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Active faults controlling spatial distribution of environmental effects and building damage induced by the February 6, 2018, Mw 6.4 Hualien (Eastern Taiwan) earthquake

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The island of Taiwan is located at the convergent plate boundary between the Philippine Sea plate and the Eurasian plate (Shyu et al. 2005). It is the product of the ongoing collision between the Eurasian continental margin and the Luzon volcanic island arc, part of the Philippine Sea plate (e.g. Shyu et al. 2005, 2016). Currently, Taiwan is experiencing a double suturing. The Luzon volcanic arc is colliding with the Hengchun forearc ridge in the south, which is in turn colliding with the Eurasian continental margin. In the north both sutures are unstitching. As a result, Taiwan is composed of three lithospheric pieces of Taiwan: the Eurasian continental margin, the continental sliver, and the Luzon arc (e.g. Shyu et al. 2005, 2016).

The two sutures are producing separate neotectonic belts along the western and eastern part of the island. Each collision belt matures and then decays progressively from south to north resulting in discrete steps, manifested as seven distinct neotectonic domains along the western belt and four along the eastern belt. Each domain define a distinctive assemblage of active structures (Shyu et al. 2005, 2016). Characteristic examples of neotectonic domains in the eastern part of Taiwan are the Hualien and Ryukyu domains, which comprise active faults capable of producing earthquakes with magnitudes varying from 7.0 to 8.0. As it is shown from the study of historical and recent seismicity of the island, the eastern part has been often struck by large and destructive earthquakes in 1811 (M=7.5), 1815 (M=7.7), 1882 (M=7.5) and 1951 (M=7.5).

On February 6, 2018, an Mw 6.4 earthquake hit eastern Taiwan with epicenter close to the coastal area north of Hualien city and focal depth around 10 km. The main shock caused 17 casualties and 285 injured in the Hualien City. The most affected area was Hualien city with VII maximum intensity. This area is composed of metamorphic rocks of the Central Range overlain by sediments of the Longitudinal Valley, which are in turn overlain by alluvial deposits. Hualien city occupies an area founded on sediments of the Longitudinal Valley overlain by recent alluvial deposits. One of the major active faults of Taiwan, the Meilun fault, disrupts these recent formations. Moreover, it ruptured in the October 1951 earthquake and produced up to ~1.2 m of coseismic vertical offsets and up to ~2 m of sinistral offsets (Hsu 1955; Bonilla 1975, 1977). The onshore length of the fault is less than 10 km. This length appears to be too short considering that the 1951 earthquake had a magnitude of 7.3 (Hsu, 1962). Therefore, the fault may extend further offshore to the north (Shyu et al. 2005).

The scientific team visited the 2018 earthquake-affected area in Eastern Taiwan and conducted a field macroseismic survey and a geological reconnaissance in order to assess the earthquake impact on the natural environment and the building stock in Hualien County and to study the factors controlling the distribution of the observed earthquake environmental effects (EEE, Lekkas et al., 2018).

As regards building damage, the earthquake caused almost identical heavy structural damage, comprising collapse of the ground floors and tilting, to 6 multistory buildings in Hualien City, while the rest of the building stock suffered light non-structural damage or no damage at all. The common damage characteristic of the inspected buildings was the decomposition of the concrete in the columns of the ground floor due to crashing, resulting in failure of columns and the subsequent tilting, while the upper floors of the structures were left intact. The observed damage is the result of the synergy of the prevailing special ground conditions at each site, the effects of the vertical component of the earthquake ground motion on the performance of concrete and reinforcement of damaged buildings, the parameters of the ground shaking as well as the type, design and construction characteristics of the affected buildings. The earthquake also caused damage to infrastructures of Hualien. Cracks indicating left lateral displacement were observed in the superstructure of a bridge.

Taking into account the distribution of building damage and the geological setting of Hualien city, it is concluded that all damage was arranged along or close to the Meilun fault that runs right underneath Hualien with a length of 5 km and a strike direction of N20°-55°E.

As regards the EEE, secondary EEE comprising ground cracks, liquefaction phenomena and slope movements were generated. Ground cracks were observed in several sites in Hualien city characterized by different direction and offsets. They indicated dextral or sinistral stike-slip offset and extension or compression. It is significant to note that they were observed close to the damaged buildings. Liquefaction phenomena included ground cracks accompanied by ejection of sand-water mixture that covered parts of the asphalt pavement in the area east of Hualien airport and outside of the perimeter wall of the military base. Slope movements were generated along steep slopes associated with faults as well as along the high and steep slopes of the Taroko Gorge located north of Hualien city.

Based on the distribution of the EEE in Hualien city, it is concluded that ground cracks and liquefaction phenomena were also observed close to or along the Meilun fault.

Taking into account the application of radar interferometry techniques by several research teams and the detection of permanent ground dislocation of tectonic origin in Hualien city (Yen et al., 2018; Huang and Huang, 2018), it is concluded that the eastern coastal part of the city located east of the Meilun fault is characterized by remarkably large uplift and northeastward displacement, while its western part located west of the Meilun fault is subsided and southwestwards displaced. Thus, the resulted displacement discontinuity coincides with the already mapped Meilun fault.

In conclusion, the spatial distribution of the environmental effects (ground cracks and liquefaction phenomena) and the building damage induced by the February 6, 2018, Mw 6.4 Hualien (Eastern Taiwan) earthquake is strongly related to and controlled by the Meilun fault which runs right underneath Hualien City.

Moreover, the observed damages resulted from the synergy of several factors comprising the soil characteristics, the effects of the vertical component of the earthquake ground motion, the construction type and the presence of the Meilun fault, which strongly affected the mechanical properties of the surficial sediments and the bedrock along or close to its trace.

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