



5.4 NAVAL RESEARCH LABORATORY RESEARCH FOCUS IN THE ARCTIC OCEAN

Dr. Richard B. Coffin

I am going to go over some basic science that we are doing at the Naval Research Laboratory (NRL). In conjunction with this work, we have developed a strong international program by signing memoranda of understanding (MOUs) with several European nations regarding operations in the Arctic Ocean.

First, I am going to provide some brief background information on methane hydrates, what we are doing, and how they could affect climate change, energy, and Navy issues.

Hydrates are clathrates that form under specific ocean pressure and temperature conditions (Figure 1). They begin to appear when the water temperature reaches 7°C, which occurs at about 550 meters depth. If you were to bring a cubic meter of methane hydrate from that depth up to the ocean surface, it would expand to 164 cubic meters of methane and 0.8 cubic meters of

Dr. Richard B. Coffin is the Marine Biogeochemistry Section Head at the Naval Research Laboratory (NRL) in Washington, DC. Rick is a NRL leader for international development of methane hydrate research. His primary research focus is biogeochemistry related to sediment and water column methane cycling. There is strong experience in applying geophysics and geochemical approaches to studying the flux of sediment methane to shallow sediment and water column carbon cycling. Field work, as Chief and Co-chief Scientist, has been conducted off the mid Chilean Margin, Hikurangi Margin off New Zealand, Cascadia Margin, along the mid-Norwegian coast, on the Texas-Louisiana Shelf in the Gulf of Mexico, and, most recently, off the coast of Alaska in the Beaufort Sea. Currently plans are being set for the Kara Sea during August 2010; this research addresses climate change and alternate energy exploration. Rick received his Ph.D. in oceanography in 1986 from the University of Delaware.

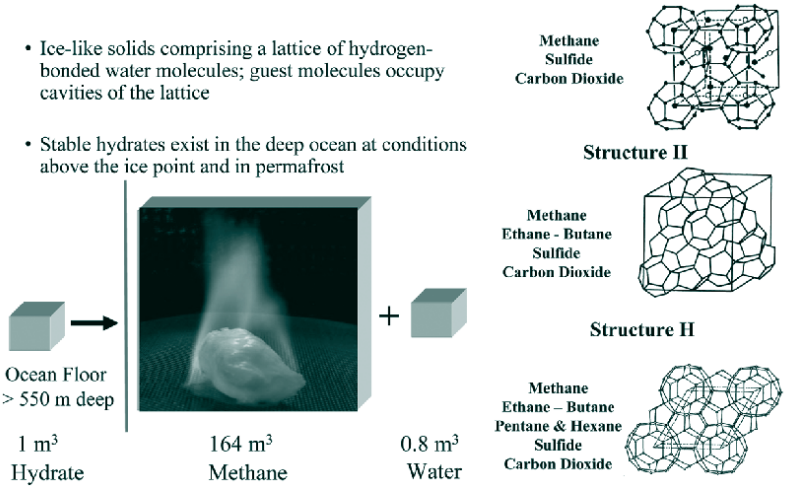


Figure 1. What Are Gas Hydrates?

water—assuming that all the lattice was saturated. Thus, methane hydrates provide both a high-density energy concentration and a high concentration of gases that can go into the atmosphere and effect climate change. We go through a lot of different structural analysis and the structures are controlled as a function of pressure, temperature, and gas composition.

Until a few years ago, it was thought that structure H was a theoretical laboratory structure that did not develop in the environment, and if anyone is interested we published a paper in *Nature* that shows that not to be the case. Structure H has been found outside of the laboratory. [1] We see evidence of it in the Gulf of Mexico and we proved it on the Cascadia margin. So, based on pressure and temperature stability, the hydrates are located around most oceans at depths between 500 and 600 meters, where the temperature falls to 7°C, the so-called “hydrate stability zone” (Figure 2). When the gas concentration is high, the right conditions of pressure and temperature lead to the formation of the ice-like clathrate structure that has high concentrations of methane.

Moving up into the Arctic, an area on which we are really heavily focusing now, methane hydrates form at much shallower depths. Given the colder temperatures, less pressure is needed for

Where gas and water are present at:

- Moderately low temperatures
- Moderately high pressures

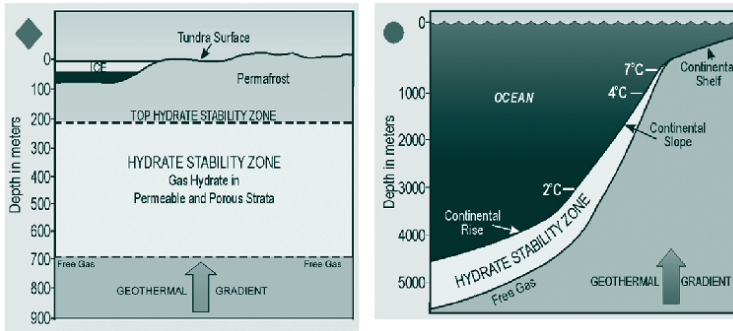


Figure 2. Hydrate Stability Zone

stability. That enables us to compare a permafrost hydrate that is very shallow relative to the deep ocean, and that is what the project I will discuss is about.

At one time, we thought that hydrates were probably an order of magnitude greater than the total petroleum gas reserves. Then, the projections went down to about half the total petroleum reserves. Now the projection is back up to two to three times more. The technology is getting better, our guesses are getting more focused, and more regions around the world are becoming identified. Although we are still guessing at it, we can say that methane hydrates are significant relative to the petroleum reserve. They are significant relative to the Earth's carbon biomass. Right now the estimate is about 700,000 trillion cubic feet (Figure 3). However, one should not assume that this total is all available as energy. We must have it concentrated and that is why we are starting to work in the Arctic Ocean.

Hydrates give the ability to start changing focus. Twelve years ago, for example, I started looking at some of the Japanese data regarding their methane hydrate exploration activities. Within the next 2 years, they were projecting that hydrates could amount to about 30% of their total energy. They have gone through a whole phase of total evaluation. This took them up on the Mallik well

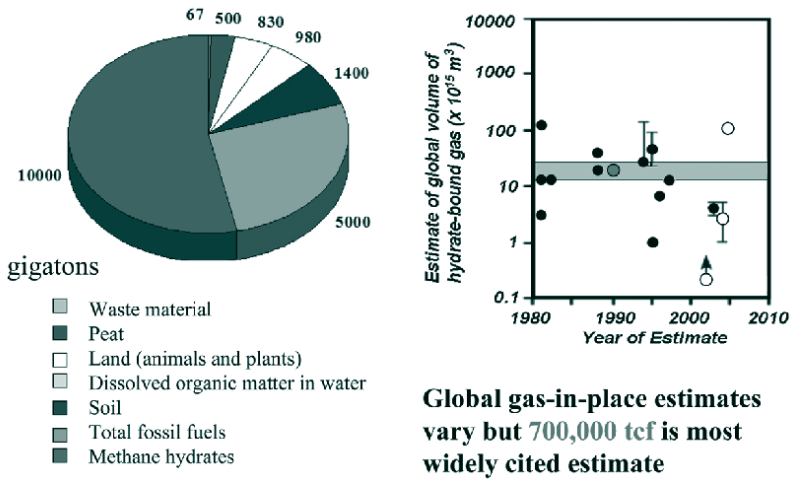


Figure 3. Global Estimate of Methane Hydrates

in the Mackenzie Delta for a large experiment. But from there, it has expanded into the Indian Ocean with heavy interest. Chevron/Texaco is doing energy exploration in the Gulf of Mexico. Because the Mallik well was discovered to be productive, BP/Amoco has moved over into the Prudhoe Bay.

From an energy perspective, Figure 4 shows the large-scale areas around the United States in which we have put our plan to work. The dark stars show where we have been working recently; the light stars show areas where we plan to go in the future. We will be off the coast of Russia near Murmansk this summer. We were in the Beaufort Sea in September 2009. We are going back for calibration of a Chevron/Texaco drill site in in the near future.

We are in an international collaboration with the Norwegians. We are going back into the Southern Ocean off New Zealand. We also hope to get over into the Bay of Bengal; we have been working at it for almost 10 years and finally have that organized. In 2011 we are returning to the coast of Chile.

Everything I have said about the development of methane hydrates as an energy source works around the experience being gained by the five nations working in the Mackenzie Delta.

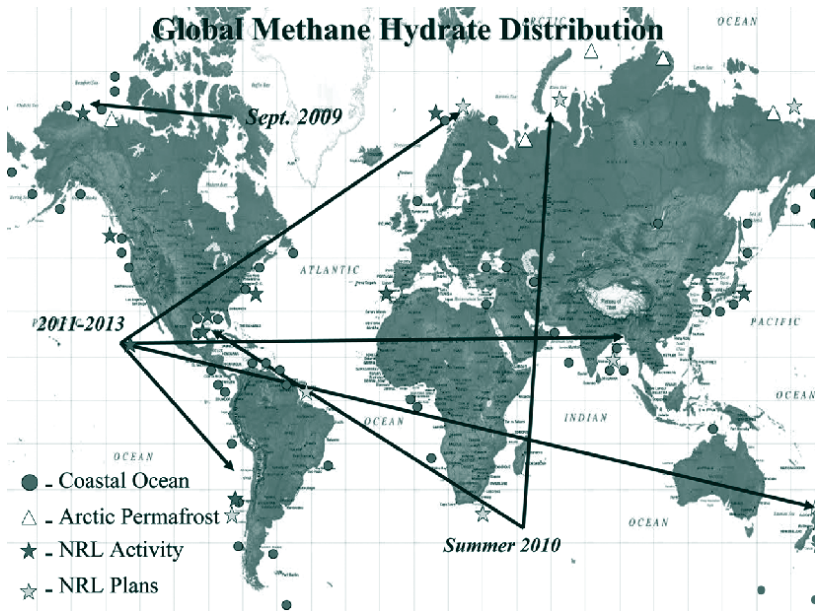


Figure 4. Global Methane Hydrate Distribution

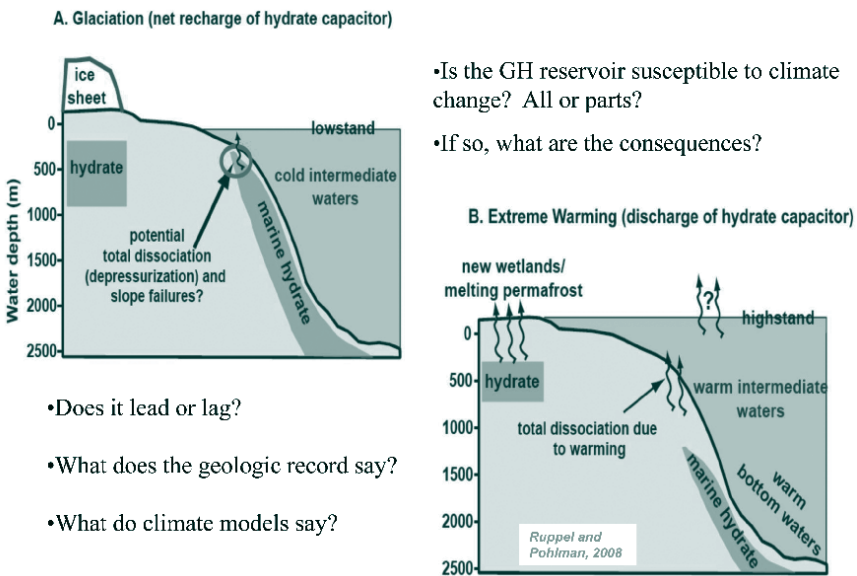
They started drilling the Mallik wells in 2002. Since then, the project has gone through steps during which they actually lit a flame for an advertisement. Now they are doing a drilling cost evaluation.

The Japanese are doing a thorough evaluation off the coast on the Nankai Trough. Other countries are starting to get heavily involved; BP/Amoco jumped over to the U.S. side of the Arctic Ocean and is starting very serious exploration efforts. Current predictions from a Department of Energy research panel project that methane hydrates could be a major component of U.S. energy production within 10 to 15 years.

We are particularly excited about the results of our recent research trip into the Beaufort Sea. We saw different data, but we did not see extensive venting. Given that the Beaufort Sea started warming before some of the other areas, we are wondering whether climate change is now so far along that we are now wondering whether it is possible that we are already losing methane into the atmosphere? The coastal slope database on methane

hydrates strongly suggests that there are definitely hydrates there. The evidence is strong relative to everywhere else I have worked in the world. When we were up in the tundra though, we could not find hydrates. Perhaps we did not get cores from the right places. We worked where all the drilling was going on, right where all the predictions say they should exist. We need to look carefully at our database. This suggests that perhaps the climate change is already on the way. Perhaps you have seen public statements regarding the massive methane melt-off in Siberia. Maybe we do need to “get ready for the methane apocalypse.”

On the other hand, there are different ways of interpreting this. I think we must be careful and understand the science. One of the other speakers said that we need risk assessment. I would argue that we need a dataset before we can start the risk assessment. I was a national biotechnology risk assessment manager for a long time and know full well that we must have data to do that. We need to develop the basic science and to look at whether the melting leads or lags atmospheric warming (Figure 5).



- Is the GH reservoir susceptible to climate change? All or parts?
- If so, what are the consequences?

- Does it lead or lag?
- What does the geologic record say?
- What do climate models say?

Figure 5. Gas Hydrate and the Climate

In 2006, the journal *Nature* published a paper saying that methane hydrates in the coastal ocean are not significant to climate change—that is a rough paraphrase of it. [2] As I recall, that statement was based on the authors looking at a 1000-year cycle from a 10,000- to 20,000-year paleo-base. I think we need more data on this. Does methane escape from the tundra first? Is the ocean second; is the permafrost next; what is the range in there? What does the geologic record say? We need that desperately. We are starting to get at that in the Beaufort Sea.

What do the climate models say? There is a lot that has to go into that for the methane. We need to know how deep we have to go, how far the heat is going to penetrate, and then what are the consequences.

Conditions in the Arctic are changing so fast that the Navy needs to know how that can affect operations there. Accordingly, we are out at sea, we are looking at gas fluxes and shallow sediments, we are looking at gas fluxes in the water column. We are looking at Arctic tundra carbon input that can affect water color, acoustics, and satellite imaging. Bubble fluxes have a strong influence on some Navy sensor systems. We need to have a thorough dataset that includes gas fluxes all the way up in the atmosphere. We can get some of that from satellite imaging. Once we have that, we can see how it will affect operations. See Figure 6 for a collaborative field plan.

Four nations and many different universities were involved in our operation in the Beaufort Sea. On the U.S. side, we had funding from the Navy and the Department of Energy. We were working out in Camden Bay. We took fiber-core, piston-core, gravity-core, and multi-core measurements through the whole expedition. These sites had very shallow gas fluxes. The fluxes in the near-shore permafrost were about the same. We then moved westward into a region where there were heavy gas fluxes. We obtained definite confirmation based on geophysical and geochemical data that there is a big hydrate bed down off the slope. This is one of the first confirmed findings in this region and we are eager to start putting this together. We have reams of data on carbon isotopes and microbial ecology and all kinds of other things. We are looking

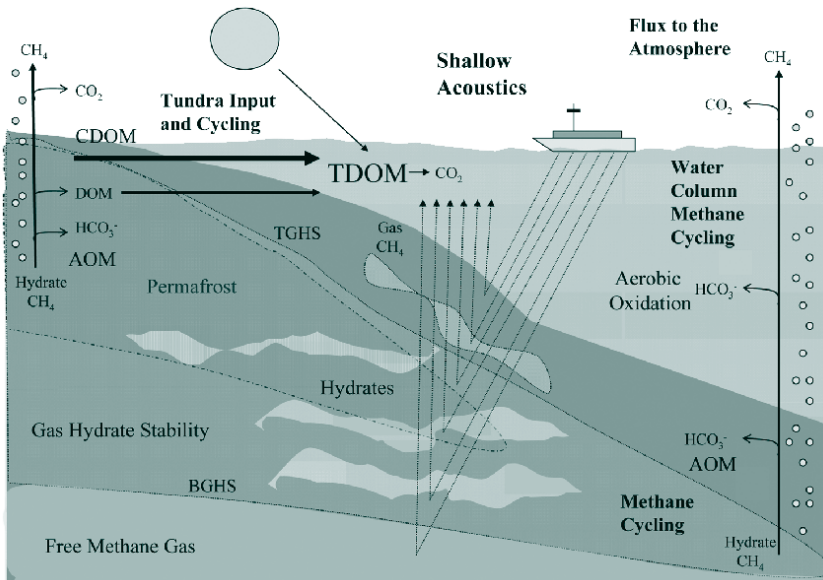


Figure 6. Collaborative Field Plan

off shore to near shore. We are doing a carbon mass balance. To model this, we have to go beyond carbon concentrations and look into what are termed “energetic concentrations” because of all the diversity in the methane cycle.

Now, let me just step back. One of the major tasks associated with any of these efforts is public outreach (Figure 7). As the chief scientist on our Beaufort Sea project, I flew up to Nuiqsut, Alaska, to describe what we were doing. They asked me a million questions about whale migration and 1-year versus multi-year ice. Because climate change is affecting their ability to kill whales, they are very focused on what is happening. I think that this public outreach is important; in fact, I am going to be back in Nuiqsut giving a description of what we were doing there. In the future, we may be able to send some graduate students there to do additional research.

Our next expedition will be up in the Kara Sea. We hope to be leaving out of Murmansk in mid-July or early August, although I am still trying to get the Russian team to set specific dates. We are



Photographs from Nuiqsut Alaska taken during a whale catch

ISSUES

- Changes in whale migration patterns
- Ice depletion influence on whale processing
- Ship traffic interfering with whaling
- Energy and shipping influence on changes in local community culture

OUTREACH

- Satellite data for ice patterns to assist with whaling
- Community meeting for information on development planning
- Hiring into science and industrial development off the coast of Alaska
- Educational support related to changes in community development

Figure 7. Public Outreach

going to compare this shelf to the Beaufort Sea, and I think we are going to see a strong difference between the two.

Another part of the Navy program is being led by Dr. Ruth Preller. Her team is trying to develop historical data on ice changes in order to make predictions regarding the nature and extent of Arctic sea ice. The statistics calculated from historical data do not match the Arctic climate change now, so they definitely need to be updated. See Figure 8.

As part of that, Dr. Preller’s team hopes to determine how fast the databases tend to change so they can understand how frequently they need to do calibration measurements.

As we have seen, the Navy is quite interested in changing ice conditions in the Arctic. In conjunction with that, NRL is working hard to understand the changing Arctic environment, with a particular focus on ice volume changes (Figure 9). Their first task is to make ground truth measurements to support model forecasting.

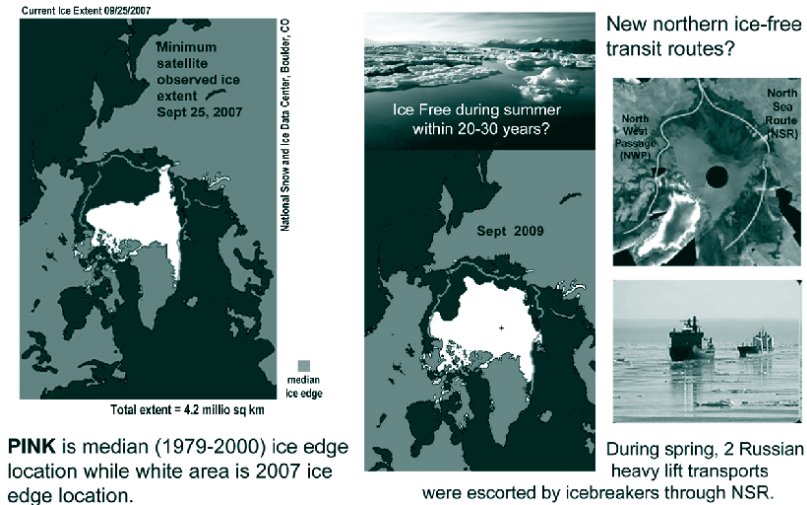


Figure 8. Changing Ice Conditions in the Arctic

- Satellite derived measurements of basin wide ice coverage (concentration) have existed since 1973 (ESMR, SMMR, SSM/I, SSMIS passive microwave data)
- However, measurements of ice thickness have been sparse in space and time
 - Sparse under ice submarine observations
 - Ice camp or field experiment point measurements (e.g., ULS)
 - Ice Mass Balance Buoys (6 cover the Arctic presently)
 - Estimates from ice concentration data (multi-year, first-year or new ice)
 - ICESat provided spatially intense but limited in time ice thickness measurements.

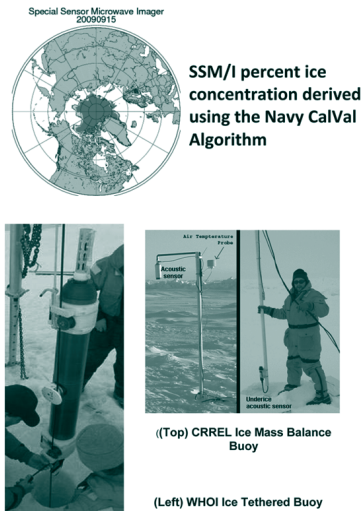


Figure 9. Ice Thickness Observations

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