

LEARNING EXPERIENCE 3

FORENSIC SEISMOLOGY

BACKGROUND AND OBJECTIVE

Seismology can be used to locate and provide information about phenomena other than earthquakes. The study of seismic records from non-earthquake related sources is termed forensic seismology. Typical sources include explosions, nuclear weapons testing and terrorist bombings. Some natural sources also fall under the forensic seismology category. Examples are sonic booms from asteroids entering the earth's atmosphere, landslides, and cave collapses. Forensic seismology uses seismic data to resolve and verify information about the source, including the location and origin time, the energy that is released, the number of separate sources, and possibly the type of source.

This exercise explores seismograms from non-earthquake events and discusses how seismology may be used to provide useful information about the event.

Procedure

- A. Look at the seismograms below of the Space Shuttle *Columbia's* reentries into the Earth's atmosphere. Figure 1 shows the sonic boom created from a successful Shuttle mission as the Shuttle reenters the Earth's atmosphere at a supersonic speed. Figures 2 and 3 show the patterns created by *Columbia's* last mission, which ended as a terrible tragedy.

Mark the location of the Shuttle's reentry and the sonic boom, if present, on each seismogram.

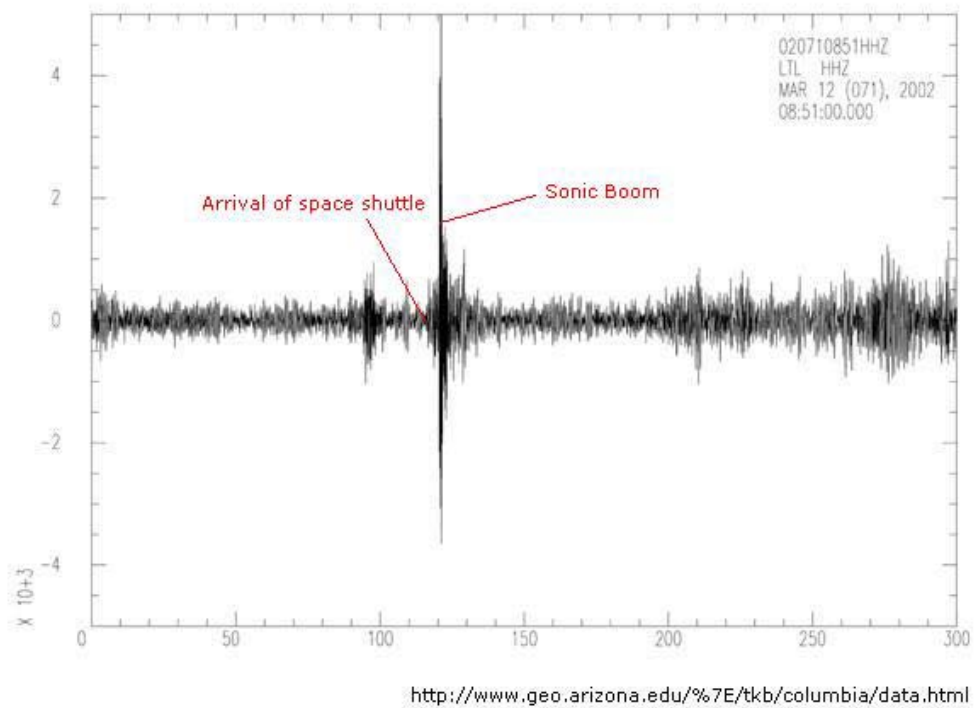


Figure 1: Space Shuttle *Columbia* Reentry on March 12, 2002.

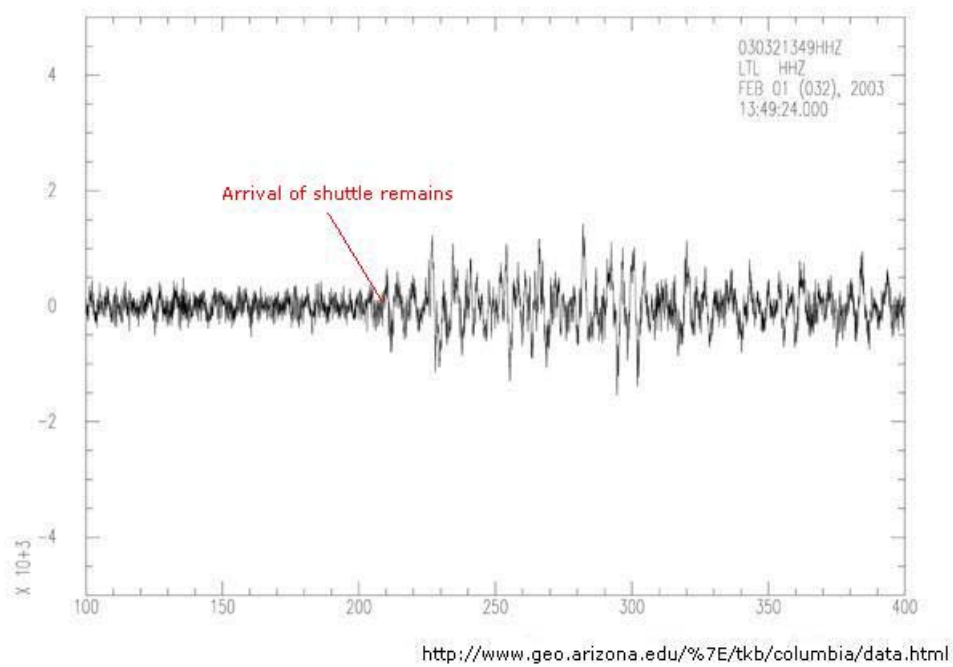


Figure 2: Space Shuttle *Columbia* Reentry on February 1, 2003.

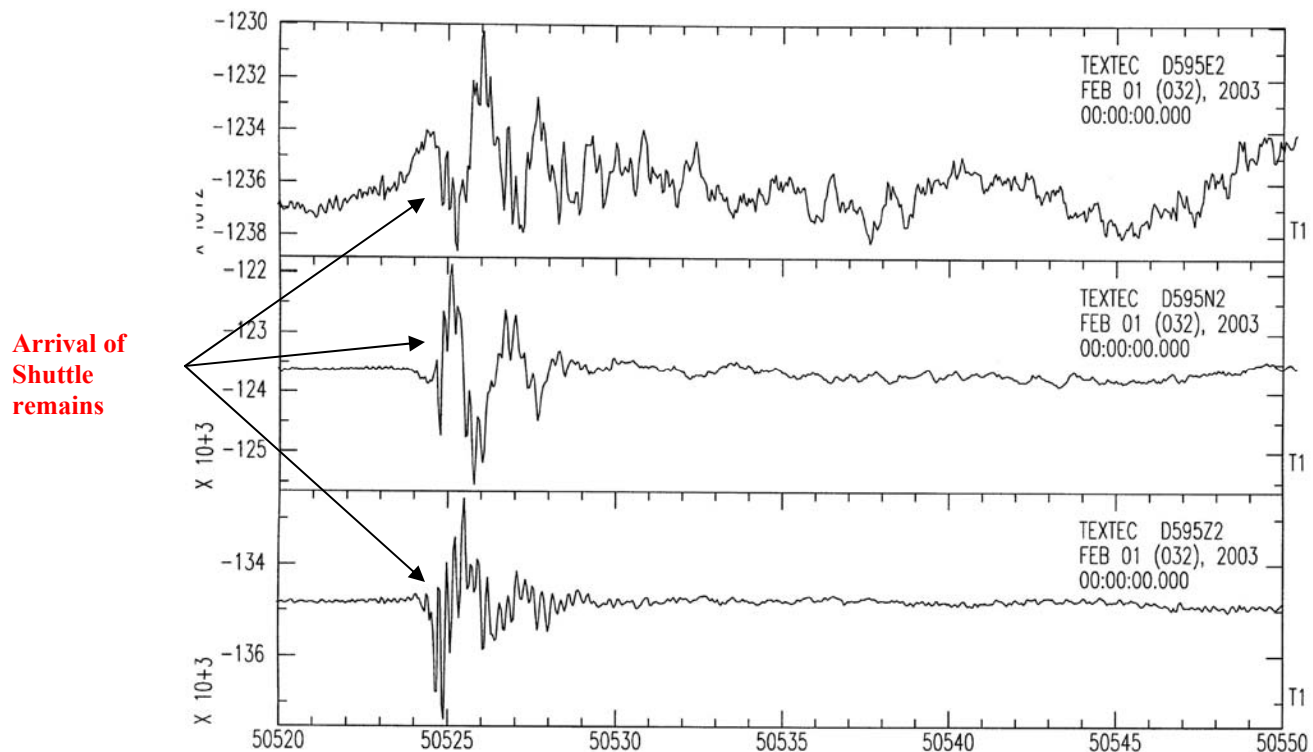


Figure 3: Successful Space Shuttle *Columbia* Reentry on February 1, 2003 (Lubbock, TX)

Questions

1. Why do you think there was no sonic boom recorded on February 1, 2003 in Figures 2 and 3? The seismic station that recorded the information in Figure 2 is located in Louisiana. The seismic station that recorded the information in Figure 3 is located in Lubbock, Texas.

The speed of the Shuttle's remains had decreased below the speed of sound at the location of these seismic stations.

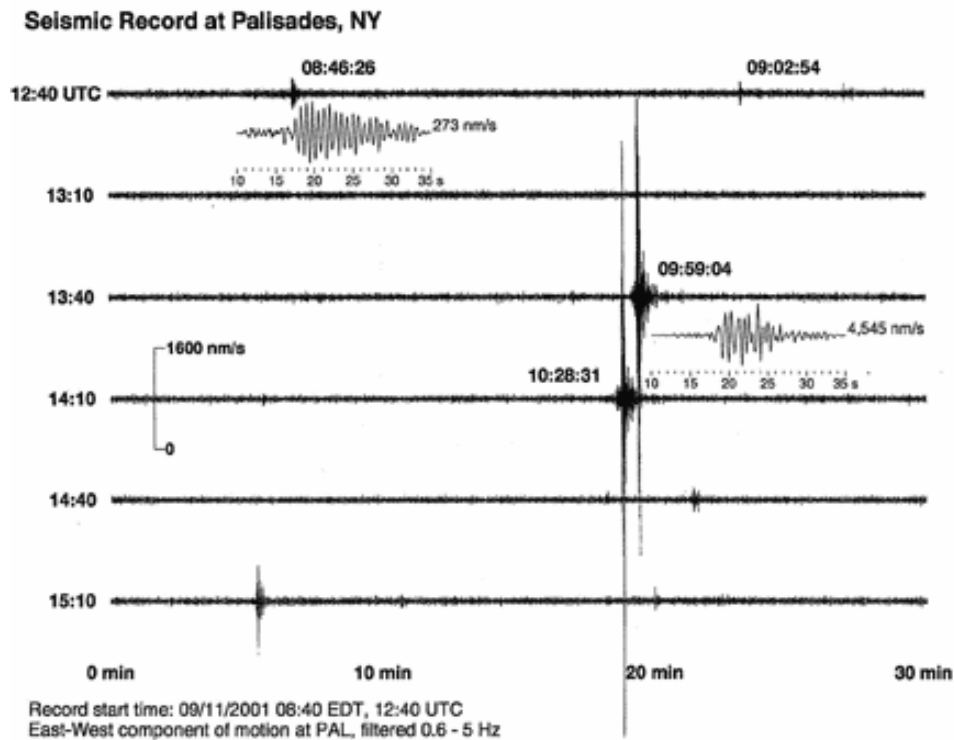
2. Explain how you think the seismograms in Figure 2 and 3, along with others from surrounding areas, were used to help in the Space Shuttle *Columbia* disaster investigation.

The arrival of the Shuttle remains on the seismogram was used to pinpoint the location of the debris so investigators would know where to look to collect it.

3. What else might create a sonic boom that can be recorded on a seismograph?

Asteroids that enter the Earth's atmosphere, aircraft (aircraft and the Space Shuttle actually create two sonic booms very close together, one from the nose and the other from the tail of the plane), the crack of a bullwhip creates a small sonic boom (probably too small to be recorded on a seismograph), and lightening.

B. Look at the following seismic recording. This is a typical recording for earthquakes. It is a continuous record of time in which after 30 minutes, the record begins on a new line for the next 30 minutes and so on. This was recorded in Coordinated Universal Time (UTC) but the times indicated on the record correspond to Eastern Daylight Time (EDT).



http://www.ldeo.columbia.edu/LCSN/Eq/20010911_WTC/WTC_LDEO_KIM.pdf

Questions

1. Look at the two events that have been enlarged to show details of the seismic waves. Can you identify the P wave and S wave arrival time?

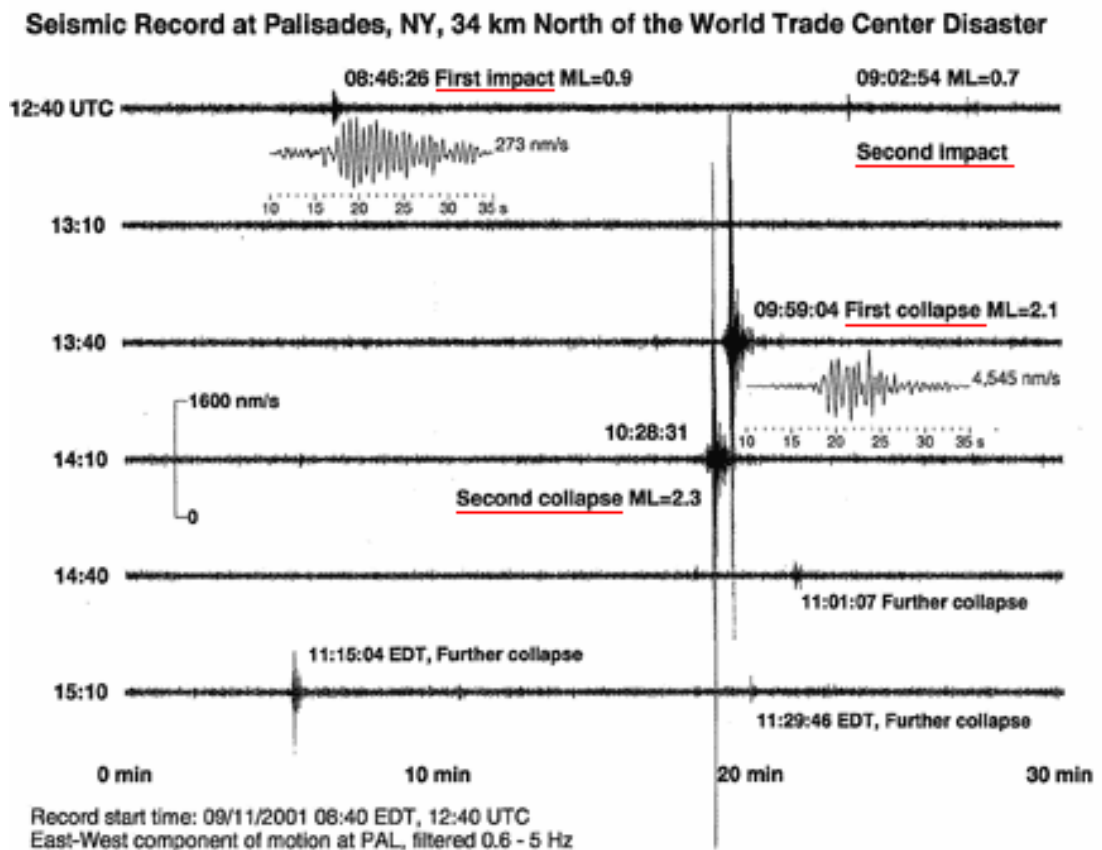
No. No significant P or S waves are observed. The waves shown on the record are surface waves.

- Focus on the first four events (those with the time of the events marked in EDT). What recent major historical event is recorded by these seismograms? Hint: Look at the title and date of the record.

This is a seismic record of the World Trade Center disaster of 9/11/01.

- Using your knowledge of recent history, try to label the source of each of the four events on the seismic record. In other words, what specifically produced the waves seen on the record?

Underlined in red below. The first event is a plane crashing into the North World Trade Tower. The second event is a plane crashing into the South Tower. The third event is the collapse of the South Tower and the fourth event is the collapse of the North Tower.



http://www.ldeo.columbia.edu/LCSN/Eq/20010911_WTC/WTC_LDEO_KIM.pdf

Forensic Seismologists used this data to contribute to the understanding of the details of what happened on that catastrophic day. Although the location of the events and the time was generally known, seismologists aided the investigation by answering questions about the cause of the collapses and exact timing of each event. For example, seismologists could not tell the actual cause of the buildings collapses on the sole basis of the seismograms, but they could use the data to rule out the likelihood the collapses were due

to ground shaking—an important finding since ground shaking may affect the structural stability of the buildings. Seismologists ruled out ground shaking as a cause by determining that the magnitudes of each event was significantly less than that of the limit for structural damage, which is believed to be about M_L 4.0 to 4.5 for that area. Actual ground motions at the site, however, couldn't be exactly determined due to the lack of data at that specific site.

FYI: Scientists believe that the strong spike in the data of each collapse is due to constructive interference of refracted wave arrivals in the area. At least one person believes that these spikes are evidence of an underground explosion, which caused the collapses (http://www.americanfreepress.net/09_03_02/NEW_SEISMIC_/new_seismic_.html). The scientific report from Columbia University's Lamont-Doherty Earth Observatory team can be found at http://www.ldeo.columbia.edu/LCSN/Eq/20010911_WTC/WTC_LDEO_KIM.pdf.

C. Two of the most significant cases where forensic seismology was the sole source of information about a disaster are the sinking of the *Kursk* and a pipeline explosion in New Mexico. The *Kursk* was a Russian nuclear submarine that sank on August 12, 2000 killing all 118 men on board. The explosion in New Mexico killed 11 members of an extended family who were camping near the explosion.

Read the two short articles attached at the end of this exercise and then answer the following questions. The articles are included with permission from the American Geological Institute.

Questions (Students)

1. What evidence did forensic seismology provide in the sinking of the *Kursk* that the first event was an explosion rather than a collision with another vessel, such as an American submarine?

The bubble signature indicative of an underwater explosion was found for the second event and the second event was very similar to the first event, implying that an underwater explosion also caused the first event.

2. The end of the article about the sinking of the *Kursk* identifies two other events where forensic seismology was used. What were these two events?

The bombings of the Murrah Federal Building in Oklahoma and the U.S. embassy building in Nairobi, Kenya.

3. What was the most significant piece of information that forensic seismology provided in the case about the pipeline explosion in New Mexico?

There was about a 25 second time span between the initial blowout of the pipeline and the primary ignition of the gas.

4. According to seismologist Keith Koper, what makes forensic seismology unique compared to other investigative techniques?

Seismic data can be obtained in real-time, while the event is occurring. Therefore, you can get the information very quickly.