An Inexhaustible Source of Energy from Methane in Deep Earth

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Untapped reserves of methane, the main component in natural gas, may be found deep in Earth's crust, according to a recently released report in the Proceedings of the National Academy of Sciences of the United States of America (PNAS). These reserves could be a virtually inexhaustible source of energy for future generations. The team of researchers from Lawrence Livermore National Laboratory, Carnegie Institution's Geophysical Laboratory, Harvard University, Argonne National Laboratory and Indiana University, South Bend, through a series of experiments and theoretical calculations, showed that methane forms under conditions that occur in Earth's upper mantle.

Methane is the most plentiful hydrocarbon in Earth's crust and is a main component of natural gas. However, oil and gas wells are typically only drilled 5 to 10 kilometers beneath the surface. These depths correspond to pressures of a few thousand atmospheres.

Using a diamond anvil cell, the scientists squeezed materials common at Earth's surface — iron oxide (FeO), calcite (CaCO3) (the primary component of marble) and water to pressures ranging from 50,000 to 110,000 atmospheres and temperatures more than 2,500 degrees Fahrenheit — to create conditions similar to those found deep within Earth.

Methane (CH4) formed by combining the carbon in calcite with the hydrogen in water. The reaction occurred over a range of temperatures and pressures. Methane production was most favorable at 900 degrees

Fahrenheit and 70,000 atmospheres of pressure.

The experiments show that a non-biological source of hydrocarbons may lie in Earth's mantle and was created from reactions between water and rock — not just from the decomposition of living organisms.

"The results demonstrate that methane readily forms by the reaction of marble with iron-rich minerals and water under conditions typical in Earth's upper mantle," said Laurence Fried, of Livermore's Chemistry and Materials Science Directorate. "This suggests that there may be untapped methane reserves well below Earth's surface. Our calculations show that methane is thermodynamically stable under conditions typical of Earth's mantle, indicating that such reserves could potentially exist for millions of years."

The study is published in the Sept. 13-17 early, online edition of the PNAS.

The mantle is a dense, hot layer of semi-solid rock approximately 2,900 kilometers thick. The mantle, which contains more iron, magnesium and calcium than the crust, is hotter and denser because temperature and pressure inside Earth increase with depth. Because of the firestorm-like temperatures and crushing pressure in Earth's mantle, molecules behave very differently than they do on the surface.

"When we looked at the samples under these pressures and temperatures, they revealed optical changes indicative of methane formation," Fried said. "At temperatures above 2,200 degrees Fahrenheit, we found that the carbon in calcite formed carbon dioxide rather than methane. This implies that methane in the interior of Earth might exist at depths between 100 and 200 kilometers. This has broad implications for the hydrocarbon reserves of the planet and could indicate that methane is more prevalent in the mantle than previously thought. Due to the vast size of Earth's mantle, hydrocarbon reserves in the mantle could be much larger than reserves currently found in Earth's crust."