Great Earthquakes and Related Tsunamis

An Online Continuing Education Course for Engineers

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Great Earthquakes and Related Tsunamis

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Course Content

1.0 Introduction

One of the great tragedies of modern times occurred in March 2011, hitting the Northeast Coast of Japan abruptly and with very little to no advance warning. This disaster came in the form of an earthquake so powerful that it knocked the earth off its axis of rotation. This great earthquake also spawned a tsunami so overwhelming that it literally wiped out several coastal towns in Northeast Japan. This tsunami encroached inland for distances of up to 5 or 6 kilometers drowning and destroying everything in its path. It was estimated that this earthquake was the largest one to strike Japan in a thousand years.

What forces within the earth generated this epic disaster? Because Japan is so well monitored by automated sensing instruments scientists have been able to accumulate a wealth of real time data about this event, thus enabling them to reconstruct and know exactly what happened. Every detail of this tragedy was recorded real time by seismometers, Global Positioning System (GPS) instruments, strain gauges and tidal gauges. For example, to monitor earthquakes, the Japan Meteorological Agency (JMA) operates a uniquely dense earthquake observation network comprised of over 200 seismographs/seismometers. In addition, the Agency operates over 600 seismic intensity meters. It also collects data from over 3,600 seismic intensity meters managed by local governments and the National Research Institute for Earth Science and Disaster Prevention (NIED). The data thus collected are input into the Earthquake Phenomena Observation System (EPOS) at the Agency's headquarter in Tokyo and at the Osaka District Meteorological Observatory on a real-time basis. The following figure gives a visual impression of the dense distribution of seismic monitoring devices throughout Japan.

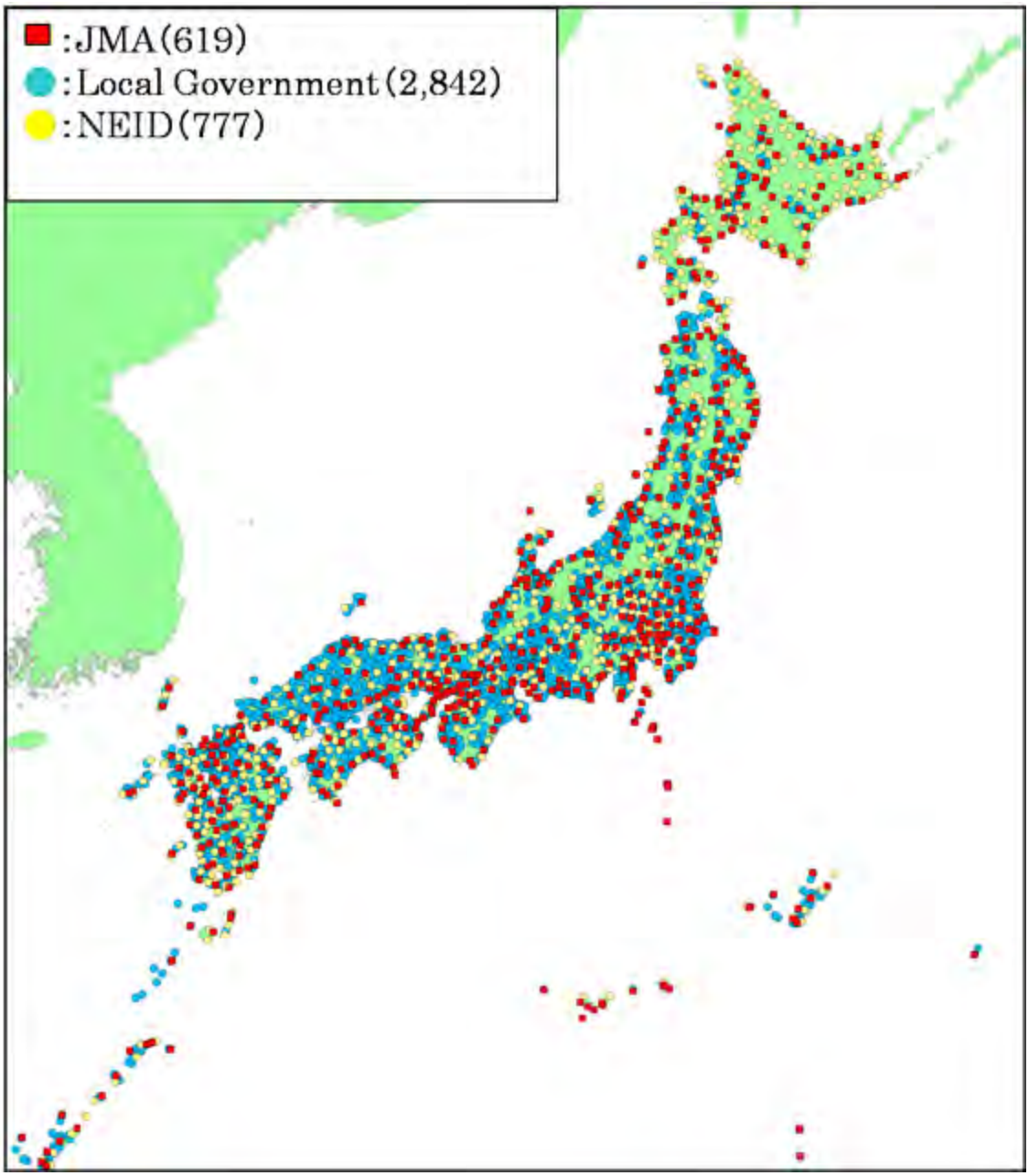

Figure 1: Sites of seismic monitoring devices deployed in Japan as of October 1, 2009 (Source: Japan Meteorological Agency).

In addition, by the time this earthquake occurred, the Geographical Survey Institute of Japan had in full operation a permanent network of over 1,000 GPS receivers deployed across the country. Each GPS receiver is housed in a 15-foot tall stainless-steel pillar. Readings are taken every 30 seconds and, using differential GPS corrections, horizontal motion of less than 0.1 inch can be

readily detected. The following photograph shows one of these fully computerized GPS sensors that recorded both the amount and direction of local displacements.

Figure 2: One of Japan's permanent GPS receivers used for monitoring earth movements.

This great earthquake and ensuing tsunami laid the coastal cities, towns and industrial facilities of Northeastern Japan to complete ruin and sparked one of the worst nuclear accidents in memory. Incredibly, however, the disaster could have been much worse without the preparations that were already in place. Clearly, however, there is still much more to learn to mitigate the impact of such overwhelming natural disasters.

2.0 The Great Japan Tohoku-oki Earthquake

On March 11, 2011, at 2:46:24 pm local time, the Northeastern half of Japan was hit by a huge tremor. As determined by the United States Geological Survey (USGS), the epicenter of this event was located at latitude 38.297^{o}N, 142.372^{o}E, about 60 miles off the Coast of Honshu, Japan. The horizontal location uncertainty is +/- 13.5 km (8.4 miles). The hypocenter of the earthquake was located at a depth of 30 km (18.6 miles), and the epicenter was 129 km (80 miles) E of **Sendai**, Honshu, Japan, 177 km (109 miles) E of **Yamagata**, Honshu, Japan, 177 km (109 miles) ENE of **Fukushima**, Honshu, Japan, and 373 km (231 miles) NE of **TOKYO**, Japan. Early analyses of the seismic records estimated the event to be of magnitude 7. But, as

data continued to flood into the observatories the numbers started to climb in quick succession. The initial magnitude estimate was revised in quick succession up to a magnitude of 9.0.

The following figure shows the location of the earthquake epicenter in relation to the mainland of Japan. The main tectonic features, namely the Plate Boundary and the Pacific and Eurasian Plates, are also shown on the figure.

Figure 3: Location of the earthquake epicenter in relation to the mainland of Japan. The earthquake occurred as a result of an abrupt displacement between the Eurasian and Pacific Plates along their common boundary.

The association between faults and earthquakes, and the relationship between the fault plane, the hypocenter (or focus) and the epicenter of an earthquake are explained and illustrated in Course C-3008 titled: “Earthquakes and Tsunamis: Fundamental Concepts”. The operation of the seismograph/seismometer and the generation of seismograms that record the ground vibrations that accompany an earthquake are also explained in the same course (C-3008).

2.1 Aftershocks

Earthquakes of this magnitude are usually followed by many aftershocks, and in the week that followed the main earthquake numerous aftershocks occurred. The main shock was followed by thousands of magnitude 4, hundreds of magnitude 5, dozens of magnitude 6 and a handful of magnitude 7 earthquakes. Every aftershock took a toll on an already frightened population and potentially every aftershock triggered a new one. The net effect is that the entire country just about ground to a halt as a result of these events.

The following figure delineates the ershocks occurred over the portion

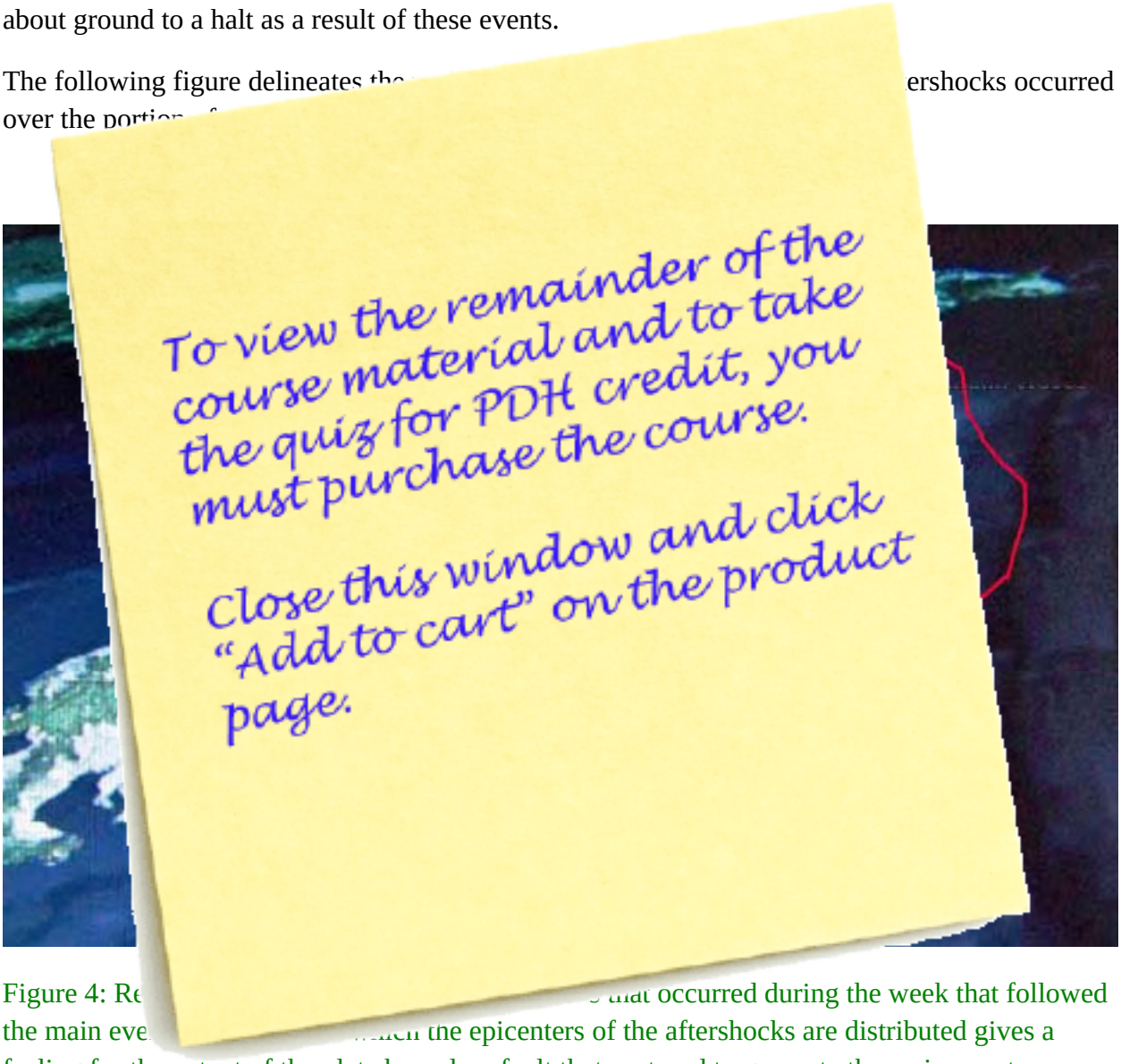

Figure 4: Re that occurred during the week that followed the main eve which the epicenters of the aftershocks are distributed gives a feeling for the extent of the plate boundary fault that ruptured to generate the main event.

3.0 Cause of the Great Japan Tohoku-oki Earthquake