Chapter 2

The Science of Inland Earthquakes

Field of expertise: Earthquake Geology

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Summary

The 2011 Tohoku earthquake released the strain that had accumulated underground in eastern Japan, but it also triggered many subsequent earthquakes as part of the reaction. Seismic activity also increased on land, and earthquakes were caused by active faults, such as the one that occurred one month later in Hamadori, Fukushima Prefecture. Although individual active faults only produce major earthquakes once every several thousand to several tens of thousands of years, the risk of inland earthquakes changes over time because they may become temporarily likelier to move due to huge subduction-zone earthquakes. Prediction evaluation that takes into account the earthquake chain is essential.

Keywords: inland earthquake, local earthquake, active fault, induced earthquakes, aftershocks

Introduction

Land earthquakes, or inland earthquakes, are earthquakes shallower than 20 kilometers in depth that occur inside the landward plate. Although they seem to be completely unrelated to the Tohoku earthquake, they are strongly influenced by huge earthquakes that occur in the ocean.

1: Problems Revealed by the Great East Japan Earthquake

What happened?

The plate boundary fault that caused the Tohoku earthquake (magnitude M9) was about 500 kilometers long and 200 kilometers wide. Its displacement reached a maximum of about 50 meters, moving the seafloor along the Japan Trench and generating a massive tsunami. The ground also moved significantly on land some distance from the epicenter, and the Oshika Peninsula in Miyagi Prefecture moved about 5 meters southeast. In just 3 minutes, the inland Tohoku region, which had been slowly compressed in the east-west direction before the main quake, was pulled in the opposite direction, reversing the location and mechanism of the earthquake. As a result, seismic activity increased in southern Akita Prefecture, off the coast of Akita, northern Aizu Basin in Fukushima Prefecture, around Nikko, northern Nagano Prefecture, near the Fukushima-Ibaraki prefectural border, and around Choshi (Toda, 2013). At a fair distance from this area, a magnitude 6.4 earthquake occurred in eastern Shizuoka Prefecture. A large inland earthquake that caused damage was also triggered (Figure 2-1a).

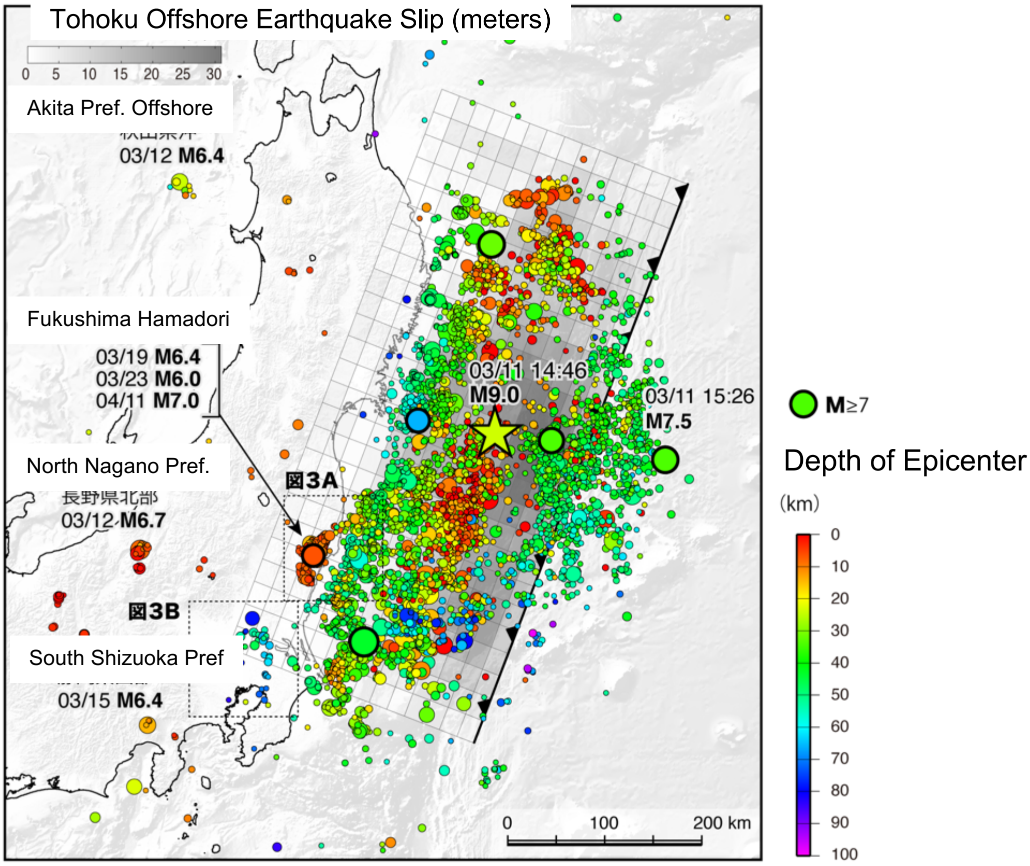

Figure 2-1 a). Outside of the epicenter of the M9 earthquake, a wide area experienced many aftershocks for about 6 months due to the 2011 Tohoku earthquake.

One month later, a M7.0 earthquake occurred on April 11 in Hamadori, Fukushima Prefecture, caused the Yunotake Fault and the Idosawa Fault in Iwaki City to shift, and a 30 kilometer long fault appeared (Fig. 2-1b).

Figure 2-1 b). The fault that appeared due to the April 11, 2011, Hamadori earthquake (M7) in Fukushima Prefecture.

Seismic activity directly beneath the Tokyo metropolitan area also increased, and Tokyo observed frequent tremors not only from aftershocks of the M9 earthquake, but also from seismic activity directly beneath it. Although seismic activity in the Tokyo metropolitan area has since waned, it is still higher than before the Tohoku earthquake (Fig. 2-2)

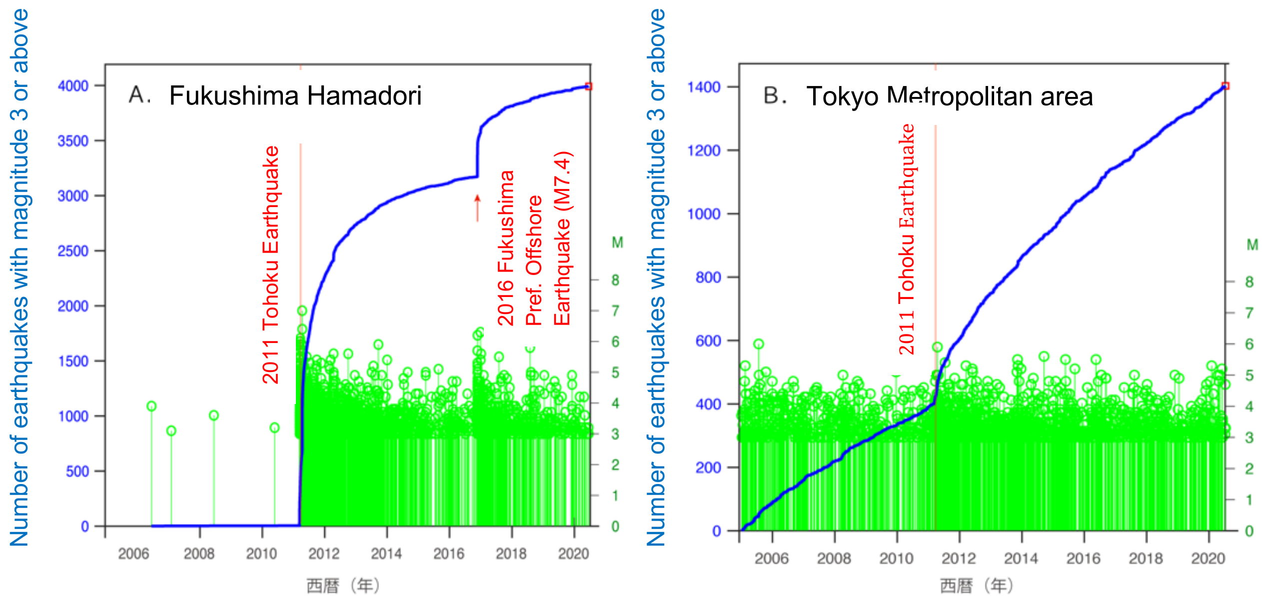

Figure 2-2. Time-series of seismic activity in Hamadori, Fukushima Prefecture (A) and the Tokyo Metropolitan Area (B). The blue line: cumulative curve, green vertical lines: individual earthquakes and their magnitudes. Seismic activity is still active in both regions.

The reality of the damage

The damage caused by the inland earthquake immediately after the Tohoku earthquake was very minor compared to the damage caused by the main shock itself. However, the Northern Nagano Earthquake (M6.7), which occurred about 13 hours later, caused a seismic intensity of 6+ in Sakaemura, resulting in partial damage to several houses, schools, and community centers, as well as road cave-ins. In addition, the earthquake in Hamadori, Fukushima Prefecture (M7.0), recorded a seismic intensity of 6-lower on the Japanese seismic intensity scale in Iwaki City, killing 4 people, injuring 10, and causing large-scale landslides in several places.

2: Paradigms Destroyed by the Earthquake

Conventional wisdom and necessary responses

Compared to ocean trench earthquakes, inland earthquakes have smaller magnitudes, but their epicenters are shallower, causing strong localized tremors with an intensity of 7 or 6 on the Japanese seismic scale. Therefore, when they occur in densely populated areas, they can cause tremendous damage. The earthquake in Hamadori, Fukushima Prefecture, was caused by an active fault. Active faults move at intervals of several thousand to several tens of thousands of years, and each time they move, they cause a localized earthquake of magnitude 7 or 8. Large earthquakes caused by individual active faults rarely occur, but since there are at least 2,000 active faults in the Japanese archipelago, the entire archipelago is subject to these kinds of damaging earthquakes every few years (Toda, 2016). On the other hand, as reaffirmed by the

Tohoku earthquake, the risk of a major inland earthquake temporarily rises sharply, immediately after an ocean trench earthquake. For example, on January 13, 1945, 37 days after the Showa-Tonankai earthquake of December 7, 1944 (M7.9), the Mikawa earthquake (M6.8) occurred in southern Aichi Prefecture. More than 2,000 people were killed and more than 50,000 houses were destroyed. The epicenter of the earthquake was the Fukamizo fault, an active fault. In 1855, about a year after the 1854 Ansei Tokai Earthquake (M8.4) and the Ansei Nankai Earthquake (M8.4), the Ansei Edo Earthquake (M7.0) occurred, killing an estimated 10,000 people in Edo. The Ansei-Edo earthquake may not have been an active fault earthquake, but it is considered to be triggered by a huge ocean trench earthquake.

The Great East Japan Earthquake and lessons learned from the past suggest that ocean trench megathrust earthquakes may cause seismic activity to increase over a wide area even after their occurrence, resulting in damage extending inland. For example, if a huge Nankai Trough earthquake occurs in the future, the short- and medium-term effects may spread to the Kanto region and southeast Japan.

3: Achievements and New Approaches

After the Hyogo Prefecture Nanbu Earthquake (M7.3) that caused the 1995 Great Hanshin-Awaji Earthquake, the Headquarters for Earthquake Research Promotion was established in the Ministry of Education, Culture, Sports, Science and Technology (then Cabinet Office). Under the direction of the Earthquake Research Headquarters, active faults across the country were vigorously surveyed (Figure 2-3), and the results were reflected in the probabilistic seismic motion prediction map (The Headquarters for Earthquake Research Promotion, 2018). However, since individual active faults cause large earthquakes only rarely, the degree of danger for several years to several decades is not always accurately indicated. Seismic activity tends to be cascading, and the effects of huge earthquakes are particularly large in both time and space. Because of this, it is important to take into account the most recent activity in addition to the long-term evaluation.

How does a single huge earthquake change the seismic activity in the surrounding area? Since around the 1990s, there has been a lot of research on stress propagation to the surrounding area as a result of fault movement and the response of seismic activity. The Tohoku earthquake boosted this situation. In addition, the 2016 Kumamoto earthquake became a chain of major earthquakes (M7.3 earthquake 28 hours after M6.5 earthquake), increasing the importance of time-dependent seismic hazard prediction, in which the probability of earthquake occurrence changes depending on the situation. At present, however, our knowledge is limited to understanding the situation after the fact and explaining the mechanism in broad terms.

On the other hand, since the Tohoku earthquake, several models have been proposed to model the source fault motion, calculate stress changes, and predict the seismic activity response in the surrounding area using immediate observation data. There have also been attempts to automate these models to predict changes in hazard levels in real time. Furthermore, the risk of damage caused by inland active faults that may be triggered by the future Nankai Trough earthquake is also being considered. In the future, these earthquake links will be appropriately reflected in earthquake damage scenarios and disaster mitigation measures. In particular, more realistic prediction and evaluation of inland earthquakes is essential to reduce the direct damage caused by seismic tremors.

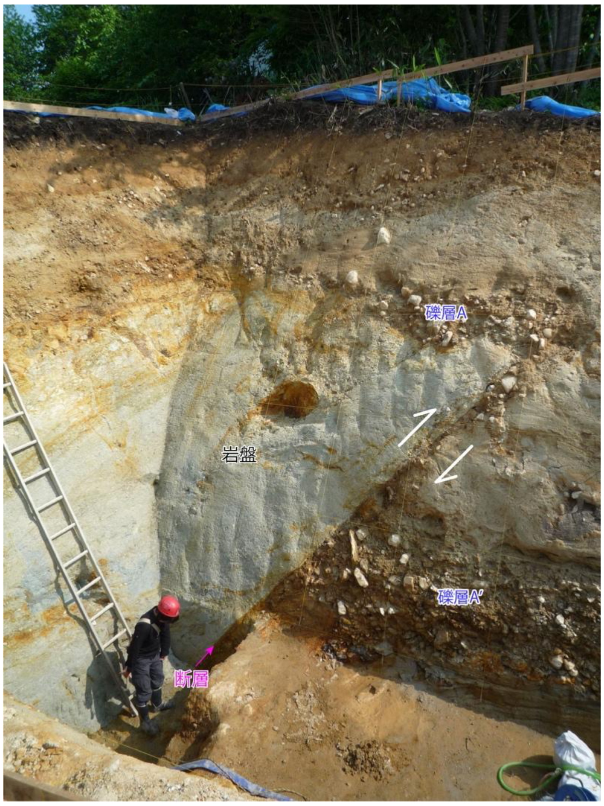

Figure 2-3. Cross-section of strata recording past fault activity exposed by trench excavation. The gravel layers A and A' were originally the same stratum, but they have changed due to past fault movement. Ichinoseki City, Iwate Prefecture.

Conclusion - From the author

When people become ill, they take immediate measures to alleviate the symptoms and search for the cause of the symptoms through medical examination and tests. Until we learn the name of the disease, we cannot relax or give the best treatment. The same applies to earthquakes. When a major earthquake occurs, the first priority is to take immediate action such as rescues, relief, and evacuation, but it is also important to investigate the cause and understand the ongoing phenomena of the earth (although in the case of earthquakes, there are no drugs or surgical procedures to control them). As with medical checkups, research to determine where the causes of earthquakes lie is essential even in normal times, and I believe that the correct understanding of hazards (disaster triggers) will lead to more effective disaster mitigation and prevention in the future.

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