Study team report of the July 27, 2022 Magnitude (Mw) 7.0 Northwestern Luzon Philippines Earthquake

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Key Facts

- Hazard Type: Earthquake
- Date of the disaster: July 27, 2022
- Location of the survey (Lat. Lon., name or address): Abra and Ilocos Sur, Philippines
- Date of the field survey: August 1-3, 2022
- Survey tools: Cameras, calipers, laser meters, drones, and inclinometers
- Key findings
  1) The epicenter of the magnitude 7.0 earthquake was located approximately 3 km away from Tayum, Abra, Philippines. Its origin was tectonic generated from the oblique movement of the Abra River Fault.
  2) Damage to houses, schools, hospitals, churches and cultural heritage structures, and roads and bridges were significant and widespread.
  3) Numerous landslides, sand boils, and ground fissures were also recorded.

Key Words: *earthquake, damage to infrastructure, structural damage, cultural heritage, landslide*

1. INTRODUCTION

Abra is a landlocked province situated in the north-western portion of Luzon, Philippines (see **Fig. 1**). At approximately 8:43 AM (PST), July 27, 2022, a magnitude 7.0 tectonic earthquake struck the province and its adjacent provinces including Metro Manila. According to the Philippine Institute of Volcanology and Seismology (PHIVOLCS), the focal depth of the earthquake is 17 kilometers (about 10.56 mi) and has an epicenter located at 17.64°N, 120.63°E and 3 km N 45° W of Tayum, Abra (see **Fig. 2**). This earthquake registered a PEIS (PHIVOLCS Earthquake Intensity Scale) of VII that is characteristic of a destructive earthquake with the presence of liquefaction, lateral spreading and damage to buildings and bridges. As of August 22, 2022, PHIVOLCS recorded a total of 4795 after-shocks. 70 of which were felt with magnitudes ranging from 1.4 to 5.1. The Situational Report No. 20[1)] issued by the National Disaster Risk Reduction and Management Council (NDRRMC) reported a total of 11 fatalities and 609 injured individuals (as of August 22, 2022). Furthermore, 155,911 families or 574,367 individuals from 11 provinces were affected by the earthquake. The NDRRMC also said that the estimated cost of damage to infrastructures has reached ₱2.65 billion.

This paper is divided into four sections; the first is the introduction, **Section 2** briefly explaining geologic and tectonic setting of Abra. **Section 3** explaining damage caused by the earthquake and **Section 4** summarizes the findings. Teams from the Association of Structural Engineers of the Philippines (**ASEP**) were mobilized to study and observe the damages incurred due to the earthquake (see **Fig 3**).

Fig. 1. Abra, Philippines

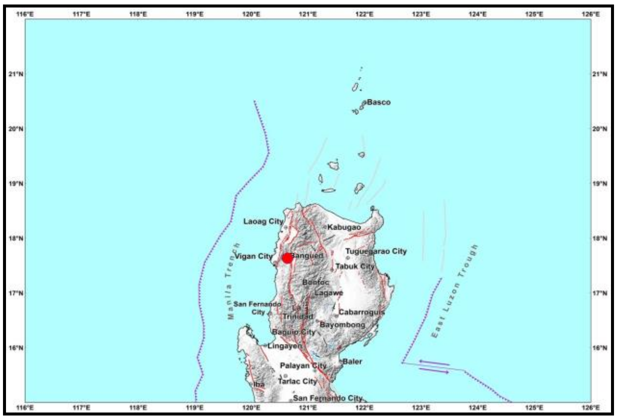

Fig. 2. Epicenter of the Earthquake

2. GEOLOGICAL AND TECTONIC SETTING

(1) Geological and tectonic setting

Abra is a province located in the Cordillera Administrative Region (**CAR**) with a total land area of 3,180.8 km^2, making it the largest province in the region. It has 27 municipalities and 324 barangays all encompassed by its lone congressional district.

Fig 3. ASEP Study Teams

The province's total population as of the May 2020 census of the Philippines Statistics Authority (PSA) is 250, 985 with a population density of 60 inhabitants per square kilometer[2)]. Its deep valleys and sloping hills are enclosed by rugged mountains, except in the Western portion where the Abra River flows towards the coastal plains of Ilocos Sur.

Abra, being in the northern part of the island of Luzon, has a complicated tectonic setting. The southern part of the island is bounded by the subducting Philippine trench in the east, and the Philippine Sea plate also subducts westward beneath the Sunda plate. However, in its northern region where Abra is located, the trench (Manila trench) is now located west of Luzon and Sunda plate now subducts eastward beneath the Philippine Sea plate[3)] (see **Fig. 4**). This complex tectonics of Luzon is evident in the area's high seismicity rates having large magnitudes including the magnitude 7.8 Luzon earthquake in 1990[4)].

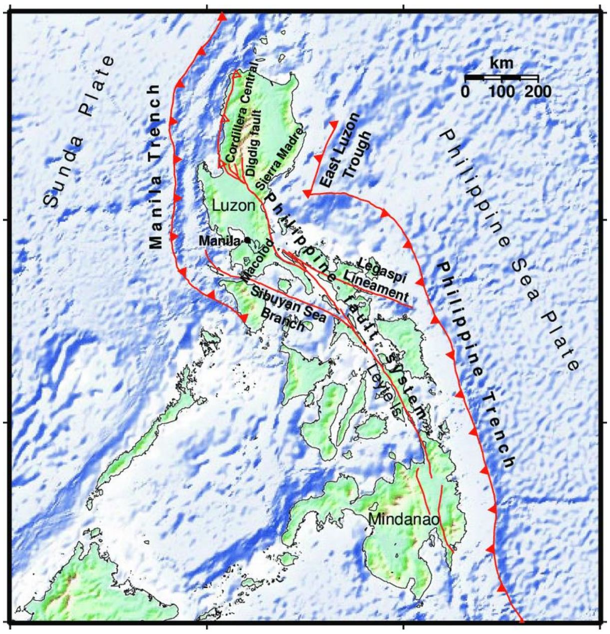

Fig. 4. Tectonic setting of the Philippines

(2) Fault setting

The earthquake was tectonic in origin and exhibited an oblique reverse faulting movement based on its location and focal mechanism[3)]. It was generated by the movement of the Abra River Fault (see **Fig. 5**). In an interview with Science and Technology Sec. Renato Solidum Jr. (then PHIVOLCS OIC), he mentioned that the Abra River Fault is an active fault that is expected to trigger a major earthquake since its last recorded earthquake, about magnitude 4 or less than 5, in 1868[5)]. In the study of Bautista and Oike in 2000, there are two earthquakes in 1868 that occurred approximately 70 km from this quake's epicenter. One was magnitude 5.8 in 18.30N 120.70E (north of Tayum) and the other is the magnitude 4.4 quake in 17.20N 121.10E (southeast of Tayum)[6)]. These epicenters were assumed only from the assumed location of highest intensity, presence of tectonic structures, and recent seismicity.

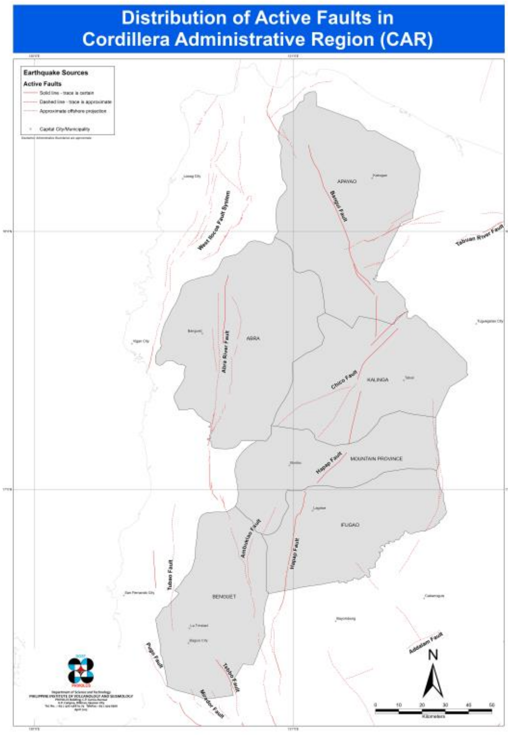

Fig. 5. Fault Systems in CAR (Source: PHIVOLCS)

(3) Main shock and aftershocks

The main shock of the earthquake was recorded with a magnitude of 7.0 and reported an intensity VII on the PEIS. In NDRRMC's latest report on August 22, 2022, there are 4,795 recorded aftershocks with 70 of them felt by the population. These aftershocks ranged from magnitudes 1.4 to 5.1.

3. DAMAGE TO STRUCTURES

This recent earthquake was one of the strongest in Philippine history. It has affected houses, bridges, towers, churches, schools, roads, highways, public and private buildings, flood control structures, and hospitals. According to the NDRRMC Site Report No. 20, it was estimated that 11 lost their lives and 609 were injured. The region mostly affected was CAR accounting for 10 casualties and 573 injured out of the total. The damages inflicted by the earthquake spanned across houses, colleges, cathedrals, towers, etc. totaling to 2,728 damaged infrastructures. The following sub-sections are the damage observed during site inspection and assessment.

(1) Damage to houses

The extent of the damage to houses were of great magnitude, affecting residence made of timber, reinforced concrete, and of those made with indigenous materials. The total affected homes were estimated to be 36,780 per NDRRMC Situational Report No. 20 (as of August 22, 2022) spanning across four regions; Region 1 to CAR's west, Region 2 to the east, and the

National Capital Region (NCR) to the south. However, the region that faced the major brunt of the damage was CAR. The region accounts for 28,516 of the total affected houses, with 640 being destroyed and partial at 27,876. Detailed breakdown of the damaged houses with corresponding regions are shown in **Table 1**.

Table 1. Damaged houses caused by the earthquake (Source: NDRMMC)

Region/ Province/ Municipality	No. of Damaged		
	Totally	Partially	Grand Total
Region 1	216	8,046	**8,262**
Region 2	0	1	**1**
CAR	640	27,876	**28,516**
NCR	0	1	**1**
Grand Total	**856**	**35,924**	**36,780**

Based on the rapid assessment conducted, majority of the damaged houses have not been in accordance with earthquake-resistant building standards. Below are the common observed failure mechanisms and findings of the team during the rapid assessment:

- Poor and substandard materials and construction practices: Failures of most of the houses attributed to the poor and substandard materials and construction practices such as but not limited to the use of undersized rebars as reinforcement for concrete hollow blocks (CHB), low quality CHB, undersized CHB (4in) in the case for exterior wall for masonry houses, without practicing the requirement of confinement zone, development lengths and hooks, etc.
- Weak out-of-plane response: The failure or collapse related to portions or panels of parapets and gables fall into this category.
- Lack of vertical confining elements and lateral restraints, unconfined wall corners.
- Inadequate reinforcement on openings: Cracks are manifested in large openings such as windows and doors. This type of failure may be attributed to the absence of lintels and additional diagonal reinforcements on openings such as windows and doors.
- Structural irregularities: An example is a residential building with significant damage is related to a soft story behavior.

Example of the residential house that were totally affected by the earthquake is shown in the following. Failure of foundation (see **Fig. 6a**), spalled wall tiles and wall cracks (see **Fig. 6b**), and cracks in openings (see **Fig. 6c**) can be observed.

(a) (b) (c)

Fig. 6. Examples of damages on residential buildings

(2) Damage to schools and hospitals

According to the NDRRMC site report, 29 hospitals were affected many sustaining only minor structural damage with no collapse reported. On assessing five out of the total damaged hospitals, minor damages on masonry walls were observed, spanning from large cracks on openings, plaster cracks, disintegration or spalling plasters at the location of embedded pipes, cracks on floors, spalled and detached floor tiles, and disintegration of wall-ground slab joints.

At least 556 schools were affected in regions I, II, and CAR. Majority of the damage were sustained cracks on masonry walls. ASEP team was requested by the Provincial Government of Ilocos Sur through the Provincial Engineering Office to inspect school buildings. Two schools were selected: the Philippine Science High School - Ilocos Regional Campus and the Mabilbila Integrated School. In the former, spalled fragments of the plaster and concrete cover were obtained from a damaged beam from a newly built building. There are also portion of the beams with exposed reinforcements (see **Fig. 7a**). The presence of impurities where also observed as manifested by the embedded pieces of plywood on concrete beams (see **Fig. 7b**). There are also large and deep cracks on beams that have been observed (see **Fig. 7c**).

(a) (b) (c)

Fig. 7. Damage on the Philippine Science High School – Ilocos Region

For Mabilbila Integrated School, specifically the 4-storey senior high building, settlement of corridor, disintegration between construction joints (see **Fig. 8a**), fine to large cracks on masonry walls, spalling of plasters, and cracks prevalent in openings (see **Fig. 8b**) were observed.

(a)

(b)

Fig. 8. Damage on 4-storey senior high building of Mabilbila Integrated School

(3) Damage to churches and heritage sites

Several church and heritage sites can be found in the inspected areas and some of these national cultural treasures are also damaged from the earthquake. In Mart 1 building in Vigan World Heritage Site (WHS), bricks were seen falling off from a wall with a crack from the bottom to the top (see **Fig. 9a**). Separation of the two walls were also seen in one corner of the mall (see **Fig. 9b**), as well as a thick surface plaster separating from a thick brick wall (see **Fig. 9c**).

(a)

(b) (c)

Fig. 9. Damage on Mart 1 Building (Vigan, Ilocos Sur)

Palacio de Arzobispado was also found to have predominantly horizontal cracks on its ground floor (see **Fig. 10a**). Visual inspection shows that these might be a manifestation of the separation of the surface plaster with the bricks and not deep cracks. Two adjacent columns exhibited cracks at its top portion possibly due to two exterior walls from an adjacent structure that might have pushed the columns during the ground shaking (see **Fig. 10b**).

(a)

(b)

Fig. 10. Damage on Palacio de Arzobispado (Vigan, Ilocos Sur)

The Vigan cathedral or the Metropolitan Cathedral of the Conversion of St. Paul the Apostle suffered moderate damage during the earthquake from various locations. From the exterior, the most visible damage is the surface plaster on the pediment (front façade) separated and fell to the ground (see **Fig. 11a**). An out-of-plane bending can also be inferred from the photos taken dis-aligning some of the bricks from a vertical alignment. Drone shots also exposed large cracks and wall separation on the pediment (see **Fig. 11b**) and minor to moderate damage on what appears to be part of the buttress (see **Fig. 11c**). From the inside, debris of bricks near the entrance fell off from the ceiling of the choir loft (see **Fig. 11d**).

(a)

(b)

(c)

(d)

Fig. 11. Damage on Vigan Cathedral

Bantay Church or the Parish of Saint Augustine of Hippo were observed to have horizontal cracks especially on the right side of the church facing the altar (see **Fig. 12**). However, it cannot be ascertained if the cracks are deep or only at the surface. Thus, GPR tests were recommended for verification of the crack's depth.

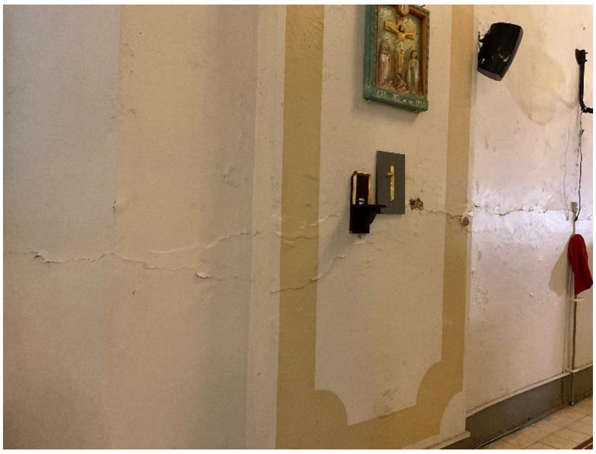

Fig. 12. Damage to Bantay Church

(4) Damage to roads and bridges

Although 91% of the affected roads and bridges are still passable to all vehicles with 0% not passable to light vehicles, 171 road and 11 bridge sections have still been affected by the earthquake including 14 national roads which have been closed due to rock fall and soil collapse[7]. In the morning of July 29, 2022, or almost 2 days after the event, the partial cost of damage to road infrastructure was already at Php 396.58 million with Php 104.53 million attributed to damage on national roads and Php 292.05 million to national bridges[8].

During the site inspection of the Don Mariano Marcos Bridge in Tayum, Abra, it was found that there was no safe access to go under the bridge. There was also a visible buckling of the top chord cross-bracings on one end of the bridge, but there is no structural damage found on its main members (see **Fig. 13**). It was considered as generally safe to operate but intensive structural assessment was still recommended.

(a)

(b)

Fig. 13. Damaged Don Mariano Marcos Bridge (Tayum, Abra)

(5) Earthquake-induced Hazards

There have been 13 recorded earthquake-induced landslides, 11 of which occurred in a neighboring region (Region 1: Ilocos Region) resulting to 5 casualties. Four of these deaths are working at a construction in Sitio Kayaddakad, Poblacion, Abra.

An earthquake-induced sinking incident was also reported by NDRRMC which happened in Sacasacan, Mountain Province. It resulted to 5 totally damaged houses and 12 partially damaged, all of which are considered unsafe for occupancy. Fortunately, it did not incur any injuries nor casualties.

Sand boils and ground fissures were also found by the team near a river in San Vicente, Ilocos Sur (see **Fig. 14a & b**).

(a)

(b)

Fig. 14. Sand boils and ground fissure in San Vicente, Ilocos Sur

(6) Damage Cost

The total estimated cost of damage to infrastructure due to the 2022 Abra earthquake is Php 2,650,063,524.47 coming from Regions 1, 2 and CAR. The breakdown of this estimation is presented in **Table 2**.

Table 2. Cost of Damage to Infrastructure per Region

Region	Cost of Damage (Php)
Region 1	1,420,290,742.47
Region 2	307,685,858.84
CAR	922,086,923.16
Total	**2,650,063,524.47**

4. SUMMARY

A magnitude 7.0 earthquake struck 3 km away from Tayum, Abra, Philippines in the morning of July 27, 2022. The strong ground motion was due to the oblique slip movement of the Abra River Fault. It claimed 11 lives with over 600 more injured. Damage to over two thousand structures were also reported. This paper reports the results of the ASEP study team's inspection and investigation of the damage observed near the earthquake's epicenter and Abra's neighboring province, Ilocos Sur. Damage to structures were significant and widespread that included houses, schools, hospitals, churches and cultural heritage structures, and roads and bridges. Other earthquake-induced hazards were also experienced such as landslides, sand boils, and ground fissures.

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REFERENCES

1) NDRRMC (National Disaster Risk Reduction and Management Council). SitRep No. 20 re: Magnitude 7.0 Earthquake in Tayum, Abra. Retrieved October 11, 2022 from http://www.ndrrmc.gov.ph
2) Philippine Statistics Authority – Cordillera Administrative Region. (2022, October 1). Retrieved October 11, 2022 from http://rssocar.psa.gov.ph/abra
3) USGS. *USGS Science for a changing world.* Retrieved October 11, 2022 from https://earthquake.usgs.gov/earthquakes/eventpage/us6000i5rd/executive
4) Philippine Institute of Volcanology and Seismology. *1990 July 16 Ms7.8 Luzon earthquake.* Retrieved October 11, 2022 from https://www.phivolcs.dost.gov.ph/index.php/earthquake/destruc-tive-earthquake-of-the-philippines/2-uncategorised/212-1990-july-16-ms7-9-luzon-earthquake
5) De Vera-Ruiz, Ellalyn. (2022, July 27). *Abra River Fault, which last moved in 1868, may have triggered powerful quake - Solidum.* Retrieved from https://mb.com.ph/2022/07/27/abra-river-fault-which-last-moved-in-1868-may-have-triggered-powerful-quake-solidus/
6) Bautista, M. L. P., & Oike, K. (2000). Estimation of the magnitudes and epicenters of Philippine historical earthquakes. *Tectonophysics,* 317(1-2), 137-169.
7) Sarao, Zacarian. (2022, July 27). *DPWH: 14 nat'l roads closed due to landslides, damage after Abra quake.* Retrieved from https://newsinfo.inquirer.net/1635971/dpwh-14-natl-roads-closed-due-to-landslides-damage-after-abra-quake
8) Cordero, Ted. (2022, July 29). *Abra quake damage to road infra at P396.6M – DPWH.* Retrieved from https://www.gmanetwork.com/news/topstories/nation/839883/abra-quake-damage-to-road-infra-at-p396-6m-dpwh/stost/

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