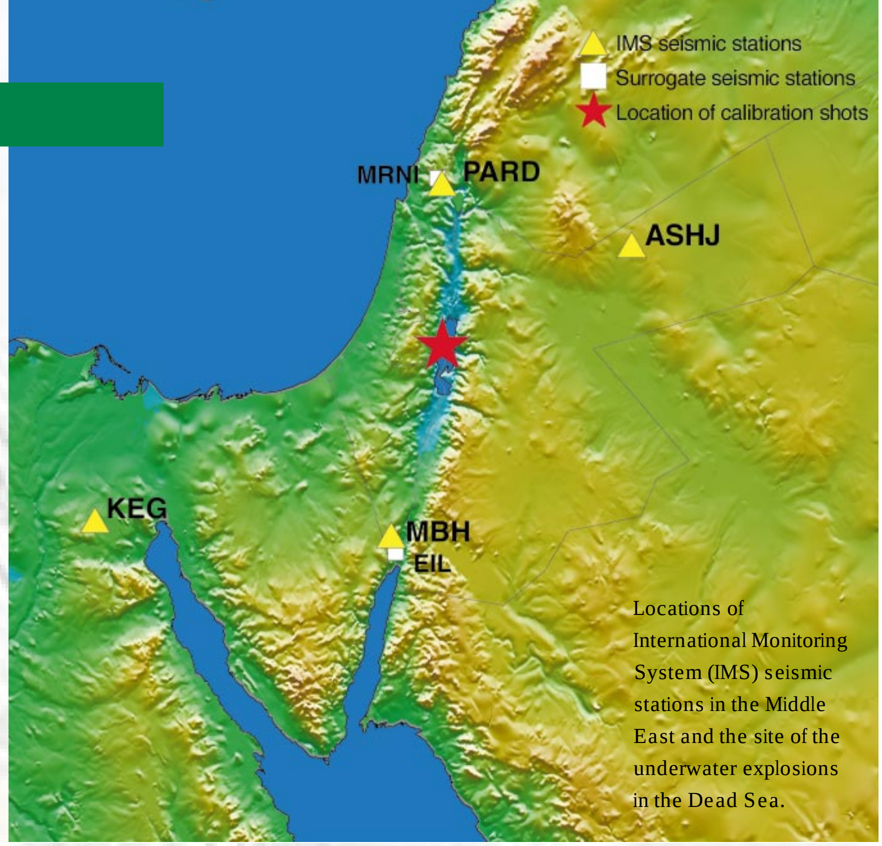
Dead Sea Explosions Trigger International Cooperation



Locations of International Monitoring System (IMS) seismic stations in the Middle East and the site of the underwater explosions in the Dead Sea.

THE Middle East has long been a region beset with tension, if not outright warfare. It is ironic, therefore, that a series of underwater explosions set off in the Dead Sea last November may, with the assistance of Lawrence Livermore seismologists, help to reduce tensions in the area and spur cooperative ventures on geophysical-related issues.

Conducted by the Geophysical Institute of Israel, the explosions were cofunded by Israel and the U.S. Defense Threat Reduction Agency. The main goal was to improve monitoring of the Comprehensive Test Ban Treaty (CTBT) by calibrating Israel's two International Monitoring System (IMS) seismic stations as well as its national system of seismic monitors. Because the tests were announced well ahead of time, other Middle East nations were afforded the opportunity to calibrate their own national seismic stations and any IMS stations on their territories. The explosions will help scientists to pinpoint the location of suspicious seismic events in the area and distinguish them from other sources of seismic signals.

According to Livermore seismologist Keith Nakanishi, detecting, locating, and identifying a clandestine nuclear test poses a particular challenge in the Middle East. International stations are few and far between in the area. Also, a large number of earthquakes and mining explosions generate thousands of seismic signals annually, some quite similar to the signals that would be generated by a small underground nuclear blast.

Additional "ground truth" for the area is sorely needed, Nakanishi says. Ground truth includes seismic data from well-documented earthquakes, mine explosions, or explosions carried out for calibration purposes. Carefully gathered data from these events improve the knowledge of how regional-specific features in the Earth's crust and upper mantle affect the travel times, amplitudes, and frequencies of weak seismic signals. Such data are particularly important to accurately determine the location and origin time of the seismic sources.

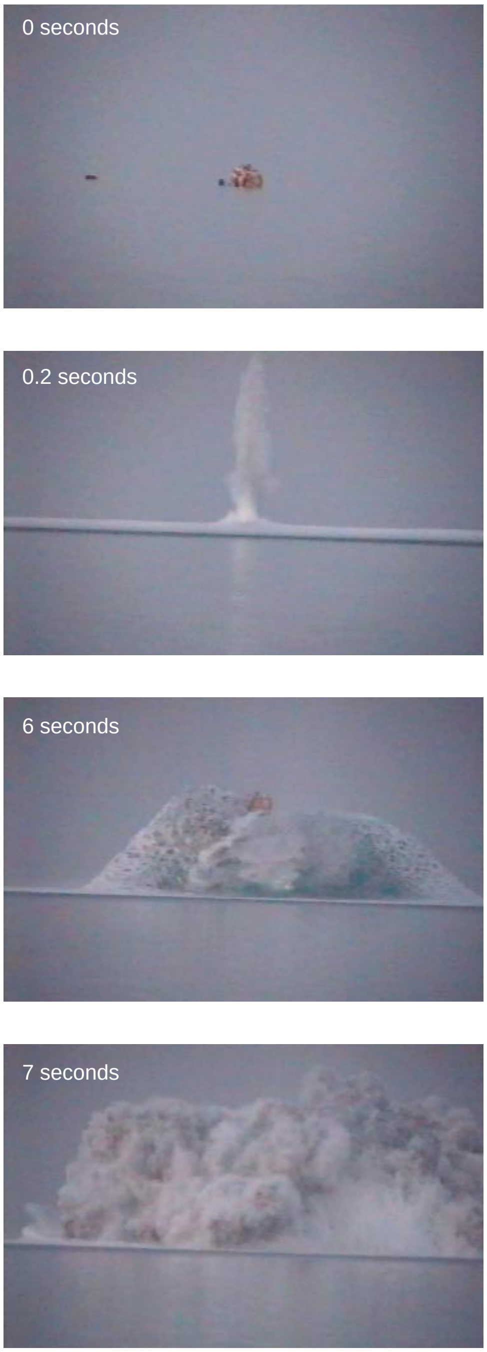
Building a Knowledge Base

For the past several years, the Department of Energy has been developing a knowledge base of regional seismic properties for the U.S. National Data Center at Patrick Air Force Base, Florida. As part of DOE's program, a team of Livermore experts is focusing on the Middle East and North Africa (called MENA) and the western part of the former Soviet Union. (See *S&TR*, September 1998, pp. 4–11, and *S&TR*, April 1999, pp. 18–20.)

The Livermore team is working to improve techniques to detect and characterize clandestine underground nuclear explosions in key areas of concern for proliferation monitoring. An important application of this technology is for CTBT monitoring. Both Israel and the U.S. have signed the treaty but have not ratified it.

For the Middle East, well-planned calibration experiments are an important means of establishing ground truth in an area whose geologic complexity rivals that of the western part of the United States. Tests conducted in water are preferable to those conducted underground, because water is an excellent medium for transmitting seismic waves. As a result, a much smaller amount of explosives is necessary for a calibration test done under water than is required for an underground test.

The Israelis detonated three underwater packages of explosives, all at the same location (about 5 kilometers from Israel's Dead Sea shores) and depth (about 70 meters below the water surface). A 500-kilogram explosive was detonated on November 8, 1999, with an approximate magnitude of 2.6 on the Richter scale, and a 2,000-kilogram explosive was detonated on November 10, with an approximate magnitude of 3.5 on the Richter scale.



Stills from a video camera show the sequence of events during the 5,000-kilogram Dead Sea explosive test captured at 0, 0.2, 6, and 7 seconds following detonation. The frame at 0 seconds shows the steel buoy used to fix the charge depth at about 70 meters.

These first two tests were conducted largely to demonstrate that underwater explosions posed no danger to people, property, or the environment. The main test, a 5,000-kilogram explosive package, was set off on November 11, producing a 9-meter-high fountain of water and an approximate magnitude of 4.0 on the Richter scale. (By comparison, a 1-kiloton nuclear explosion would produce a magnitude in the range of about 4.0 to 4.5 on the Richter scale.)

Experiments Were Well Characterized

To be particularly useful, seismic calibration tests must have well-defined locations and origin times. For the Dead Sea tests, these parameters were well determined, says Nakanishi, who attended planning meetings in Israel that focused on such requirements. The location of each test was known to an accuracy of 20 meters, the depth was established to within an accuracy of 5 meters, and the time was determined to an accuracy better than 20 milliseconds.

The explosions were recorded by the Geophysical Institute of Israel and its network of seismic stations, including two IMS stations located in the southern and northern areas of the country. The events were also recorded by a group of more than 30 smaller stations that form Israel's national seismic network and by a few temporary stations Israel installed on the Dead Sea shores. Seismic stations in neighboring countries such as Jordan, Egypt, and Saudi Arabia reportedly also recorded the tests. The Geophysical Institute distributed data electronically to interested parties, including Nakanishi and his colleagues, within a few days.

The Livermore team is analyzing the Dead Sea data and using the results to refine the DOE's knowledge base for the area. For their part, Israel, Jordan, and other Middle East nations are using the data to strengthen their own national means to identify the magnitude and location of any clandestine nuclear blasts and future earthquakes and to better distinguish between the two.

Nakanishi predicts that the explosions will prove as valuable for earthquake monitoring as for CTBT monitoring. "The area is riddled with faults and has a long history of earthquakes dating to Biblical times," he says. The most dangerous fault is the Dead Sea Rift Valley fault that stretches from Syria through Israel and into East Africa, with one fault branch underlying Haifa, Israel. In 1995, an earthquake of magnitude 7.1 on the Richter scale occurred on the fault in the Gulf of Aqaba in the Red Sea near the Israeli city of Eilat.

Well-calibrated seismic networks will allow scientists to better locate the origin of future earthquakes. "By knowing what fault caused the earthquake, we'll know what to expect in terms of aftershocks," Nakanishi explains. He notes that seismic safety has become a larger concern in the area following the strong 1999 temblors in nearby Turkey.

International Meeting to Focus on Tests

The Dead Sea tests will be the focus of a week-long international workshop to be held this spring, facilitated by Nakanishi and several Livermore colleagues. Each participating nation will share the data recorded at their seismic station. "Jordan and Israel share the Dead Sea," Nakanishi points out. "Each will bring its one-half of the coverage from the tests. By pooling the data, we'll have a full 360-degree coverage."

Nakanishi is hopeful that representatives from Saudi Arabia, Egypt, Jordan, Israel, Cyprus, Lebanon, Turkey, Kuwait, Qatar, Yemen, Oman, and the Palestine Authority will attend. The meeting has the blessing of the U.S. State Department and of the United Nations Educational, Scientific, and Cultural Organization (UNESCO), the meeting's official sponsor.

Nakanishi says that the workshop can also help to reduce political tension. "Regional cooperation in seismology can encourage participation in other technical discussions and increase security in the area," he says. By sharing data and discussing results, participants can be assured that if clandestine nuclear testing is taking place, they would be able to quickly identify it. The data will also help characterize the area for earthquake hazard mitigation and support basic seismic research.

Livermore scientists hosted a similar workshop in 1997 in Cyprus. The focus then was the 1995 Gulf of Aqaba earthquake; interest in the earthquake was high because of its potential negative impact on economic development in the area. "It was a great opportunity for people who don't ordinarily meet to discuss matters of common interest in a neutral venue," says Nakanishi.

He observes that seismic waves respect no boundaries or political or religious beliefs. Because better understanding of ground motion helps every nation, seismology may be a contributor to lessening tensions in an area that has had more than its share of tremors.

—Arnie Heller

Key Words: Comprehensive Test Ban Treaty (CTBT), Dead Sea, Defense Threat Reduction Agency, Gulf of Aqaba, knowledge base, Middle East and North Africa (MENA), seismic monitoring, United Nations Educational, Scientific, and Cultural Organization (UNESCO).

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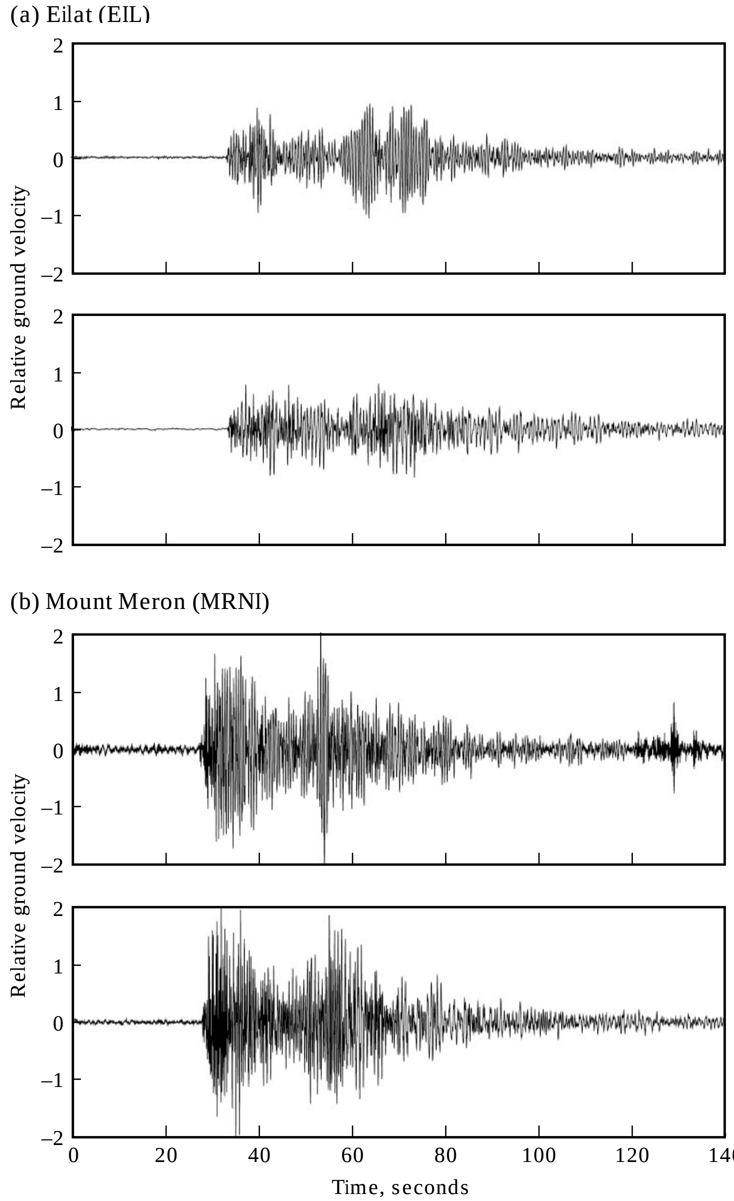

Seismograms from the second and third Dead Sea shots as recorded at Israel's International Monitoring Stations in (a) Eilat and (b) Mount Meron. The locations of these stations are shown on the map on p. 21. (The plots of the first shots are not shown because one of the stations did not provide recordings for the first day.)