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The 2018 Hokkaido Eastern Iburi Earthquake and its Aftermath

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The central Hokkaido, Northern Japan, was struck by an earthquake of M6.7 on September 6, 2018. Its deep hypocenter of 37 km might result of a complex crust and upper mantle structure in Hidaka arc-arc collision system. A seismic intensity of 7 on the Japan Meteorological Agency (JMA) scale was observed at Atsuma Town. About 90% of the casualties were due to the multiple earthquake-induced landslides in Atsuma Town, and a significant number of houses in the urban areas of Sapporo were damaged due to soil liquefaction. Destruction of electric power facilities near the epicenter caused a long-term power outage in approximately 2,950,000 houses in Hokkaido. The widespread blackout caused secondary damages to utilities, civil life, and economic activities in the region. The number of refugees from this incident was approximately 13,111 in maximum, and the economic damage also increased further as a result of the electric blackout. The Hokkaido Prefectural Government immediately applied the Disaster Relief Act on that accrual day. On September 28, 2018, the National Government certified the event as the Designated Disaster of Extreme Severity.

Keywords: the 2018 Hokkaido Eastern Iburi Earthquake, JMA seismic intensity 7, multiple landslides, liquefaction, blackout

1. Overview of the Earthquake

The 2018 Hokkaido Eastern Iburi Earthquake with M6.7 occurred on September 6, 2018 at 03:07 (Japan Standard Time, JST, same hereinafter) (**Fig. 1**). The 37 km depth of the hypocenter was unusual for an inland earthquake and it might reflect a complex subsurface of the Hidaka collision system [1]. A seismic intensity of 7, which is the maximum level on the JMA's scale, was observed at Atsuma Town (residential total population 4,624: 0.09% of Hokkaido Prefecture's total population of 5,310,559; same as below), near the epicenter. The intensity in Atsuma Town was announced only at 15:30 on the same day due to a telecommunication problem at the seismic station. An intensity of 6 upper was observed at Abira Town (population 8,068: 0.15%) and Mukawa Town (population 8,222: 0.15%), and 6 lower in Sapporo City Higashi-Ku (population 261,980: 4.93%), Chitose City (population 97,070: 1.83%), Hidaka Town (population 12,186: 0.23%), and Biratori Town (population 5,107: 0.10%) [2, 3]. The largest acceleration was 1,796 gal at the K-net Oiwake station in Abira Town [2].

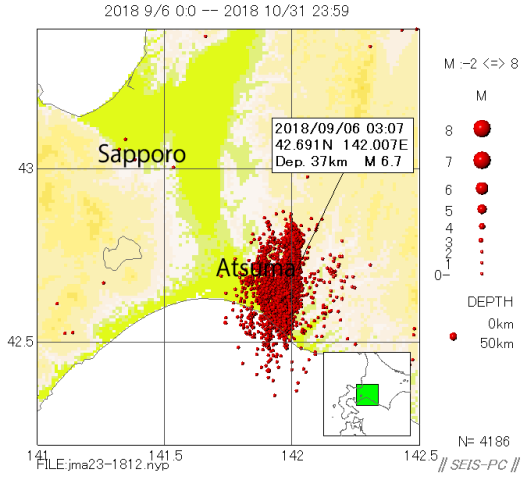

Fig. 1. Mainshock and aftershock epicenters from September 6 to October 31, 2018. Data were from the Japan Meteorological Agency.

Active aftershocks also occurred, e.g., M5.4 at 06:11 on September 6 (maximum intensity 5 lower) and M5.2 at 08:58 on October 5 (maximum intensity 5 lower). A total of 312 aftershocks with intensity 1 or above were observed until the end of October 2018 [2].

2. Overview of Casualties and Damages

2.1. Casualties

This earthquake causes several human casualties: 41 fatalities, 18 heavy injuries and 731 minor injuries (as of 17:30 October 29, 2018) [4]. The greatest human damage occurred at Atsuma Town with a total of 36 fatalities due to earthquake-induced landslides [4].

2.2. Multiple Landslides, Liquefaction and Building Damages

Strong ground shaking of the intensity 7 triggered simultaneous multiple landslides in Atsuma Town. The total collapse area of 13.4 km^2 was the largest record since 1891, Meiji era [5]. Surface geology of thick pyroclastic fall deposits due to nearby volcano eruptions was considered to be related to the incident [6]. Collapsing of houses due to landslides led to several deaths in Atsuma Town. The landslides also desolated forest resources, while debris flows accumulated on the farmland, destroying a number of agricultural facilities [4].

Liquefactions due to strong ground shaking were reported. A significant number of residential houses were damaged by the liquefaction and its related phenomena in Kiyota Ward of Sapporo City (population 114,540: 2.16%), with about 50 km epicentral distance and 5 upper intensity [7].

Damage to dwelling houses due to seismic shaking and liquefaction was reported as follows: 409 completely collapsed houses, 1,262 destroyed and 8,463 partially destroyed (as of October 29, 2018) [4]. A maximum of 192 completely collapsed houses were registered at Atsuma Town. The number of half and partial housing destroyed of 498 and 3,307 in Sapporo City (population 1,955,115: 36.82%) were the largest among municipalities [4]. It reflected exposure population due to higher population density in urban Sapporo area.

2.3. Electric Power Blackout

Strong seismic shaking attacked the electric power facilities near the focal region. The largest thermal electric power plant in Hokkaido, Tomato-Atsuma Station, is located 18 km away east-southeast from the epicenter. Multiple consecutive factors such as the shutdown of the Tomato-Atsuma electric power plant, and the shutdown of the hydroelectric power plants due to trouble in electric power lines, led to the long-term blackout in the whole Hokkaido area of 2,950,000 houses at 03:25 on September 6, 2018, 18 minutes after the mainshock [4, 8]. Emergency generators were activated at the Tomari nuclear power plant because of the loss of external electric power [4].

The electric power loss in Hokkaido caused severe damage to its livelihood and economic activities. Though the recovery time varied from place to place, it was not restored till September 8 [9]. Several seismic stations were operated with the help of emergency batteries [10]. The recovery time of the Institute of Seismology and Volcanology of Faculty of Science, Hokkaido University was at 14:00 on September 8.

3. Overview of Responses

3.1. Response by National and Local Governments

The national and Hokkaido local governments quickly established a disaster countermeasures office in 2 minutes after the mainshock occurrence at 03:09 on September 6, 2018. The Prime minister's and governor's designations were issued at 03:10 and 03:17 respectively. The Japan Disaster Medical Assistance Team (DMAT) set up a coordinating headquarter at 03:50 and the Cabinet Office Initial Emergency Survey Team was dispatched to Hokkaido from Tokyo at 06:10. The Hokkaido Prefectural Government held its first Prefectural Disaster Management Headquarter meeting and dispatched liaison to devastated areas at 07:00. The first Cabinet Office Ministerial meeting was convened at 07:37, where the Governor of Hokkaido took the decision to employ the Disaster Relief Act to the whole region at 15:00 [11, 12]. Rescue operations by the National Police Agency, Fire and Disaster Management Agency, Self-Defense Force and Coast Guard organizations salvaged 147 victims [11].

Total 383 evacuation shelters accommodated 3,744 refugees till 13:30 on September 6 and on September 7, the maximum number of shelters and refugees were 768 and 13,111, respectively [9, 11]. Transportation of first aid materials began on September 7 by the Self-Defense Forces without waiting for a request from the affected districts [12]. A disaster volunteer center was also opened on September 7 in Atsuma Town [12]. This disaster was assigned as the "Designated Disaster of Extreme Severity" by the National Government on September 28. Refugees started to move to temporary housing from November 1 [12].

3.2. Response of Earthquake Investigation Agency

First press release by the JMA was issued at 05:10 on September 6. Afterwards, JMA continued intermittent press releases. The Headquarters for Earthquake Research Promotion (HERP) convened an extraordinary earthquake investigation committee meeting on September 6 and issued evaluation results of this earthquake [13]. The Geospatial Information Authority of Japan provided aerial photos before and after the disaster, information on crustal deformation and maps of the landslides and sedimentary distribution via internet [14].

4. Disaster Features and Problems

The epicenter of the mainshock was located near the major active fault of the Ishikari-Teichi-Toen fault zone (southern part) (ITT). Evaluation of this fault zone by the Headquarters for Earthquake Research Promotion (HERP) suggested the anticipated maximum magnitude of $>$ M7.7 [15]. A depth of 37 km foci was, however, significantly deeper than the depth of an anticipated fault by the HERP. Relationship between this earthquake and the active fault zone has been in debate. In Sapporo urban area, the observed intensities were larger than the anticipated Mw7.1 scenario earthquake in the ITT by the HERP [16]. It is preferable to reexamine strong motion evaluation procedure for deep inland earthquake.

Cause of fatal human damage was mainly due to multiple landslides triggered by the earthquake [4]. Landslide

mapping and field investigations suggested that surface volcanic pyroclastic falls might act as a disaster predisposition [6]. Landslide devastated residential sites in Atsuma Town have been designated as the Sediment Disaster Danger Zone by the local government [17]. Authorities must continue to improve hard and soft measures, and awareness of residents in warning areas. The housing restriction is one of the candidates in future measure.

The "Hokkaido blackout" was the first experience not only in Hokkaido area but also in modern Japan. Electric power loss caused serious secondary disasters in utilities, e.g., water supply outage (68,335 housing maximal), traffic suspension on roads, railways and airlines, and logistics [4, 9]. All Hokkaido residents were unable to obtain disaster information via television. Internet via mobile IP connection was almost unstable due to battery shortage of individual mobile phone devices. Furthermore, critical human suffering would have been expected in the winter season if heating had been lost due to blackout.

All economic activities were suspended by the blackout. The damage amount in agricultural and animal industry was 18 billion JP Yen [9]. Forest industry reached to 52 billion JP Yen [9]. Estimated total sales losses in commerce and industry due to blackout reached to 132 billion JP Yen [9]. Thus, it is necessary to consider different ways to ensure a stable power supply for expected natural disasters. Blackout caused the suspension of shop checkouts and electronic money systems. Cash withdrawal from ATMs was also halted. This resulted in a negative impact not only for civic life but also disaster responses and restoration. It is also desirable to examine highly redundant settlement systems including cash out by debit card.

Tourism is one of the most important industries in Hokkaido and the impact amount of its consumption has been estimated as 36 billion JP Yen [9]. Therefore, authorities and tourism companies must ensure safety measures to tourists in the event of a disaster. Enhancement of safety measures will give future tourists a peace of mind.

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