Forensic seismology tested on 2006 munitions depot 'cook-off' in Baghdad

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Still from a video of the the ammunition "cook-off" that followed a mortar attack on US Forward Operating Base Falcon filmed by soldiers stationed there. The "cook-off," which continued for hours, was recorded by a nearby seismic station, giving seismologists the opportunity to test their ability to identify munitions from their seismic signatures.

On Oct. 10, 2006, a mortar round hit the ammunition supply depot at the U.S. Forward Operating Base Falcon south of Baghdad. The round

started a smoldering fire punctuated by whizzing skyrockets, a rain of incandescent fragments, and massive explosions that bloomed into mushroom clouds. Soldiers who videotaped the "cook-off" can be heard wondering what exactly was in the dump and how much longer the explosions would continue.

But the soldiers weren't the only ones recording the cook-off: a seismometer just four miles away was also registering every boom and shock. The seismometer was one of 10 installed in 2005 and 2006 in northern and northeastern Iraq to study the seismic properties of the Earth's crust in that area so that it would be possible to quantify the yield of nearby earthquakes or nuclear tests.

The principal investigator on the team that deployed the seismometers was Ghassan I. Aleqabi, PhD, a seismic deployment coordinator in the Department of Earth and Planetary Sciences in Arts & Sciences at Washington University in St. Louis. Iraqi in origin, Aleqabi had obtained his PhD in seismology at Saint Louis University and settled in Saint Louis.

Installing and maintaining instruments in war-torn Iraq was sometimes a hair-raising business. Installation of the seismometer that recorded the cook-off had to be delayed until April 2006 because it was dangerous even to enter the city. And, once deployed, the seismometers, which recorded 100 samples per second, filled their hard drives in a few months, so someone had to return to the sites to bring out the data.

Then the ammunition dump went up. Aleqabi and his colleague Michael Wysession, PhD, professor of earth and planetary sciences in Arts & Sciences, were curious and decided to see if the seismometer had recorded the cook-off. "Sure enough, you could see a whole sequence of explosions," Wysession said.

They report what they found online in the Dec. 22 issue of the *Bulletin of the Seismological Society of America*. "It was an accident that we got such a rich recording," Wysession said. "But sometimes science works that way; you get lucky."

Shock and awe

Analyzing the record in various ways, they found that some types of weapons jumped right out at them. "Mortar fire has a very specific signature that is always the same," Wysession said. "If you make a spectrogram, which breaks out the signal into different frequencies, you see that the firing of the mortar produces one set of frequencies and the case splintering around the explosive produces another. When you see those signals you know that's a mortar firing. You can begin to pick out what's going on."

Passing helicopters produced lovely swooping S-curves in the seismograms as they moved toward and away from the seismometer and their dominant frequency dropped (the same effect that makes the siren on an emergency vehicle drop in pitch). "You can look at how much the frequency drops and over what length of time and determine how far away the helicopter is, and how fast it's going, which is really fascinating," Wysession said.

But they also discovered some limitations. It was not possible to read every little rumble and report. The seismometer, for example, picked up two different car bombs, but their seismic records looked very different. By checking with counterterrorism intelligence sources, Aleqabi learned more about the bombs. One had detonated in a fairly open space at a university and the other had gone up at a checkpoint in a narrow street lined with tall buildings. The checkpoint explosion reverberated in the small spaces, creating a more complex sound pattern that made it harder to figure out the explosive type and yield.

But looking at the seismic recording before and during the cook-off, the seismologists could reconstruct the sequence of events that led to the catastrophe. About 7:22 local time they could see the signatures of mortar fire in the record. At 7:31, a helicopter flew by. An explosion at 7:36 was the one that probably ignited the cook-off, but it was followed by a series of small explosions that gave the soldiers on the base time to take cover. Then, at 7:40, there was a huge explosion and all hell broke loose.

Seismic sleuthing

Seismometers were developed to record earthquakes, Wysession said, but then they turned out to be useful for monitoring nuclear tests, and now people are using them in all kinds of creative ways. "We can independently verify with seismometers the occurrence of global warming because we can track the decadal increase in the storm intensity globally," he said.

Seismology is also used as a forensic tool, he said, to help investigative agencies and insurance companies piece together what happened during terrorist attacks or industrial accidents. One of the leaders in this field is Keith Koper, a Washington University alumnus who is now a professor of seismology at the University of Utah.

Unfortunately, given recent terrorist attacks in Paris and elsewhere around the world, this paper may be more timely than the authors ever expected it to be, Wysession said. "A network of seismometers in an urban area could tell you a lot about a terror attack." A real time-array, he points out, might have prevented the ammo "cook-off." Because the "cook-off" was preceded by a volley of mortar fire—and mortar firings have a unique seismic signature—it might have been possible to pinpoint the source of the rounds before the round that destroyed the ammo depot was fired.

"I think we'll hear more about forensic seismology as time goes on," Wysession said.

More information: "Characterization of Seismic Sources from Military Operations on Urban Terrain (MOUT): Examples from Baghdad," *Bulletin of the Seismological Society of America*, 2015.

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