

Letter From the Desk of David Challinor
July 1998

For millennia humans burned wood to cook and warm themselves; they then used this energy source where wood was plentiful to operate early steam engines and to smelt iron ore well into the 20th century. The carbon petroleum age began in the 19th century with the exploitation of coal, followed by crude oil and natural gas. Unlike wood, however, carbon petroleum-based fuel is not renewable in terms of human life spans. At the current rate of global consumption, known reserves of oil and gas will be exhausted some time in the middle of the next century. If we assume the world's human population will have begun to level off then, short of about 10 billion from our current total of about 5.8 billion, what other practical energy sources remain? Solar and wind power work satisfactorily only in specific locations, and nuclear power still has too many associated risks to enjoy the political support necessary for its exploitation. There is, however, a vast reserve of potential energy stored in methane hydrate crystals, located mostly at the bottom of the sea. The amount is estimated to be double the predicted reserves of the world's coal, oil and natural gas. If the combustible methane gas (CH₄) locked in these crystals can be captured efficiently from the seabed, it should meet the globe's energy requirements for centuries.

Methane is an odorless volatile gas produced as a by-product of bacterial metabolism. For tens of thousands of years bacteria living in ocean sediments have fed on the organic particles that rain down from the rich sun-lit waters of the ocean's surface. As this organic material is metabolized (eaten and digested) by anaerobic bacteria (bacteria that live independently of oxygen), methane is released as a by-product. The methane produced by anaerobic bacteria bubbles up through the deep ocean sediments and contacts water molecules near the sediment surface layer. The cold temperature and the great pressure are two key elements that cause a molecule of methane, as well as other gases, to combine with water molecules to form hydrates.

A hydrate unit is a crystal shell consisting of a score of water molecules surrounding a free-floating gas molecule. These hollow crystals (hydrates) fit together in a tight lattice structure and look something like ice. However, unlike ice, they form generally above the freezing point of water. The crystals are cube-shaped with six square sides, unlike hexagonal ice crystals, which also have six sides but are not all square. Even more amazing the hydrates are flammable if, as in the great majority of cases, the trapped gas is methane. Because the gas in the hydrates is compressed by the weight of the water above it, a cubic foot of methane hydrate from the sea bottom would expand to 164 cu. ft. at sea level room temperature.

Theoretically most ocean bottoms should have the right conditions to produce hydrates, but for reasons still not clearly understood the hydrates seem to be confined to waters of about 1,000 feet deep off continents. Perhaps the continental waters are so enriched by nutrient run-off from land that the rain of organic matter to the seabed there is considerably greater than at mid-ocean; thus the more food, the more bacteria, the more methane produced.

Hydrates, although plentiful, are hard to find and appear in various forms: nodules, layers, veins or even as tiny particles scattered in sediments. One of the few places in which visible hydrate lobes emerge above the sediment floor is the Gulf of Mexico. However, they also have been discovered in sediment cores taken from ocean depths of almost two miles or from soil samples only 40 feet below the permafrost along the Canadian Arctic coast.

When hydrate layers form over sediment surfaces at continental margins, they function as an inverted shallow bowl that traps the methane gas bubbling up from deeper sediment levels. Great quantities of methane and other gases may have been concentrated over millennia until one of three events occurred: an earthquake, reduced water pressure from falling sea level, or rising water temperature that cracks or destroys the storage shell. The sudden release of the long-stored methane to the ocean surface has profound consequences. Such an event may have occurred about 55 million years ago, when an enormous quantity of methane gas estimated at a trillion tons burst from the ocean depth in many parts of the world. Temperatures rose to such levels that thousands of marine organisms were killed in an extinction event that rivaled that of the disappearance of the dinosaurs ten million years previously.

The evidence for this event first appeared in 1991 from a core drilled 1.3 miles deep into a submerged ridge off Antarctica. The core showed a sudden (within about 1000 years) extinction of about two-thirds of all the organisms then living at the sea bottom. Cores from both Caribbean and European waters showed similar extinction patterns suggesting one of the major extinctions in the history of life on earth. Curiously no such sudden massive extinctions were found among shallow water marine species or terrestrial organisms. Thus whatever caused the bottom-dwelling animals to die could not have been an asteroid strike such as is speculated to have caused the extinction of dinosaurs.

Former conditions under which animals once lived can be reconstructed from precise ratios of various carbon and oxygen isotopes found in fossil remains. A significant drop in the proportion of oxygen-18 in the fossils of deep-sea sediment dwellers indicated that the ocean temperature had risen rapidly (by 4°C or 7.3°F) over a 1000-year period. Furthermore, when carbon isotopes were examined from the same period, carbon particles in rocks showed a sudden shift from carbon-13 to carbon-12, not

only in deep-sea rocks, but also in shallow water and terrestrial rocks. An isotopic shift of this nature indicates that some enormous, drastic event occurred that was powerful enough to change the isotopic reading of all the material in the world's carbon cycle.

To effect this change, 55 million years ago, a tremendous amount of carbon must have been released. It has been calculated to have been 200 times all the carbon currently stored in the wood of the entire world's forests today. Although there were thought to be three times as many wetlands then as now, swamp-produced methane was probably too limited a source for a carbon release of this size. Only deep-sea methane hydrates could be the source for this much carbon-12, which may have been released by higher global water temperatures caused by a disruption in the great ocean conveyor belt (discussed in my June 1998 letter).

Although such a massive methane release evidently occurred 55 million years ago and drastically altered life on earth, the odds are remote that such an event would happen today: seawater temperature is much lower than it was at the Paleo/Eocene era boundary and the ocean climate system is further from the critical climate-altering threshold than it was then. However, the warm period that started in the Eocene certainly encouraged terrestrial mammal evolution, especially among the ungulates, ancestors of today's horses, cattle, rhinos and camels as well as the earliest primates.

Today's humans, the evolutionary descendents of these early primates, are the world's dominant mammal, but to maintain this supreme position we are dependent on vast amounts of energy. Early attempts at bringing volatile methane hydrates to the surface have been frustratingly ineffective. Released from their high pressure, low temperature surroundings, the methane hydrates pop, fizzle and bubble away in seconds. The deep-sea hydrates discovered to date are so dispersed that the gas they contain cannot efficiently be pumped to the surface. However, on Alaska's North Slope subsurface hydrates are trapped in porous sandstone strata sandwiched between impervious shale. Their gas could be tapped by a process called depressurization by which a well is drilled into the free natural gas zone below the sandstone hydrate layer. The well reduces the pressure that has immobilized the methane in the hydrates and allows the methane at the bottom of the hydrate layer in the sandstone to escape into the free natural gas zone below it. Thus the methane gas released from the hydrates mixes with the methane in the free natural gas and the methane from both sources can be brought to the surface.

Depressurization could release only an insignificant fraction of the potential methane hydrate reserves. Another technique is to release the methane from the hydrates by forcing high-pressure steam into the hydrate vein. High temperature will also break down the hydrates to release methane and this approach appears more promising than depressurization. The technology for tapping this potentially huge energy source is still in its early development, but as the earth's conventional carbon petroleum reserves are depleted, the incentive to develop alternate energy sources will rise.

We invest considerably more today on space exploration than on exploring the seabed. What we have found there are amazing energy resources, but we still have only a limited understanding of their origins and of their scale. The seabed is an exciting frontier and one I believe more directly beneficial to our future well-being than what we may find on the moon or on Mars. Unfortunately, the expensive low orbit manned space program is more politically appealing than the exploration of the deep seabeds. Only a future critical energy crisis could possibly reverse the priority of our current space program and assign appropriate resources to ocean bottom surveys that may better insure the welfare of future human generations.

David Challinor
202-673-4705
202-673-4607 Fax