Overview of the 2011 off the Pacific coast of Tohoku Earthquake and the lessons learned from the earthquake

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1. Introduction

Ten years have passed since the 2011 off the Pacific coast of Tohoku earthquake of M9.0 (hereinafter referred to as the "Tohoku-oki earthquake"). The whole picture of this earthquake is gradually becoming more evident. In my talk, I will describe an overview of this earthquake and the lessons learned from it. Please refer to Dr. Shishikura's lecture in this session for details of the tsunami deposits and Prof. Satake's lecture for details of the tsunami.

2. Before the earthquake

Although an ancient document showed a huge earthquake with a large tsunami in Miyagi prefecture in 869 A.D., it was not until around 2000 that the existence of the earthquake was proven from the tsunami deposits. It was only in 2010 that we learned that similar earthquakes had repeatedly occurred at intervals of about 600 years, with the last event about 600 years ago (Okamura et al., 2010).

On the other hand, the plate boundary off Miyagi and Fukushima prefectures had been strongly locked from the beginning of GNSS observations in Japan in 1994 until the end of the 20th century. Since the beginning of the 21st century, the locking had been loosened (e.g., Suito et al., 2011), which is considered as a precursor to the Tohoku-Oki earthquake. However, seismic quiescence was observed during the period when the locking appeared to be strong (Katsumata, 2016), and thus the strong-locking period might be rather abnormal.

A slow-slip event occurred off Miyagi Prefecture from February 2011, which triggered the March 9 foreshock (M7.3), and the afterslip of this foreshock is thought to have triggered the March 11 main shock (Ito et al., 2013). In other words, seismic slip and slow slip occurred alternately like a domino effect, leading to the occurrence of the Tohoku-oki earthquake.

3. Main shock

At the time of the earthquake, a vast plate boundary extending about 500 km N-S and about 200 km E-W was slipped, and a slip of about 50 m occurred near the trench (e.g., Iinuma et al. l., 2012). The reasons for such large slip include the existence of a large strong patch (e.g., Kato and Yoshida, 2011), the fact that the slip penetrated the trench (Ide et al., 2011), the occurrence of the thermal pressurization (e.g., Mitsui et al., 2012), and small elastic constants in the shallow part (Lay et al., 2011). The reasons for the vast slip area are considered to be wide conditionally stable regions (Hori and Miyazaki, 2011) as well as the large strong patch.

4. After the earthquake

The earthquake was followed by large-scale afterslip and viscoelastic relaxation (e.g., Sun et al., 2014). The Pacific coastline had been subsiding for more than 100 years before the earthquake (e.g., Nishimura, 2012), and it also subsided at the time of the earthquake, followed by uplift to the present. This pattern occurred because of the main rupture zone location, which was on the shallower side of the plate boundary, and the viscoelastic relaxation (Sun and Wang, 2015). According to a viscoelastic relaxation model inferred from the postseismic deformation data, such an earthquake is expected to be followed by the uplift of the coastline for about 300 years, followed by subsidence for about 300 years before the next M9 earthquake occurs (Sasajima et al., 2019).

5. Concluding remarks: lessons learned from the earthquake

The reason why we could not foresee such a huge earthquake can be summed up in one sentence: we "overlearned" the limited information we had. The information obtained from this earthquake is invaluable, and it is vital to learn from it, but we should not overlearn it. Otherwise, what we have learned will turn into preconceptions, and the next M9 earthquake will be an "unexpected earthquake" again. Great care must be taken to prevent this from happening.

Keywords: Tohoku-oki earthquake, lessons learned from the earthquake

