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The Mw 7.3 Fukushima, Japan Earthquake of 16 March 2022

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Earthquake Source Characteristics

A magnitude Mw 7.3 earthquake occurred at a depth of 63 km within the subducting Pacific plate about 50 km offshore of Fukushima, Japan on 16 March 2022 (USGS, 2022). The earthquake was preceded by a M 6.4 foreshock approximately 2 minutes earlier. A Mw 7.1 earthquake occurred about 15 km east of these events in February 2021. The events of 16 March occurred in the vicinity of the rupture area of the 11 March 2011 Mw 9.1 Tohoku earthquake (Risk Frontiers Briefing Notes 217, 228, 240 and 437), which was widely felt on the islands of Honshu and Hokkaido in Japan and killed approximately 16,000 people.

The 16 March 2022 Fukushima earthquake occurred within the subducting Pacific plate (left panel of Figure 1) and had fault dimensions of about 25 x 25 km and about 2 m of fault slip. The fault plane is shown by the red rectangle in the right panel of Figure 1. The 11 March 2011 Tohoku earthquake occurred far offshore on the plate interface along the Japan trench and extended about 500 km north-south from latitude 36 – 40 degrees, approximately parallel to the red-coloured zone in the right panel of Figure 2, with a down-dip width of about 225 km and a fault slip of about 30 m.

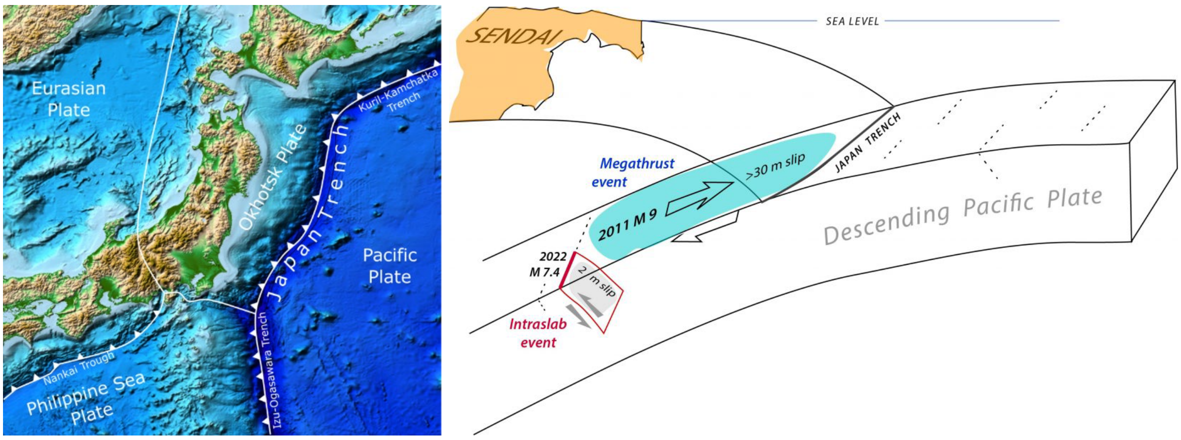

Figure 1. Left: Subduction zones along the Pacific coast of Japan Source: USGS. Right: Cross section showing the fault plane of the 16 March 2022 earthquake within the subducting Pacific plate in the red rectangle and the fault plane of the 11 March 2011 earthquake on the Okhotsk – Pacific plate interface in blue. Source: Toda and Stein, 2022.

Earthquake Ground Motion Levels

The 2022 earthquake caused an upper 6 on the Japan Meteorological Agency (JMA) intensity scale of 7 in parts of Miyagi and Fukushima prefectures. At an intensity of upper 6, many people find it impossible to remain standing or move without crawling and can be tossed though the air. The peak acceleration maps of the 2011 and 2016 earthquakes are shown on the same scale in Figure 2. JMA Intensity 6 upper corresponds to a peak acceleration of about 1g, which is shown by the dark red colour in Figure 2.

These maps show that, despite the large difference in their magnitudes, these two earthquakes generated similar peak acceleration levels in their epicentral areas. The 500 km length of the rupture zone of the 2011 event caused the affected area to extend further north and south than the 2022 event.

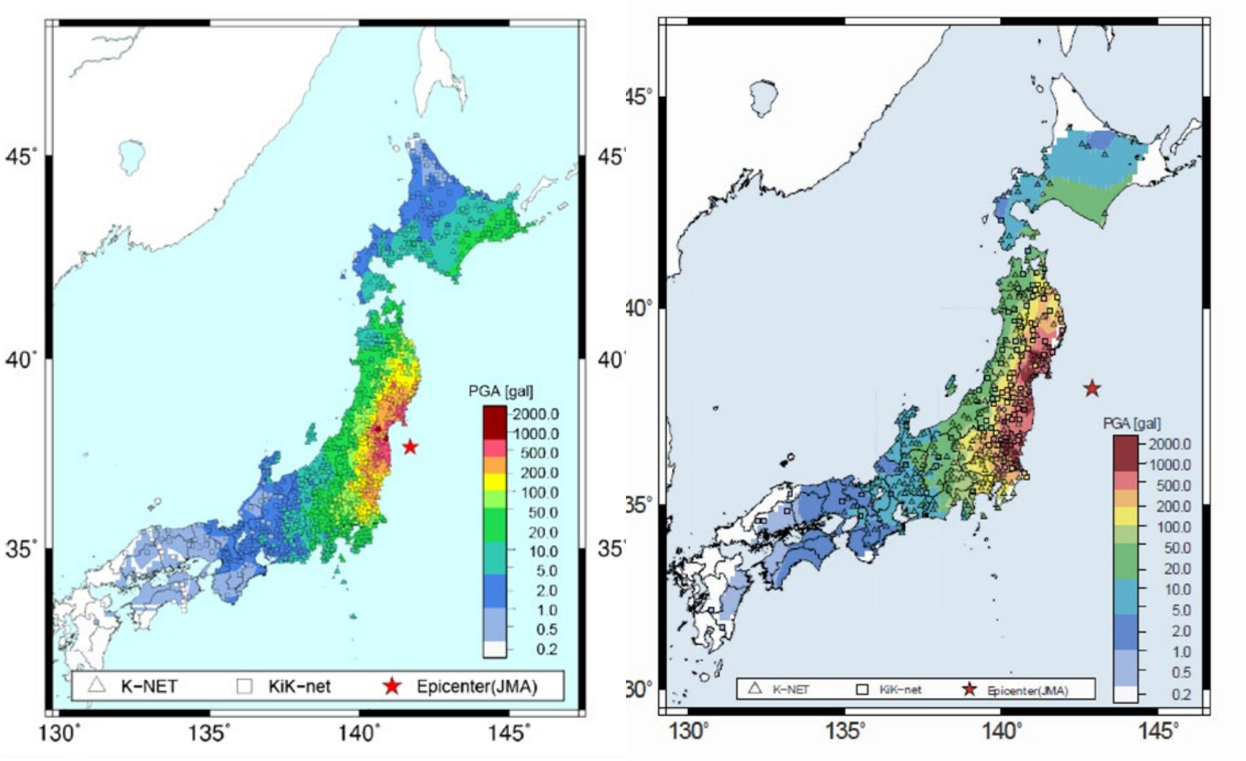

Figure 2. Peak acceleration of the 16 March 2022 Mw 7.3 (left) and 11 March 2011 Mw 9.1 earthquake (right). Source: USGS.

Tsunami Warning

The 63 km depth of the 16 March 2022 earthquake immediately indicated that it would not generate a large tsunami like that generated by the 11 March 2011 Mw 9.1 Tohoku earthquake which led to extensive destruction along the Japanese coast and caused the deaths of about 16,000 people in the Tohoku area. Nevertheless, the earthquake prompted the JMA to issue a 1-metre tsunami warning for the Pacific coast of Miyagi and Fukushima prefectures, but the warning was lifted about 6 hours later after only relatively small tsunami waves were observed. Tsunami waves of up to 30 centimetres were earlier measured in Ishinomaki Port in Miyagi Prefecture.

Earthquake Casualties

The 16 March 2022 earthquake caused three deaths and about 100 injuries over a wide area including Miyagi, Fukushima, Kanagawa, Ibaraki, Iwate, Akita and Yamagata prefectures, with many of these in the coastal city of Soma in Fukushima. This low toll is a reflection of the extraordinarily good performance of buildings in Japan during earthquakes, which was also conspicuous in the 11 March 2011 Mw 9.1 Tohoku earthquake.

Power Outages

The earthquake caused widespread power grid failures and power outages in northeastern and eastern Japan, affecting a total of more than 2.2 million households, including about 700,000 in Tokyo, according to TEPCO Power Grid Inc. and Tohoku Electric Power Network Co. At least 6.1 gigawatts of gas and coal-fired power capacity was shut down after the earthquake, and the Tokai Mura nuclear power plant was safely shut down. It took over a day to restore power in some regions.

Japan's nuclear energy authority said it had detected no abnormalities at the Fukushima No. 1 nuclear plant, which went into meltdown caused by tsunami inundation in the 11 March 2011 earthquake. However, the cooling of the spent fuel pool at the Fukushima No. 2 plant's No. 1 reactor was stopped, while power for the No. 3 reactor had been temporarily shut down but later restored. This is troubling, given the lessons that should have been learned in the 2011 event (Risk Frontiers Briefing Note 240).

Tohoku Electric Power Company has found no reports so far of damage at the Onagawa nuclear power plant in Miyagi Prefecture. This has been attributed by Ibrion et al. (2020) to a culture of safety implemented by its operator, a culture that was found by the Fukushima Nuclear Accident Independent Investigation Commission to be notably lacking in the Tokyo Electric operated Fukushima nuclear plant in the 2011 event (Risk Frontiers Briefing Note 240).

I had the opportunity to inspect the reactor building of the Onagawa nuclear power plant after the 2011 Tohoku earthquake. The engineers had used magic marker highlighters to mark miniscule harmless cracks a few centimetres long and fractions of a milimetre wide in the thick concrete upper walls of the building, which experienced peak accelerations comparable to the design level of 0.6g, and sustained ground motion levels for over one minute. The recorded tsunami height of about 13 metres exceeded the plant's anticipated maximum level of 9.1 metres, but the tsunami washed around the foundations without causing any damage. Unlike its tsunami performance, the seismic performance of the Fukushima nuclear power plants was also good. Given the absence of tsunami hazard in Europe, the rapidly increasing climate risk, and warfare now occurring in Europe with fears of energy security, the precipitous abandonment of nuclear power in Europe following the 2011 Tohoku earthquake is now being reconsidered in some European countries.

Shinkansen Bullet Train Derailment

A Tohoku Shinkansen bullet train with 75 passengers and three crew on board derailed between Fukushima Station in Fukushima and Shiroishizao Station in Miyagi (Figure 3), but no injuries were reported. They were trapped inside the train for about four hours after the derailment caused a power outage on the train, before getting off the train and using an emergency stairway exit along the line.

For all Shinkansen trains, an early warning system detects the P (compressional) waves, which are usually not damaging and travel faster than S (shear) waves, which arrive a few seconds or tens of seconds later and potentially cause damage, providing an opportunity to brake the train.

A passenger reported that the train had been slowing down after the first earthquake alert was issued following the Mw 6.4 earthquake, and stopped just before the second, more powerful Mw 7.3 earthquake occurred two minutes later. If that is the case, the derailment may have occurred after the train had stopped. However, as suggested by the Japan Transportation Safety Board, it seems more likely that the train was traveling very slowly when the second earthquake damaged the viaduct (shown in Figure 3) and derailed the train.

Nevertheless, a halted train is not immune to derailment. To guard against derailments, JR East has installed L-shaped brackets designed to hook the cars on the rails, thus preventing them from colliding with side walls. JR East developed the brackets following the derailment of Joetsu Shinkansen cars after a powerful earthquake in Niigata Prefecture in 2004. JR East has also taken measures to prevent trains from tipping by installing devices to fix the rails firmly in place so that they will not tilt. The devices were installed on approximately 1,000 km of track, including at the site where the derailment occurred.

This is the second derailment of a bullet train carrying passengers since 23 October 2004, when the Mw 6.6 Chuetsu earthquake derailed a Joetsu Shinkansen in Niigata Prefecture, northwest of Tokyo. When the 2011 Mw 9.1 Tohoku earthquake occurred, 27 Tohoku Shinkansen trains were running and all came to a complete stop safely.

The earthquake damaged rails at 10 locations and 24 electric poles, while severing overhead power lines at two locations. There were 20 cases of structural damage to other facilities such as stations and viaducts. It is expected that service will not be completely restored until 20 April 2022.

The poor structural performance of bridges such as the Shinkansen viaduct is in marked contrast with the excellent performance of buildings in the 2022 Fukushima earthquake. This dichotomy in seismic design in Japan dates back to the 1970s, when building engineers adopted the use of ductility – for example, using rebar in concrete structures. Ductility allows for bending without breaking, providing controlled damage in buildings in very strong earthquakes, so they fail safely without causing deaths and injuries. Meanwhile, civil engineers, teaching in separate university departments (Doboku as against Kenchiku), still insist on tolerating no damage to provide the laudable (but practically unattainable) goal of uninterrupted service. They design for strength, but when the seismic demand exceeds that strength there can be brittle and potentially disastrous failure. This dichotomy was very evident in the 1995 Mw 7.0 Kobe earthquake, which caused widespread damage to bridges (including Shinkansen viaducts) but limited damage to buildings designed for ductility following code upgrades based on ductility in 1971 and 1980.

Figure 3: Left: derailed bullet train on bridge near Shiroshi. Miyagi Prefecture. Source: Mainichi Shimbun. Right: Damaged bullet train viaduct Source: Xinhua/Zhang Xiaoyu.

References

Ibrion, M., N. Paltrinieri and Nejad, A. (2020). Learning from non-failure of Onagawa nuclear power station: an accident investigation over its life cycle. Results in Engineering Volume 8, 2020, 100185, ISSN 2590-1230, https://doi.org/10.1016/j.rineng.2020.100185.

Risk Frontiers (2011). The Mw 9.0 Tohoku, Japan Earthquake of 11 March 2011. Briefing Note 217.

Risk Frontiers (2011). Recovery from the 2011 Tohoku, Japan Earthquake and Tsunami. Briefing Note 228.

Risk Frontiers (2011). Report of the Fukushima Nuclear Accident Independent Investigation Commission. Briefing Note 240.

Risk Frontiers (2021). Ten years after the 2011 Tohoku, Japan earthquake and tsunami, Briefing Note 437.

Toda, S., Stein, R. (2022). 'Triplet' earthquakes strike near Tohoku, Japan, but a rupture gap remains, Temblor, http://doi.org/10.32858/temblor.246

USGS (2022). M 7.3 - 57 km ENE of Namie, Japan. https://earthquake.usgs.gov/earthquakes/eventpage/us6000h519/dyfi/intensity

Wikipedia (2022). https://en.wikipedia.org/wiki/2022_Fukushima_earthquake

Xinhua (2022). http://www.xinhuanet.com/english/20220317/75253b2c1f964c64a4afeae0e5dafce0/c.html