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The 2022 Twin Earthquakes and Tectonic Environment in Kyaing Tong Basin, Eastern Myanmar

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Authors' contributions

This work was carried out in collaboration between both authors. Both authors read and approved the final manuscript.

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ABSTRACT

The first earthquake of magnitude 4.8 struck at 57 km south of Kyaing Tong, latitude 21.1141°N longitude 99.850°E, on 21st July 2022, at 16:40:08 UTC (11:07 a.m. local time) at the depth of 10 km. Immediately after 30 minutes on the same day of 21st July 2022, the second earthquake with magnitude 5.9 occurred, 53 km south of Kyaing Tong at latitude 21.150°N 99.863°E, 17:07:26 UTC (11:37 a.m. local time) at 10 km depth. Focal mechanism solution for the first event was left-lateral strike-slip faulting and the second by normal faulting with a component of strike-slip component (United States Geological Survey). Many lesser aftershocks followed the main shocks and continued since July and still ongoing up to date in 2022. Twin earthquakes ruptured along the Wan Ha fault which bounds the southeast side of the Kyaing Tong basin, eastern Myanmar. The rupture propagated southward. The Kyaing Tong basin is one of the tectonic basins in the Paleo-Tethys suture zone in eastern Myanmar. These earthquakes are due to the movement of Wan Ha fault, affected the town Kyaing Tong where it caused some houses and schools collapsed. No casualty was reported. According to data from USGS, and other earthquake agencies, there is a clear increase in detected earthquakes, particularly smaller quakes of magnitude around ≥ 1.0 and ≥ 2.0 at shallower depth of 1000 meter. From the studies of satellite images, aerial photographs,

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shaded relief map and Digital Elevation Model map, several lineaments are visible and detailed mapping of these lineaments show the strike-slip faults in ENE-WSW direction and normal faults in NE-to NNE-striking direction. NW-SE extension is evident by the occurrence of brittle normal faults and NE-to ENE-oriented sinistral strike-slip fault. Within this zone is the trace of regional compression in a NE-SW direction. This region is presently undergoing active tectonic deformation, as indicated by current seismicity and earthquake focal mechanism solution.

Keywords: Twin earthquakes; rupture; tectonic basin; volcanic; extension; compression; normal fault; strike-slip fault.

1. INTRODUCTION

The aim of this article is to gather information of the twin earthquakes which has not been experienced in understanding of earthquake seismology in Myanmar and to correlate the seismicity with tectonics. The Kyaing Tong earthquakes of July 21, 2022 occurred in Kyaing Tong basin in eastern Myanmar and the eastern Myanmar can be tectonically divided into two terranes as the Shan Massif terrane in the west and the Paleo-Tethys suture zone to the east. The delineation of the western boundary of Paleo-Tethys suture zone as the site of closure of Paleo-Tethys Ocean in Myanmar territory was recognized and this zone is believed to be a tectonic linkage between Changning-Menglian belt of Southwest China and Inthanon Zone of West Thailand. The area along the Than Lwin River and further east of it was largely covered with Upper Paleozoic and Mesozoic units overlying unconformably the Lower Paleozoic units and the basement rocks of Pre-Cambrian. A large number of chromite, gabbros and volcanics occur near Kyaing Tong-Tarchilek area [1]. The suture zone is located between Loi-se-Loi-len fault in the west and Chiang Rai Tectonic Line to the east (Fig. 1). Southeastward extrusion of the Indochina plate controls the active tectonics of eastern Myanmar. "The satellite imagery of the suture zone shows a bookshelf-pattern of conjugate active strike-slip faults arranged in parallel in NE-or ENE-WSW direction. Structurally, the eastern Myanmar belongs to the Indochina plate which is between the Red River fault in the east and Papun –Three Pagoda fault in the west" [2]. In the eastern Myanmar there are many hot springs associated with extrusive rocks, probably penetrated the Paleozoic and Mesozoic platform carbonates during the Upper Tertiary or Late Tertiary-Quaternary volcanism. The town Kyaing Tong is located in Kyaing Tong Basin which is formed at the tip of the Jinghong fault in the north, and the Wan Ha fault in the south, and the NW-SE trending faults are bounded in the west and the east.

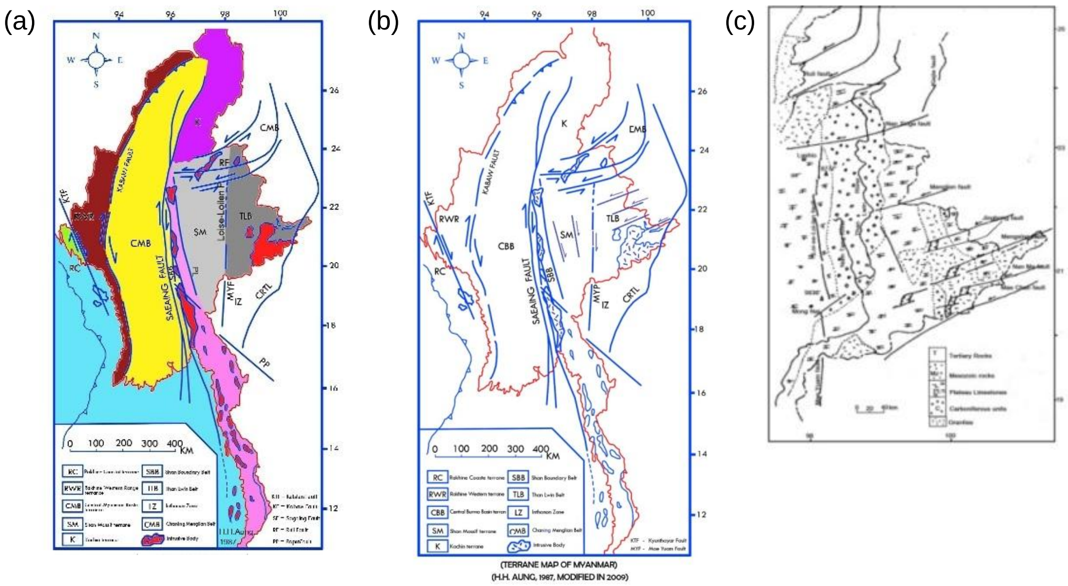

Fig. 1. (a) Map of tectonostratigraphic terranes of Myanmar H.H.Aung, (drawn in1987,modified in 2009), (b) Map showing SIBUMASU block with longitudinal faults and Paleo-Tethys suture zone with ENE-trending faults,(c) Geological map of suture zone

2. TECTONIC BACKGROUND

Several NE-to ENE-oriented sinistral strike-slip faults that appear to be active on Landsat images are Mae Chan fault, Nan Ma fault, Mengxing fault, Jinghong fault, Menglian fault and Nanting fault in the north. These active faults are probably results from bookshelf faulting due to the present NW-SE right-lateral shear parallel to the Red River fault. Several zones of aligned short fault segments arranged in left-stepping en echelon pattern may represent late Cenozoic sinistral slip of through-going fault system.

Between these fault segments of the fault zone, many of localized pull-apart basins occur at fault bends or near the tips of the fault segment of NE- to ENE-trending sinistral faults. These basins are Kyaing Tong basin, Mongphat basin, Mong Yong basin, Tarlay basin and Tarchilek basin (Fig. 2 a, b). “Active tectonics over much of eastern Myanmar has been compatible with NE-SW striking maximum stress and minimum stress striking NW-SE. In eastern Myanmar, ENE- or NE-oriented faults that dominate the crustal fabric are active as indicated by their sharpness of their traces on satellite imagery and seismicity” [3]. Le Dain et al. (1984) summarized the historical earthquakes of Myanmar in which earthquake of 26 December 1941, M=7; 16 April 1941, M-7; 2 February 1950, M=7.0 respectively occurred within the broad seismically active belt [4]. Laos earthquake of 16 May 2007 with M=6.3 occurred near Mae Chan fault. The recent Tarlay earthquake of 24 March 2011 (M=6.8) occurred on the Nan Ma fault in eastern Myanmar [5]. An earthquake occurred near the trace of Loi-se-Loi-len fault, 25 miles northeast of Nam Sam (Southern Shan State) on 8 November 2011 with magnitude 3.5 and an earthquake with magnitude 3.8 occurred 25 miles NE of Kun Hing (Southern Shan State) near a fault very close to Than Lwin River. An earthquake with magnitude 3.1 occurred on 27 June 2012 at 20 mile northwest of Tarchileik (Southern Shan State). Numerous events of earthquakes and geometry on active faults clearly show that the active tectonics of this region is dominated by strike-slip faulting and normal faulting. The stress fields of the region from the studies of focal mechanism solution of earthquakes [6,7] indicate that this area has been undergoing NW-SE extension and NE-SW compression [2].

3. METHODOLOGY

3.1 Setting

Two earthquakes occurred with a magnitude 4.8 at 11:07 p.m. and a second, magnitude 5.9 at 11:37 p.m .local time. Both struck from the same location, 57 km kilometers and 53 kilometers south of Kyaing Tong (Fig. 3).

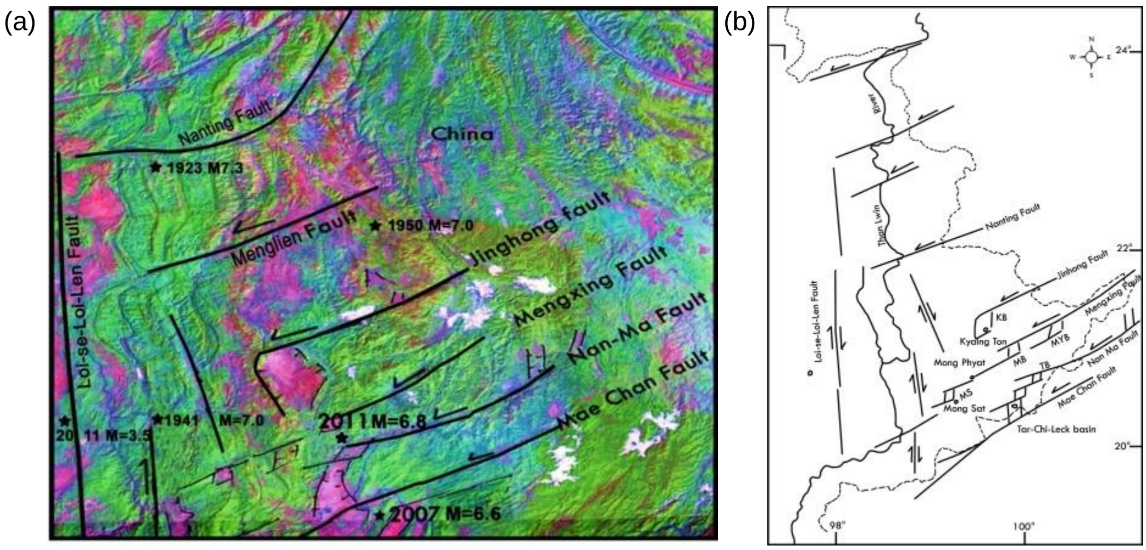

Fig. 2. (a) Satellite map showing sharpness of topographic features and active faults and occurrences of earthquakes associated with extensional basins, (b) Map of line drawings showing extensional basins

Fig. 3. Google Earth map showing location of two earthquakes M 4.8 and M 5.9 on Wan Ha Fault with focal mechanism solution of earthquake

The Kyaing Tong earthquake of July 21, 2022 was significant earthquakes with twin events so close in time, and its aftershocks continued into October, and still occurring up to date of 2022 (Fig. 4 a,b,c,d). The effect of such powerful shocks was to double the duration of ground shaking, and to double the area affected by the strongest shaking. The epicenter of the first event is at latitude 21.1141°N longitude 99.850°E.The epicenter of second event is at latitude 21.150°N longitude 99.863°E. Several aftershocks continued in a zone with (24) mile long, parallel to Wan Ha fault trace.

Aftershock activity is markedly concentrated toward south of the fault to the Tarchilek area. These earthquakes are due to the movement of Wan Ha fault, affected the town Kyaing Tong where it caused some houses and schools collapsed. No casualty was reported (Fig. 5. a, b, c, d).

Locations of the two main shocks suggest that fracturing started in the west and progressed eastward only four kilometers away along the same fault. The 2022 Kyaing Tong earthquake occurred in a plate interior setting with the focal mechanism solution (USGS) of a left-lateral strike-slip faulting with a component of normal faulting. Kyaing Tong is located in a localized rift basin where a segment of the Jingong fault steps to the Wan Ha fault. The event showed that earthquake along a ENE-WSW striking Jinghong fault was dominated by left-lateral strike-slip faulting which in turn generate the normal fault to down faulting.

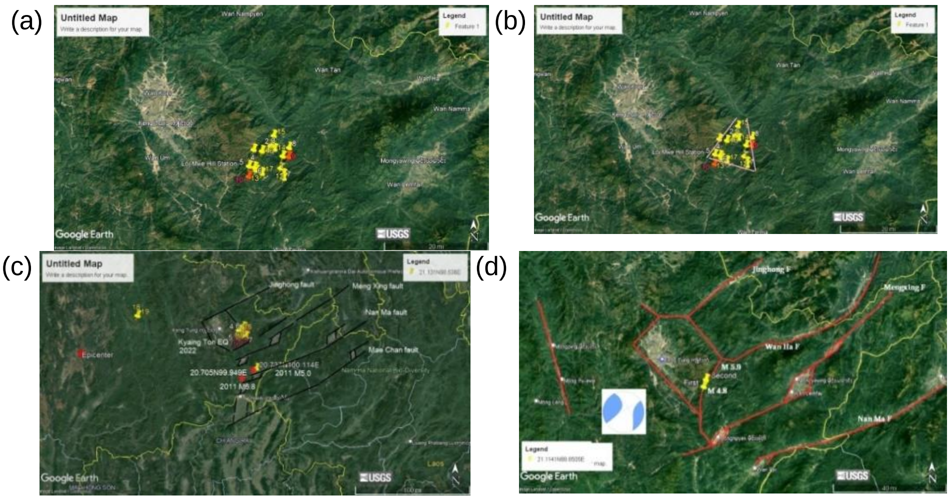

Fig. 4. Google Earth maps (a) and (b) show aftershocks of Kyaing Tong earthquake concentrated on Wan Ha Fault, southeastern side of the basin, (c) show the relation between seismicity and extensional basins in suture zone, (d) showing locations of main shocks of Kyaing Tong earthquake and focal mechanism solution

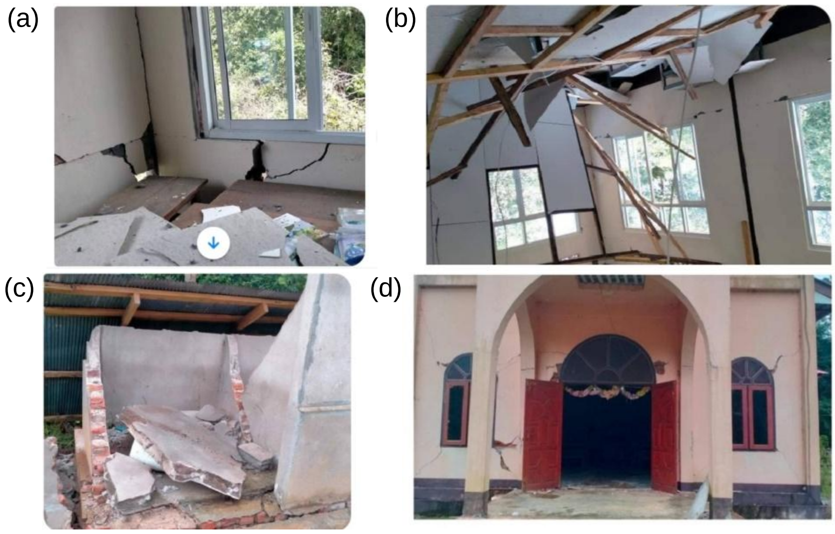

Fig. 5. Mosaic of photos (a,b,c,d) show damages to the buildings in Kyaing Tong(Source-internet)

3.2 Method of Analysis

A detailed morphotectonic study was carried out in the area using satellite images, Digital Elevation Map map, shaded relief map, 1:24,000 scale aerial photographs and 1:63360 scale topographic maps, to correlate the seismicity with tectonics. From these studies, it is found that there are two prominent lineaments striking in NE-or ENE- and N-S or NNE direction in which NNE-SSW direction are normal fault character.These normal faults are developed by NW-SE oriented tensional stress and ENE-WSW trending faults are formed by NE-SW compression. The NNE-SSW fractures represent the transfer fault for the ENE-WSW fractures in this Paleo-Tethys suture zone. Horizontal movement along the left-lateral strike fault generates the normal fault to down-faulting [8]. The study of drainage pattern in Kyaing Tong area depicts generally rectangular pattern in which streams consist mainly of straight line segments with right-angle bends and its tributaries join larger streams at right angles. Most of the rocks in Paleo-Tethys suture zone are granitic rocks, platform carbonates and volcanic rocks. Large complex of granitic rocks at the east of Than Lwin River that can be correlated with granites east of Fang (N.Thailand) was assigned to early Triassic [9]. These granites belong to Northern Thailand and migmatite complex of S- type of Cobbing et al. (1992) [10]. As of mineral deposits in eastern Myanmar, iron-Manganese ores are found in Plateau Limestone Group of upper Paleozoic shelf sediment of stratigraphic terrane. Occurrences of residual soil with Manganese, andesite and ferruginous soil are widespread in a zone, northeast of Tarchilek [11].

4. RESULTS

4.1 The Coupling Mechanism between Active Tectonics and Pore Fluid Pressure in Kyaing Tong Basin, Paleo-Tethys Suture Zone, Eastern Myanmar

Geodetic data reveals a NW-SE-oriented elongated basin called Kyaing Tong Basin in suture zone and it is surrounded with (4000-7000) feet mountain ranges associated with rectangular drainage pattern. Study of shaded relief map of Kyaing Tong basin shows tectonic configuration of faults in Kyaing Tong area and DEM map depicts location of the town Kyaing Tong in tectonic basin and its topographic features (Fig. 6 a, b, c, d). The focal mechanism solution of the twin earthquakes suggest that the event may be a mixed shear-tensile (opening rupture) on the ENE-WSW striking fault which bounds the Kyaing Tong basin on the southern side. In the eastern Myanmar there are many hot springs associated with extrusive rocks probably penetrated the Paleozoic and Mesozoic platform carbonates during the Upper Tertiary or Late Tertiary-Quaternary volcanism [12].

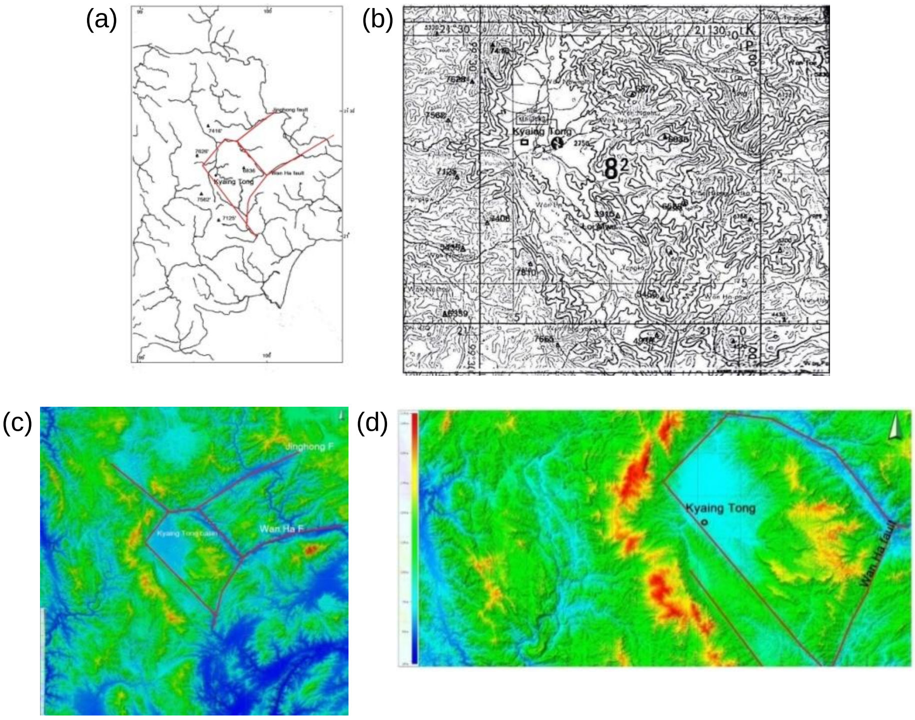

Fig. 6. (a) Map of rectangular drainage pattern in the Paleo-Tethys suture zone, eastern Myanmar (b) topography of Kyaing Tong area with spot height and contouring, (c) Shaded relief map of Kyaing Tong basin showing tectonic configuration of faults in Kyaing Tong area.(d)DEM map show location of the town Kyaing Tong in tectonic basin and its topographic features

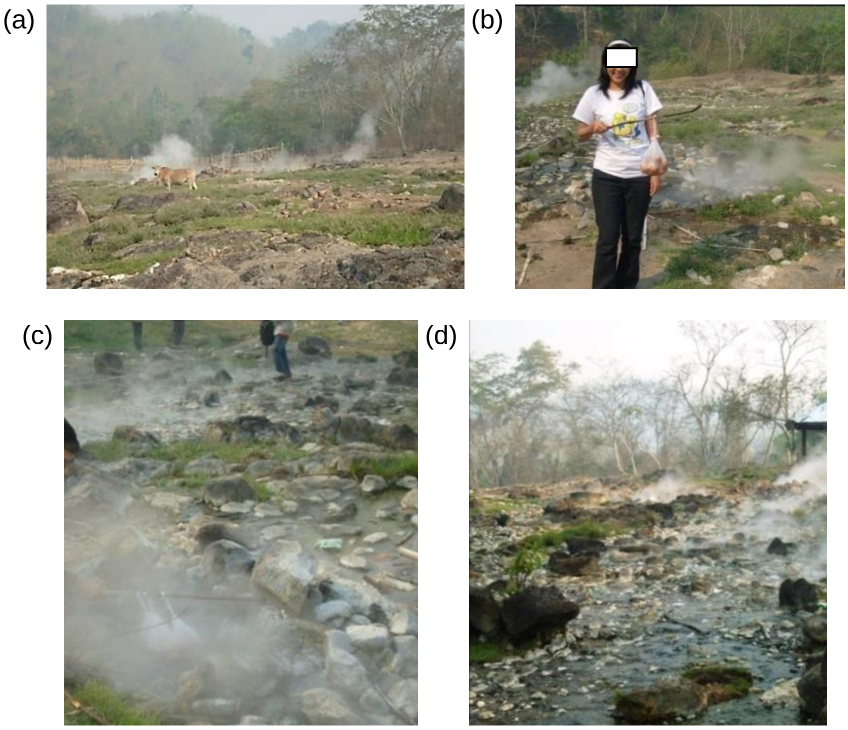

Fig. 7. Photographs (a,b,c,d) show hydrothermal activity in Mong Sat- Mong Phat-Tarchilek area

Among many hot springs in the suture zone in eastern Myanmar, Kaungdaing hot spring (20° 35' N/ 96° 53' E) approximately 20 km southeast of Heho, a karst spring originated in Ordovician limestone; a series of hot springs near Namon and Lashio (22° 56'N/ 97° 47' E) which are associated with fault lines; Hsipaw hot springs near Kyaukme; Keng Tung hot spring which is located very near to Kyaing Tong (21° 17' N/ 99° 36'E) are well known places [13]. Some places near the town Mong Sat-Mong Khote, there are occurrence of hot springs as shown in the photographs (Fig. 7 a, b, c, d). The presence of pressurized fluids influences the mechanical behavior of faults. Pore fluids are fluids that occupy pore spaces in a soil or rock. The fluid reduces the normal stress thus reducing principal stresses. In general, failure of faults is governed by Mohr-Coulomb failure criteria.

"When a fault is critically stressed, a small increment of shear stress or small decrease of shear strength may lead to fault rupture" [14]. "The presence of pore fluid pressure in the underlying rocks increase with critically stressed faults may induced or trigger significant seismicity" [15]. Hydrothermal activity occurs at many levels in the Earth' crust, from deep-down a kilometer (3280 feet) or more to the surface with hydrothermal fluids generated by igneous, metamorphic and sedimentary processes or a combination of these. Here in Kying Tong, fluids have risen up from (7-8) feet according to local finding (source: internet). "Fluid pressurizing event is responsible for the earthquake and seismic events characterize active hydrothermal and volcanic areas and may be due to magma / fluid migration" [16]. "The statistics of earthquake data in the global catalog are consistent with the idea that a single physical triggering mechanism is responsible for the occurrence of aftershocks, foreshocks, and multiplets" [17]. "Therefore the dynamics of hydrothermal systems must be taken into account in the seismic hazard evaluation. The complex interaction that can occur between mountain and surrendering area, especially sedimentary basin, illustrate the fact that topography should be taken into account when assessing seismic hazard" [18]. "Analyses of earthquake damage worldwide suggest that the severity of shaking depends on several local site-specific factors besides the distance and magnitude of an earthquake. Local site conditions can lead to amplification of seismic waves and to unusually high damage. Unconsolidated materials, such as sediments and landfills, amplify ground motions. Certain frequencies of ground shaking may generate disproportionately large motions because of wave resonance and/or focusing in basins" [17].

5. DISCUSSION AND CONCLUSION

Earthquake disasters are related to the local site specific characteristics and seismic stress field. Co-seismic changes like migration of spring and stream, sinking of the ground are common styles of deformation during compressional earthquake. The 2022 Kyaing Tong earthquake event showed that earthquake along an ENE-WSW striking Wan Ha fault was dominated by left- lateral strike-slip faulting, which in turn generated the movement along the NNE-SSW trending normal fault that bound the basin near the town Kyaing Tong. The focal mechanism solution of this earthquake suggests a normal faulting. Therefore, the deformation mode for Kyaing Tong area is inferred basically to be a combination of normal and left-lateral strike-slip faulting. The dynamics of hydrothermal systems must be taken into account in the seismic hazard evaluation. The complex interaction that can occur between mountain and surrendering area, especially sedimentary basin, illustrate the fact that topography should be taken into account when assessing seismic hazard.The frequency level of earthquakes in the past and the repeatability of the seismic hazards are important factors in determining the risk of earthquake hazards.

COMPETING INTERESTS

Authors have declared that no competing interests exist.

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