist

Tim Collett, drilling engineers from Chevron, several drilling technology firms, and Scripps project scientist George Claypool as chief scientist.

For oil companies, pushing the envelope of exploration increases the risks associated with coming into contact with hydrates. One industry fear is that natural or human-caused changes in the temperature of the world ocean could affect the low temperatures that hydrates need to exist near the seafloor and cause them to decompose.

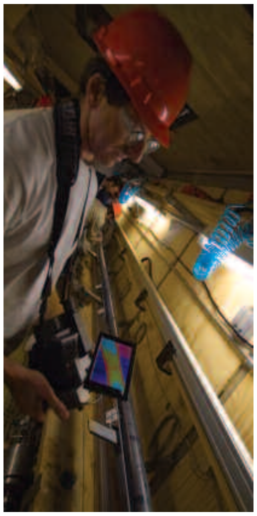
Such a sudden disruption could alter the surface of the ocean floor, bending pipelines, damaging platforms, and endangering the lives of those working on them. While such a broad-scale episode has not been known to take place, the threat is there as is the everyday nuisance already posed by hydrates. Oil companies operating in the gulf have rated pipeline blockage by hydrates as the No. 1 routine impediment to their chief operational goal, steady oil and gas flow. It's an expense that makes its way to your neighborhood gas pump.

"The need to work with hydrates affects your bottom line," Collett said. "The cost impact could even influence whether a project is even successful."

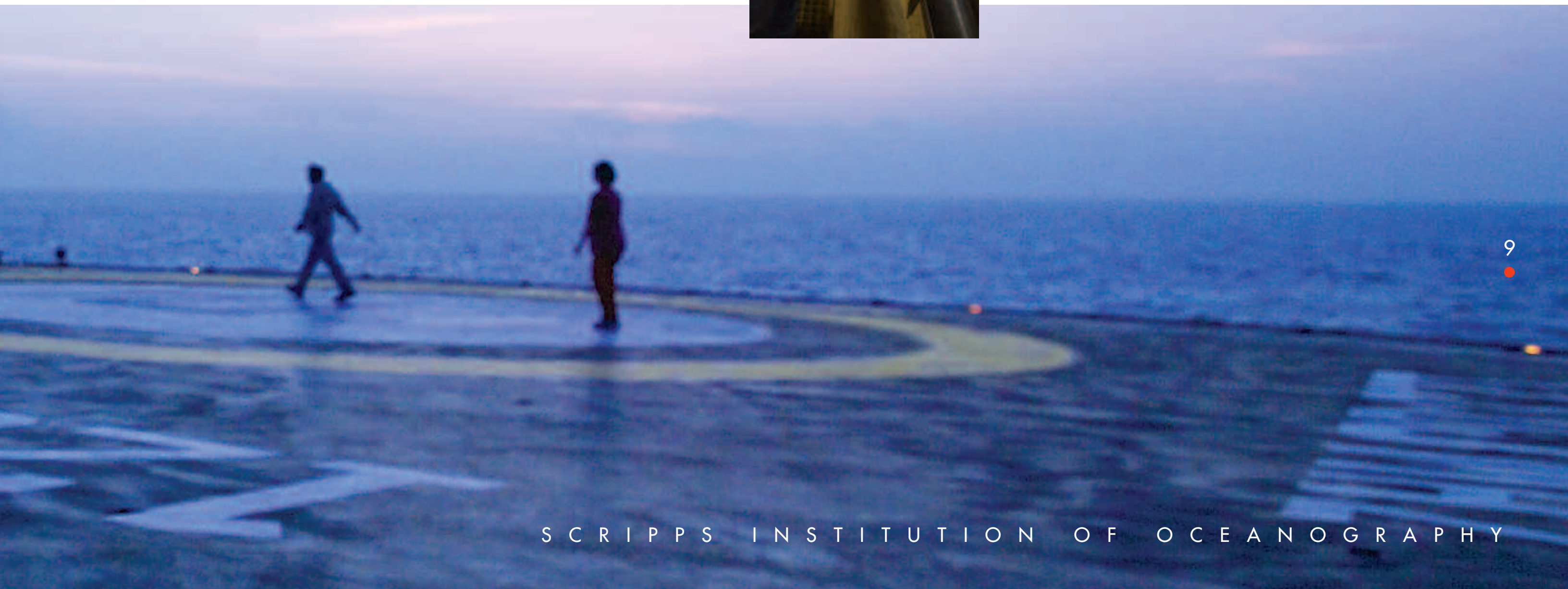


"It's only been in the last 10 to 15 years that we've been able to work in the marine depths where hydrates occur."

—Tim Collett



The 24-hour operation of Uncle John means activity takes place from dusk (left) to dawn when a pair of researchers take an exercise lap aboard its helipad (bottom). ***Above and right,*** *Sediment cores are fed into a van on deck refrigerated to 5 °C (41 °F).* ***Near right,*** *Researchers collect fluids and scan the core segment with a heat-detecting infrared camera in search of cold hydrate chunks.*



STOREGGA SLIDE

CHARLIE PAULL, A SCRIPPS alumnus and currently a marine geologist at Monterey Bay Aquarium Research Institute, hopes to soon take part in a cruise to the Norwegian Sea where a cataclysmic slope failure event took place 8,200 years ago.

The so-called Storegga Slide was a series of undersea sediment collapses that sent a mass of land the size of Iceland tumbling into an undersea valley. One specific slide was big and sudden enough to trigger a tsunami that sent waves 15 meters (46 feet) high smashing into now-populous coastlines in Norway, Iceland, and Scotland.

Many researchers believe that the collapse occurred after hydrates in the shelf dissociated and rendered the shelf unstable. Possibly a trend of rising deep ocean water temperatures over the previous 1,000 years had set the stage for the hydrate breakdown.

Paull is interested in the related questions of what happened to the methane that was in the sediment disturbed by the gas hydrate and believes the answer may lie within remaining hydrate fragments in the area where the dirt and clay finally came to rest.

"We still want to find out what was the fate of the gas that was involved in this landslide," Paull said.

The industry's policy has simply been to avoid hydrates as much as possible, even if that limits access to rich reserves. But as energy needs increase, demand for oil compels companies to deal with them.

In 2001, the U.S. Department of Energy and a consortium of companies ranging from Chevron to Halliburton to the French firm Total convened to address the problem. Two sites in the gulf, where exploratory seismic reflection data indicated the possible presence of gas hydrates, emerged as prime candidates for exploration. At one, an undersea feature called Keathley Canyon, acoustic signals had picked up the presence of a bottom-simulating reflector, a contrast between gas and solid states of methane that mimics the seismic contrast between the seafloor and the water above it. *Uncle John* was dispatched to these sites with the mission of verifying that hydrates and underlying gas were behind those signals.

"WE ARE JUST STARTING TO APPRECIATE THE SIZE OF THE GAS HYDRATE RESERVOIR IN THE EARTH, BUT JUST BECAUSE IT'S A RESERVOIR DOESN'T MEAN IT'S RECOVERABLE TO WHERE YOU CAN STICK IN A STRAW AND SUCK IT OUT."

—CHARLIE PAULL

A GIANT LEAP IN TECHNOLOGY

A month into the cruise, Kastner, Collett, and the other researchers had come to sound like wildcatters who had seen their share of dusters. Disappointing technical problems meant that the first location, Atwater Valley, yielded almost no intact hydrate samples. At Keathley Canyon, the team checked its excitement about what might come up in each new core—with good reason. Few samples appeared there either.

Kastner decided to make hydrates one of her specialties after a 1986 research cruise off Peru. Since then she has developed ways to locate hydrates in cores even if clathrates are no longer present. The melted clathrates tend to dilute the salt in surrounding water. Methane also has an inverse relationship with sulfate, which makes the discovery of one a clue to the absence of the other. In the areas covered by the *Uncle John* cruise, clathrates had likely melted on the way to the surface, leaving Kastner to search for proxies in chunks of ooze from 1,330 meters (4,360 feet) below the surface. By the end of the trip, she had concluded that there were hydrates where the seismic data had predicted they would be even if they were not apparent in the cores.

Though actual clathrates had proved elusive, Kastner noted philosophically that the cruise had achieved several technical firsts: New pressurized cores enabled researchers to perform multiple analyses on samples without having to depressurize them, allowing the samples to remain in their natural state.

"There was a very big leap in technology," Kastner said. "We could do

A crew member ascends the Uncle John *derrick.*

more sophisticated measurements with pressurized cores than ever before."

Kastner was joined on the trip by members of the lab of geophysicist Neal Driscoll, Scripps's principal investigator on the project. Driscoll's main interest is to understand the role hydrates play in maintaining or jeopardizing the stability of undersea slopes. For many, a journal article authored by Driscoll and others was the first notice that concerns about slope collapse should not be limited to the oil industry.

Driscoll's paper in the May 2000 issue of *Geology* began: "The outer continental shelf off southern Virginia and North Carolina might be in the initial stages of large-scale slope failure."

His team went on to document the existence of large cracks in the continental shelf that seemed to be slipping. They sketched out a scenario of the tsunami that could follow such a collapse, predicting that it would unleash upon the Virginia and North Carolina coasts the equivalent of a storm surge spawned by a category three or four hurricane. In this instance, though, residents would have about 90 minutes from the time the slide took place to run for their lives. The paper's prediction reached a wide audience, thanks mostly to the flood of media accounts that seized on the frightening scenarios it proposed.

In a less-noticed follow-up study published last year, Driscoll and colleagues found more evidence pointing to hydrate decomposition as the most likely source of the shelf's instability. The cracks in the shelf appear to have been caused by gas blowouts, releases of enormous bubbles of melted methane that have taken place within the past 20,000 years.

"We found huge anomalies of methane occurrences associated with these cracks and also anomalies in

Above and opposite page, *Neal Driscoll examines split cores at the Scripps Rock Dredges and Sediment Cores Collection.* **Below,** *Kept intact with liquid nitrogen, a hydrate clathrate vanishes quickly at room temperatures, leaving behind only water (bottom) and invisible gas.*

“The relationship [between hydrates and climate change] is only there when you have catastrophic events. I think slope failure is a possibility in our lifetime.”

—Miriam Kastner

salinity. Expulsion of fluids is still active in these cracks,” Driscoll said. “Does this increase or decrease the risk of slope failure? We don’t know because our knowledge about slope failure is still in its infancy.”

FILLING IN THE GAPS

“Imminent” is a word with varied meanings in the hands of a geophysicist. Driscoll says shelf collapse off the coast of Virginia is imminent. He means that a day of reckoning will befall the state sometime in the next 10,000 years.

Some methane hydrate researchers tend to consider insignificant the risk arising from the 50-year trend of ocean warming that some ascribe to human activities. It’s a mere sneeze on a geological scale. It would take about 1,000 years for that warm water to reach the deep ocean. Not to mention, says Collett, that there has been a counteracting trend of rising sea levels over the past 10,000 years that recent warming has been helping along in its own small way.

Beyond that there is little agreement about how we’ll come to know hydrates in our lifetimes. Kastner believes that while we may not cause a large-scale methane release by our own actions, a natural triggering event—a very large earthquake or landslide for example—could provide a massive hydrate displacement that would push climate changes wrought by man into overdrive.

“The relationship [between hydrates and

climate change] is only there when you have catastrophic events," Kastner said. "I think slope failure is a possibility in our lifetime."

The United States has access to other oil and gas reserves in sufficient quantity to make hydrate research for energy exploitation a second-tier priority at the moment. That supply-and-demand metric governs how many more trips like the *Uncle John*'s will take place in the future and how fast researchers can fill in gaps in knowledge. However, countries like Japan and India with few other fuel resources at their disposal are leading much more strident hydrate exploration programs, a fact that prompts Collett to put his money on energy development as the most likely motivation for hydrate research in the near future.

Kastner and Driscoll are skeptical of economic development, noting that despite the apparent abundance of hydrates, it is unclear which marine settings contain them in easily recoverable quantities. The array of speculation reveals how much we have yet to understand about hydrates, phantoms from Earth's last frontier preparing to introduce themselves to us in one fashion or another.