Looking at Earth in Action


Surface outcropping of the San Andreas Fault near Parkfield, California.

EXPERIMENTAL geophysicists at Livermore are tackling diverse challenges such as the storage of nuclear wastes, discovery of new energy sources, mitigation of greenhouse effects, and better understanding of nuclear weapons. They set up experiments in the laboratory so they can examine how specific environments alter material properties. According to Brian Bonner, who leads the Laboratory's Experimental Geophysics Group, much of what these scientists do is "indoor geophysics," bringing Earth into the laboratory.

"Natural systems are so complex that we can often learn more about the physical processes in the laboratory—where we can isolate the controlling variables and study the processes systematically," says Bonner. In this way, researchers can better understand the geophysical processes occurring deep within Earth's subsurface and across the vast expanses of its surface.

Indoor Geophysics

Much of the group's work involves subjecting materials to extreme temperatures and pressures. Earth and the other planets in our solar system are places of extreme conditions: Earth's interior can reach pressures of more than 350 gigapascals and temperatures of 6,000 kelvins. (Normal surface pressure at sea level is 1 atmosphere, or about one-ten-thousandth of a gigapascal.)

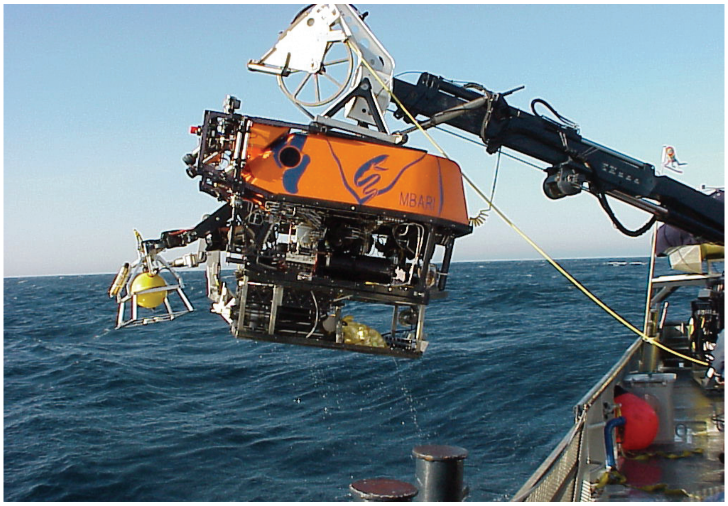
Because these extreme conditions are similar to those produced by nuclear detonations and other high explosives, the geophysicists also contribute their expertise to projects in support of Livermore's stockpile stewardship mission. In one of the Laboratory's early efforts to develop a science-based stockpile stewardship program in the absence of nuclear testing, Livermore geophysicist Jagan Akella used the diamond anvil cell, which was developed to study molten iron at Earth's core, to examine the melting of metals used in nuclear weapons. (See *S&TR*, March 1996, pp. 17–27.)

No Fault Zone

The group is also working on projects that involve traditional applications of geophysics, such as the dynamics of earthquakes. Jeff Roberts, a Livermore experimental geophysicist, recently collaborated with Stephen Park and colleagues from the Institute of Geophysics and Planetary Physics at the University of California at Riverside to study the San Andreas Fault near Parkfield, California. Parkfield is a small town in central California, halfway between Los Angeles and San Francisco. Earth scientists have studied this area for decades because earthquakes occur frequently in this region of the fault.

The Parkfield team investigated an area just west of the visible surface trace of the fault and extending 3 kilometers below the surface. Data recordings from this region indicated anomalous electrical conductivity, which many geophysicists attribute to the fractured rock being saturated with brine. Laboratory experiments indicate that the resistivities of rocks in this anomalous zone were comparable to the resistivities of sedimentary rock samples taken along the eastern border of the fault.

One interpretation of this finding is that the anomalous conductivity is caused by a plunging syncline—a trough of sedimentary rock—



Livermore geophysicists and researchers from the Monterey Bay Aquarium Research Institute are measuring the dissolution kinetics of carbon dioxide and methane hydrate at sea-bottom conditions. Here, a pressure vessel containing hydrate samples is being lowered to the experimental site—the underwater Monterey Canyon, about 15 kilometers off the coast of central California.

adjacent to the fault. The researchers conducted further experiments in the region to determine the exact location of the syncline and compared those results with other data. From this analysis, the team proposed that part of the San Andreas Fault may actually lie about 1 kilometer west of its mapped location. This proposal is controversial, and further research will be needed to confirm or disprove the revised location of the fault.

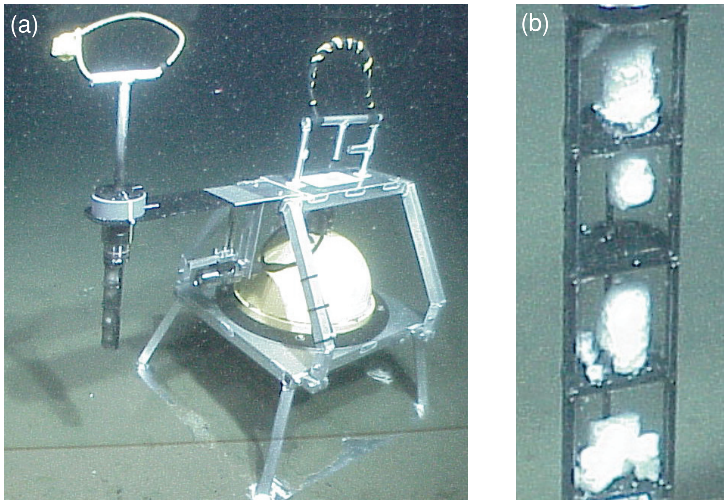
Under the Sea

Other members of the Experimental Geophysics Group are studying the changing environment under the sea floor, where gas hydrates—crystalline solids that look like water ice—lay trapped in marine sediments. According to Livermore geophysicist William Durham, the amount of carbon bound in gas hydrates worldwide is estimated to be twice the amount of carbon found in all known fossil fuels on Earth. (See *S&TR*, March 1999, pp. 20–22.)

"Not only are gas hydrates possible alternative carbon fuel sources," says Durham, "but they also could be important in mitigating global warming." One possibility being explored is using carbon dioxide hydrate as a means of removing carbon dioxide from the atmosphere.

To examine the stability of these hydrates, Durham's team collaborated with researchers from the Monterey Bay Aquarium Research Institute to measure the dissolution kinetics of carbon dioxide and methane hydrate at sea-bottom conditions. For this experiment, which received funding from Livermore's Laboratory Directed Research and Development Program, researchers grew cylindrical samples of pure methane and carbon dioxide hydrate in the laboratory by combining either cold pressurized methane gas or pressurized liquid carbon dioxide with water ice.

They then transported the hydrates to the experimental site—the underwater Monterey Canyon, which lies about 15 kilometers off the coast of central California in Monterey Bay. The samples were placed in a pressure vessel and delivered to the sea floor—more than 1,000 meters deep. Once the vessel was in position, it was opened in view of a time-programmable underwater video system. The images captured by the camera allowed the team to measure the shrinkage rates of the samples and thus calculate how quickly the hydrates dissolved. The carbon dioxide hydrate dissolved completely in 4 to 6 hours. The methane hydrate was far more stable at sea-floor conditions. In fact, these samples had not completely dissolved when the researchers returned the next day.



(a) The pressure vessel is delivered to the sea floor—more than 1,000 meters deep. Once the vessel is opened, (b) samples of pure methane hydrate and carbon dioxide hydrate are recorded by an underwater video system. Using data from the recording, researchers measure the shrinkage rates of the samples to calculate how quickly the hydrates dissolved.

Understanding the stability of hydrate deposits is relevant to several research areas. For example, astrophysicists are interested in methane hydrate because it is a building material of the outer planets in our solar system. Methane hydrate deposits also occur on Earth near conventional oil deposits. Drilling companies need accurate locations of hydrate deposits because drilling through these pockets could lead to catastrophic events, such as undersea landslides, explosions of freed gas, or even, according to Durham, tsunamis.

Bringing It All Together

When Livermore's Experimental Geophysics Group looks beneath Earth's crust, under its sea floors, and into the sedimentary rock formations at its surface, the research encompasses much more than geology. The group's work touches national security, environmental science, the discovery of new energy sources, and even astrophysics.

"This group faces an evolving series of interdisciplinary challenges, and our broad collective expertise helps us meet them," says Bonner. "We have geologists, people with physics and chemistry backgrounds, an engineer or two, and even one group member whose first degree was in economics. When we don't have the right talent in house, we form collaborations inside and outside the Laboratory. Our experience is that adaptable, versatile people do well at finding solutions to crosscutting problems."

—Maurina S. Sherman

Key Words: gas hydrates, geophysics, ice physics, methane hydrate, San Andreas Fault.

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