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The Main Structure of Epicenter Area and Aftershock Ditribution of Large Earthquake (Ms = 6.7)

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Abstract: *Studying the crustal dynamic structure of the epicenter area is to better understand about the seismogenic source of large earthquakes. Tuan Giao Earhquake with Ms = 6.7 (24 June, 1983) is most destructive event in Northwest region of Vietnam, therefore the objective of this research is to clarify the specific features of the seismotectonic conditions in the focal area. The results can be obtained:*

1) Before Tuan Giao earthquake there had been a long lasting seismic quiescence in the epicenter area. There is a manifestation of rather low seismic activity in Tuan Giao region before this earthquake occurred.

2/ The size of the Tuan Giao Earthquake source is about 676 km^2 with the parameters of the source: length (L) = 33km; width (W) = 21km; and focal height (H) = 17 km. The upper-crust boundary (Moho surface) varies in a rather complicated manner and has a depth varying between 32 km and 36 km. The depth of the seismogenic layer is about 17 km, it's mean that the earthquake epicenters are concentrated mainly in range of 4 to 21 km.

3/ There are high seismicity areas based on application Modal of Analogue Identification (MAI) such as Pa Ham; Tuan Giao; Luan Chau; Thuan Chau; Than Uyen, Song Ma with maximum magnitude 6.0 ÷ 6.9 and Earthquakes with maximum magnitude 5.0 ÷ 5.9 are likely to occur in areas of Muong Lay, Pa Hang, Tua Chua, Quynh Nhai, Mai Son, Muong Trai, Phu Ba.

Keywords: *Crustal structure, seismic source, earthquakes hazards, earthquakes prone.*

1. INTRODUCTION

At 14.18 (GMT+7) of 24 June 1983 in the area of Pu Nhung mountain, about 11 km NW of Tuan Giao town a destructive earthquake took place with magnitude was 6.7 in Richter scale with a maximum intensity on the surface reaching 8-9 in MSK-64 scale [4,6,11,16]. The earthquake caused great losses to Tuan Giao, Lai Chau, Tua Chua, Thuan Chau, Quynh Nhai and Dien Bien areas. Besides the losses in terms of human lives, houses, public facilities and crops, the earthquake also caused many geologic hazards such as land cracking, landslide, slumps, subsidence, changes flow of springs, etc..

The Tuan Giao earthquake was one of the two strongest earthquakes occurred in the Northwest region of Vietnam territory in the last century (the previous one was the Dien Bien earthquake in 1935 with M_s=6.8). Some of domestic and foreign scientific papers has been focused on the Tuan Giao earthquake [4,5,6,8,11,13,16] but still need a research to understand better of the seismotectonic condition and maximum earthquake in the Tuan Giao area. The Northwest Vietnam is most strong earthquakes-prone area, therefore studying of the sources condition as well as the rule of seismic activities in Tuan Giao area are both necessary and high scientific significance. The results of this studies will allow us to understand better the rules of seismic activities in the areas where strong earthquakes have been occurred, but also apply in studying the structural characteristics of the others seismic sources in whole Vietnam territory.

The main objective of this paper clarify the basic features of crustal structure, seismotectonic conditions and the manifestation of seismic activities in Tuan Giao and adjacency area. The result has been completed on the basis of the previous studies of authors [4, 6,13] and the updated the field work data from various subjects as; structure geological, geomorphology and geophysics survey since 2001 up to present. The coordinates of the study area are: φ = 21⁰00 ÷ 22⁰20' N; λ = 103⁰00 ÷ 104⁰00' E.

2. GEOLOGICAL AND TECTONIC SETTINGS

2.1. Geological condition

In studied areas includes the geological formations aged from Proterozoi up to Quaternary which strong separated by faults system and deformed by different orogenesis of Indoxini and Hexciny [12,18]. The distribution of geological formation and the relationship (fig.1) are;

*Nam Co formation (PR_{1-2} nc), d*istribution of a range extending from southeastern of Nam Muc to the Nam Co with the composition is mainly quartz, mica-schist garnet, sericite schist quartzite. These were divided into three parts: the lower part of sericite quartzite, quartz-sericite schist, and the middle consists mainly of quartz sericite schist, quartzite lens thin and the upper part is a sericite schist, quartz sericite schist, quartz-mica schist. Overall thickness of the layer is 2000-

2100m which lies unconformably in the Song Ma formation *(ε_2 sm).*

Song Ma formation (ε_2 sm) is distributed in the northeast part of the Nam Co anticlinorium's and extended toward Song Luong River. The composition includes conglomerate, shale stone with pebbles, sericite schist, clay, lime green, quartzite with the total thickness is 500-870m and covered conformably in Ham Rong formation.

Formation Ham Rong (ε_3 – O_1hr), distribution of in the northeast part of Tuan Giao, and it is divided into two division; the lower part consists of limestone alternating thin layers of shale limestone, upper part includes sericite schist, limestone, shale, sandstone contains limestone, limestone. The thickness of Ham Rong formation is 400-900 m and it covered conformably in the Song Ma formation.

Pa Ham Formation (O_3 – D_1ph), sedimentary rocks composed of carbonate rocks, terrestrial and greenstone, these rocks exposed in the anticlines of Tuan Giao and complex anticlines Song Ma. Pa Ham formation unconformably lied on the Cambrian rock of Song Ma formation ($\varepsilon_2$sm). Pa Ham formation includes of two part; The lower part composition consist mainly of black shale alternating gray limestone, clay, shale serixit, light-colored limestone, shale quartz - mica, thickness of 700 m. The upper part contains actinolite mainly shale, eruption base, powder, green tuff, sericite shale, lenses of limestone, marble stone.

Nam Pia formation (D_{1-2}np), distribution on the western drainage of Tuan Giao which composes of conglomerate, quartzite, shale, clay, lime, lime lens and the thickness of 350-600m. All formation lies conformably under the Ban Pap formation (D_{1-2}bp).

Ban Pap formation (D_{1-2}bp), distribution of large sequences in North to South of Tuan Giao which contains limestone, shale, fine-grained black limestone with the total formation thickness of 350-950m. The formation D_{1-2}bp covered conformably in the D_{1-2}np formation. In addition the formation investigated apart in Tua Chua, north and east of Thuan Chau, Phong Tho.

Bac Son Formation (C- Pbs), the distribution of these sediments range in southwest Lai Chau and few distribution in southwestern Thuan Chau. The composition consists mainly of thick limestone distribution, or mass, fine particles with a thickness of 700- 900 m.

Cam Thuy formation (P2ct), the sedimentary rocks of formation splayed into the long narrow strip of Northeast - Southwest direction which located in Northeast of Tuan Giao and Thuan Chau area. The formation is composed mainly of mafic effusive rocks and sediment terrestrial alternating tuff, the formation covered unconformably in limestone age of Carbon-Permi (C-P_1).

Vien Nam formation (P_2-T_1vn), the formation consists of effusive mafic rocks such as basalt, porphyritic basalt, almonds, diaba, xpilit altered, tuff, which distribute in Northwest - Southeast to coincide with the deep faults zone of Da River. The thickness of formation is about 400-500 m.

*Tan Lac Suite (T_1tl), t*he formation consists of terrestrial carbonate with mainly composition of red-brown clay with pebbles, limestone clay, and siltstone. Tan Lac formation distributed in banks of Da River and along the western of Fansipan mountain range. The formation covered gradually over the carboniferous rock aged T_1dg (Dong Giao formation) and P_2–T_1vn (Vien Nam formation).

Dong Giao Suite (T_2đg), the mainly rock of formation is carbonate rocks which distribute in range of Northwest - Southeast along with the synclinal Da River complex The formation Dong Giao can be divided into two parts; The lower part consist of grey calcareous siltstone to bright calcareous siltstone with the thickness of 600m. The upper part is composed of fine-grained light-colored stone with calcareous siltstone and a thickness of about 700 m.

Muong Trai formation (T_2mt), Muong Trai formation includes terrestrial carbonates rocks alternating the mafic effusive rocks and distribute along the Da River. The formation is divided into three parts; the lower part found in the east of the Muong Trai and Quynh Nhai area which consists of terrestrial rocks, carbonate eruptions alternating rarely effusive mafic rock and thickness of this part is 600- 800 m. The middle part found in eastern of Quynh Nhai and western of volcanic Tu Le zone which include lime, calcareous clay, limestone and muddy-calcareous clay with a thickness of 400 m. The upper part consists of shale stone, siltstone, and sandstone which distribute in the east of Quynh Nhai and the southwest of volcanic eruption Tu Le area.

Suoi Bang Suite (T_3n-r sb), the age of sediments containing coal-bearing Triassic Nori – Ret distributed mainly in Dien Bien Phu, Quynh Nhai areas and formed long in range of the Northwest – South with the thickness of about 1100 m. The formation is divided into two parts; the lower part is sedimentary conglomerate, shale, sandstone powder mix bright colors, are not set up the sediment Cacni and found in Dien Bien Phu, Quynh Nhai, North of Than Uyen and Muong Trai. The upper part is charcoal sediments of subcontinent environment and includes shale stone, sandstone, siltstone which distribute over Da River and Dien Bien Phu. The formation covered conformably into the continental rock of red - early Jurassic age.

The composition age of Jurassic - Cretaceous consists of subalkaline effusive rocks and their tuf of Ngoi Thia

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formation ($J-K_?nt$) and Tu Le (K_2tl) formation which is not conformably lying each other. The creation of this formation occupies a large area of northeastern edge volcanic Tu Le Ngoi Thia.

Tu Le formation (J – K tl), the composition of Tu Le formation is distributed mainly in the south of Than Uyen and along the east side of Fansipan which include acid eruption, rhyolite, focfia - rhyolite, fenzit, stone-gray to dark gray in bedded.

Ngoi Thia formation (Knt), the formation includes acid effusive rocks as; octofia, comedit, rhyolit focfia, sub-volcanoes and volcanic rock they are distributed over a large area south of Than Uyen and separated by faults in northwest – southeast direction.

Yen Chau formation (K_2yc), the formation consists of three parts which gradually conformable each other: The upper part is mainly of conglomerate and less sandstone with the typical colors of red brown (continental environment) with the thickness of 800 m. The middle part is mainly of sandstone, siltstone alternating conglomerate with typical red color and the thickness of 700m. The upper part is mainly of lime conglomerate, sandstone, and red siltstone with a thickness of 300 m. The Yen Chau formation distributed spread along Da River and Yen Chau.

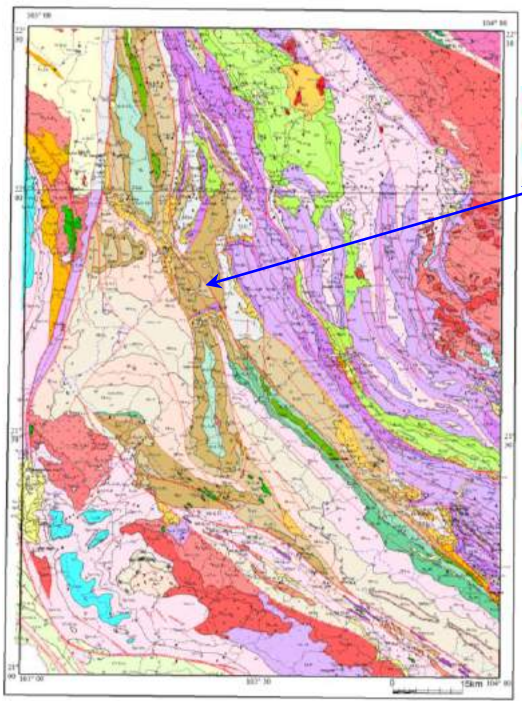
Quaternary sedimentary (Q_{IV}), composed of sand, pebbles, gravel, soil... have been deposited along rivers, streams, the river terrace or narrow valleys. They are distributed along the faults and the karsts relief such as: the narrow valleys of Than Uyen, Tuan Giao, Muong Ang, Thuan Chau, Dien Bien Phu. However the thickness of Quaternary sedimentary is rather low and small of material deposition.

The various magma formation in the region such as, Dien Bien complex of late Permian age *(δ- γP_3đb)* which directly penetrated the formation of Ma River (ε_2 *sm*), Da River (C_3-P_1sd), and recently these data isotopic age have allowed more firmly of Dien Bien complex age of late Permian with the range of 252 to 266 million years.

Complex systems Phu Sa Phin *(εJ -γKpp)* which includes agricultural and intrusive granitic alkaline volcanic and syenit granosyenit closely related to the origin, space and time into creating the rhyolite- Jurassic-Cretaceous. The Phu Sa Phin complex Jurassic-Early Cretaceous is age prior of K_2 yc.

Complex systems Ye Yen Sun (*γJ-Kys)*, the rocks of this complex extend the North West - South East are identical to the sequence Fansipan with the main lithological components include: granosyenit, biotite granite, aplit, pecmatit and we have some Jurassic-Cretaceous age in early (before forming of Yen Chau K_2yc).

Pu Sam Cap complex *(ε- γpc)* with the main lithological components of is porphyritic syenit of granules, large particles of Syenit-Trachyt shaped, light-colored granite and alkali. The age of the complex Pu Sam Cap is assigned to Paleogene age by isotope analysis of K/Ar of 29 to 56 million years.



24, June 1983
Ms = 6.7

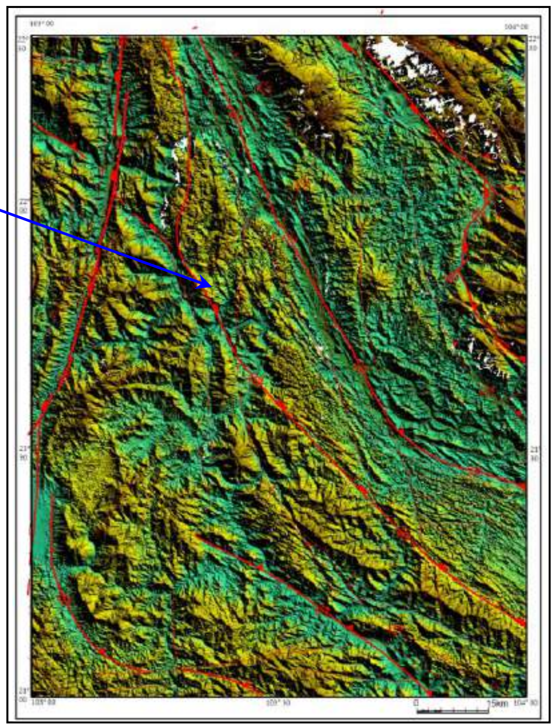


Figure 1: Geological map of Tuan Giao area (after Tuyet. T.D, 1976)

Figure 2: Geomorphology of Tuan Giao area (from DEM of 30 m)

The modern tectonic activities exposures clearly by active fault in the DEM analysis (fig.2) with the main direction in the Northwest-Southeast and general features of the lineaments as: topographic features, straight valleys, continuous scarps, straight rock boundaries, systematic offset of rivers. In addition based on the geomorphology field work, earthquake distribution, hot spring exposure, tectonic scarp, triangular facet which combine with geophysical survey and analysis to identify the active of faults system in the region such as; Son La, Lai Chau-Dien Bien, Song Ma, Phong Tho, Muong La-Bac Yen, Tuan Giao, Sin Ho [6,7,8,9,10,13,17]

2.2. Tectonic settings

According to Bach L.D and Tuyet T.D [12,18] the earth crust in the NW of Vietnam is the product of Pre-Cambrian, Phanerozoic mobile belts and Mesozoic-Cenozoic intra-plate activated superimposes structures. Belonging to the Pre-Cambrian series is the Phan Si Pan, Nam Co structures and possibly also the basement of Pu Si Lung structure (fig.3). The Phan Si Pan continental massif is a folded structure formed by the activities of the Early Pre-Cambrian mobile belts, through the following main periods: the development of the ancient mobile belt in Early Proterozoic - Riphean and the tectonic collision, convergence, folding and formation of modern continental crust at the beginning of Late Riphean. Nam Co is the remnant of a continental structure formed in the ancient (Pre-Cambrian - Late Riphean) mobile belts. They were split by rifting and played the role of micro-continents in the activities of the Early Phanerozoic mobile belts.

The structures are subdivided by age as follows: a) Early Paleozoic: Song Ma, Thuan Chau; b) Late Paleozoic - Early Mesozoic: Muong Te, Song Da. The Song Ma zone was initiated by rifting during the destruction of the Late Riphean continent, resulting in the formation of basins with oceanic crust. On the modern structural plan, the Song Ma ophiolite is a linear allochthonous structure overlapping the Nam Co micro-continent by abduction mechanism, generated in the process of closing the newly created Song Ma oceanic structure at the beginning of Middle Paleozoic [12].

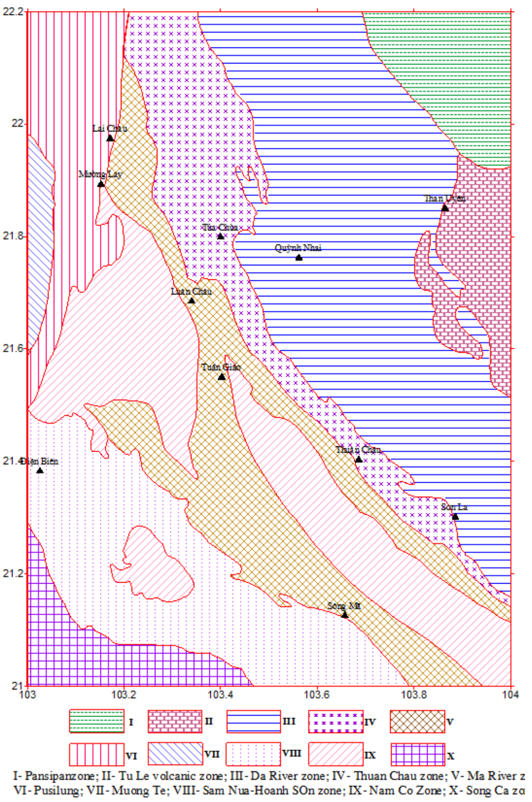


Fig 3. Tectonic setting (after Bach.L.D 1990)

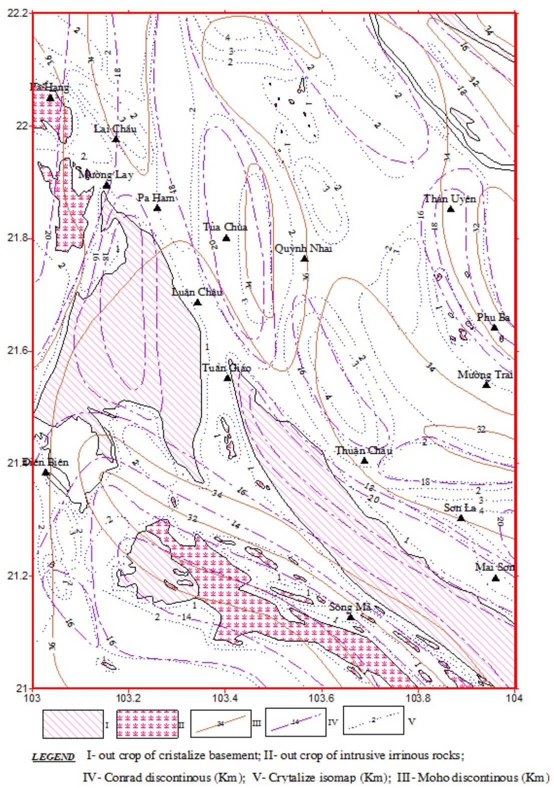


Fig 4. Sketch of crustal structure of Tuan Giao area

2.3. Earth's crust characteristics

The combination of geophysical methods used in studying the structural characteristics of the earth crust in the Tuan Giao area and surroundings includes [2,6,14]: 1/Geomagnetic; 2/ Gravity; and 3/Georadar method, which was also used by the authors in this study.

On the basis of the available data (Bouguer gravity map of 1/ 50,000 scale; Aeromagnetic map of 1:200,000 scale; 10 profiles of detailed Gravity, ground Magnetic and Georadar survey of 1:50,000 scale) and the methods of study presented above [2,6,7,13], the authors have compiled an earth crust structure map of the study area (fig 4). The result shows as follow:

a/ Crystalline basement surface: The crystalline basement surface in the study area varies in a relatively complicated manner. The depth to the basement is not great, in average 3 ÷ 4 km. The deepest place of the basement surface coincides with the Tu Le Mesozoic depression (h_k = 5 ÷ 6 km). This surface reflects the difference in density between the sedimentary and granite layers, which varies between 0.03g/cm^3 ÷ 0.09g/cm^3 whereas the density of the sedimentary layers varies between 2.63g/cm^3 ÷ 2.68cm^3.

b/ Conrad surface: Further below is the Conrad surface lying at the depth of 15 ÷ 22 km where the density of the granite layer varies between 2.68g/cm^3 ÷ 2.73g/cm^3. This surface represents the difference in mean density between the "granite" and the "basaltic" layers.

c/ Mohor surface: The lowermost is the Mohor surface at the depth of 35 ÷ 40 km where the density of the basaltic layers varies between 2.89 ÷ 2.93g/cm^3. The Mohor surface represents the difference in average density of the basaltic layer and the mantle (whose density are 3.3g/cm^3).

d/ Main fault systems: The authors with subdivision of the faults into various orders describe the faulting diagram of the study area. It should be noted that this subdivision is only qualitative and is based mainly on the structural characteristics: The extents, the expression on the Bouguer gravity anomaly map, the roles of the faults in respect to the geologic structure and the basic boundary surfaces of the earth crust such as the crystalline basement surface, the Conrad surface, the Mohor surface as well as the lateral heterogeneity of the crust density [6,7,9]. Some main faults are described in table 1.

Table 1: *Some main fault in Tuan Giao area*

No	Name of Faults	Strike	Dip direction	Depth of penetration
1	Fansipan (1)*	NW - SE	SW	60
2	Tu Le (2)*	NW - SE	SW	35 ÷ 40
3	Phong Tho (4)*	NW - SE	NE	30 ÷ 40
4	Song Da (7)*	NW - SE	NE	30 ÷ 40
5	Son La (29)*	NW - SE	NE	60
6	Tuan Giao (8)*	N - S	W	30 ÷ 40
7	Lai Chau - DienBien (13)*	N - S	E	60
8	Song Ma (25)*	NW - SE	SE	60
9	Dien Bien - Tinh Gia (23)*	NW - SE	NE	30 ÷ 40

(1) - Corresponds to the number of faults in figure 8a*

As we know, a deep-seated fault is a vulnerable place of the earth crust favorable for the release of energy and is the place where focal of strong earthquakes are concentrated on. Thus the existence of active deep-seated faults may be considered as a precondition for the generation of strong earthquakes. The epicenter distribution map shows that all strong earthquakes occur in fault zones. On the Son La fault occurred the Tuan Giao earthquake - 1983 (with M_S=6.7 in Richter scale), on the Lai Chau - Dien Bien fault occurred two earthquakes in Lai Chau - 1914 ($M_S \approx 5.0$ in Richter scale) and Dien Bien -1920 ($M_S \approx 5.0$ in Richter scale). Comparing the fault distribution map based on gravity data and the earthquake epicenter distribution map it is seen that the areas with maximum value of gravity gradient coincide with the areas where earthquake occurs. Thus, the areas with strong seismic activities usually have high gravity gradient. This dependence proves more the efficiency of the gravity method in tectonic research in areas with similar geologic and geophysical conditions as in our country.

3. THE FEARTURES OF TUAN GIAO EARTHQUAKE SOURCE

The main previous studies listed in [4,11,16] have briefly addressed the characteristics of the Tuan Giao earthquake source. The main parameters referred to in these studies are the focal depth; the shape of the epicenter area and the kinetic characteristics of the main fault related to the focus. Within the framework of this study the authors present some new results of determining the source and focal depth of Tuan Giao earthquake on 24 June 1983 based on the analysis of the aftershock distribution law.

3.1. Aftershock distribution and size of Tuan Giao earthquake source

3.1.1. Theoretical background

Usually major earthquakes entail a series of minor earthquakes, which occur in sequence immediately after the main shock and have the same focal characteristics, called aftershocks. An earthquake with Ms = 7.0 in Richter scale may entail thousands smaller earthquakes (aftershocks). The aftershocks reflect directly the relationship between the fault slipping surface and the earthquake. The main shock creates abrupt increase and decrease of stress and impacts on the surrounding environment, making the stress in this area change in a complicated manner. Thus, within the fault zone and the areas adjacent to the main epicenter occurs the process of rebalancing the Stress State of the earthquake source, thus generating the aftershocks. Typical aftershocks appear immediately after the main shock and are distributed mainly within the earthquake source. In general, the magnitudes of aftershocks are always smaller than that of the main shock (but they still cause additional destruction). The total amount of energy released by the aftershocks usually does not exceed 10% of that of the main shock. The frequency of earthquake aftershocks decreases quickly with time.

On the basis of studying the earthquake aftershock distribution law in Japan, Omori established an

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empirical formula reflecting the acting process of aftershocks (Omori's law formula in 1894) follows:

$$n = \frac{c}{(k+t)^{p}} \qquad (1)$$

where: n- is the frequency of aftershocks at the point of time t after the main shock; k, c, p - are the constants depending on the magnitude of the main shock, p - usually falls within 1.0 ÷ 1.4. Thus, based on the aftershock distribution the devastation areas of most earthquakes can be determined. The size of the devastation area is directly proportional to the magnitude of the main shock. In 1954, Utsu and Seki established an empirical formula for determining the size of the earthquake source [20]:

$$\text{LgA} = 1.02\ \text{Ms} + 6.0 \qquad (2)$$

Where A is measured in cm^2

Actually, the earthquake sources are determined by aftershocks occurring 1-2 days after the main shock. This has been proved by studies on focal mechanism of earthquakes worldwide. The aftershocks occurring after 2 days or later are considered to be generated by sources beyond that of the main shock.

3.1.2. Area of the Tuan Giao earthquake source

Within the first five months after the main shock (the Tuan Giao earthquake) of 24 June, there ware 223 aftershocks with Ms > 2.6 recorded, half of which occurred in the first 4 days. The aftershocks of Tuan Giao earthquake continued to occur in 1984 and later but with less and less frequency and intensity. The area of the source of Tuan Giao earthquake was determined in this study based as:

The distribution of aftershocks was occurring within two days after the main event, 24 and 25 June 1983 (index 1), the result of this analysis shows (fig. 5, fig.6) that the source of the Tuan Giao earthquake has a length (L) of 33 km and a width (W) of 21 km, since then its area is: S = 21 × 33 = 693 km^2. Based on the empirical formula (2), for Tuan Giao earthquake with Ms = 6.7 we have:

LgA(cm^2) = 1.02 × 6.7 + 6.0 = 12.83 and A = $10^{12,83}$ = 676.1 km^2.

The difference of the source areas determined by the two above methods is as follows:

$$S = \frac{S - A}{S} \times 100\% = \frac{693 - 676.1}{693} \times 100\% \approx \pm 2.5\%$$

According to Utsu and Seki, the free coefficient of the empirical function (2) is a constant characterizing the tectonic condition of each study area. Applying formula (2) to the case Tuan Giao earthquake we get the following expression for calculating the area of the source: Lg(686.2).10^{10}(cm^2) =1.02Ms + b. with Ms = 6.7.

$$b = \text{Lg}\,(686{,}2).10^{10} - 6{,}834 \approx 6{,}01.$$

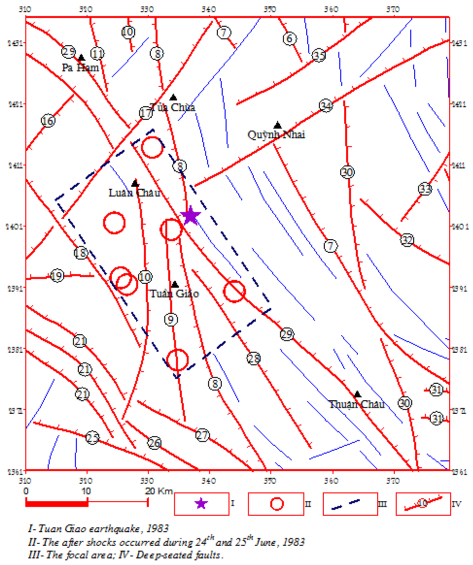


Fig 5. Epicenter of Tuan Giao Earthquake

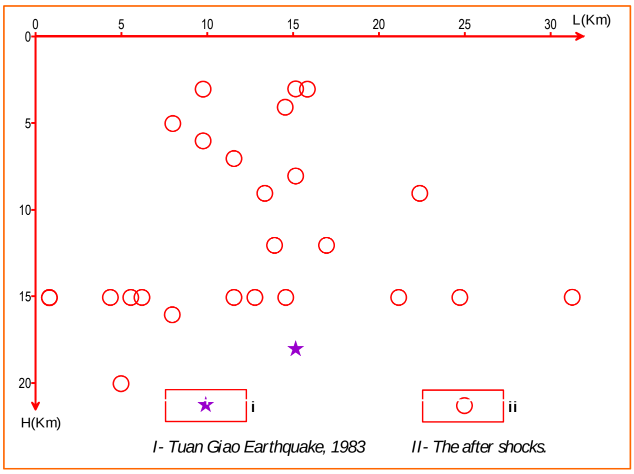


Fig 6. Hypocenter of main shock and aftershock In Epicenter of Tuan Giao Earthquake

3.1.3. Distribution of aftershocks with focal depth and focus height

Within 6 months after the Tuan Giao earthquake of 24 June 1983, in the area adjacent to the focus 25 aftershocks with Ms > 3.0 were recorded (index 1).

The aftershocks of Tuan Giao earthquake are mainly distributed within the depth limit from 3 to 20 km. If the focal depths of aftershocks are considered to reflect the structural characteristics of the earthquake source, the height of the source of Tuan Giao earthquake can be determined as 20 - 3 = 17 km (fig.6).

3.2. Characteristics of seismic activities

According to statistical data, in Tuan Giao area 229 earthquakes had been recorded with various magnitudes (fig.8a) there ware; 02 of destructive event with Ms 6,8 and 6,7 (Dien Bien 1935, Tuan Giao 1983); 04 events of rage magnitude Ms = 5.0 ÷ 5.9; 46 event with Ms of Ms 4.0 ÷ 4.9; and the remaining events with Ms<4.0. The statistical analysis of earthquakes is carried out in order to find out the distribution laws of seismic activities in space and time.

3.2.1. Spatial distribution of earthquakes

Area distribution of earthquake epicenters, a distribution map of earthquake epicenters of Tuan Giao area and the surroundings is shown in (fig.7a). The most prominent feature here is the concentration of epicenters in zones coinciding with the major tectonic fault zones of the earth crust:

The Lai Chau - Dien Bien earthquake zone is developed along the fault zone of the same name in sub-meridian direction. This is a zone with strong seismic activities and probably it still extends further northward (into the territory of China) and southward (into the territory of Laos), the earthquake recorded in this zone with $M_s = 4.6 \div 5.5$.

The NW-SE trending Son La earthquake zone is developed along the Son La and Song Da fault zones. Many earthquakes with Ms ≥ 3.0 occurred within this zone, especially the Tuan Giao earthquake of 1983 (M_s= 6.7).

The Song Ma - Dien Bien - Tinh Gia earthquake zone extends in NW-SE direction. Within this zone occurred the Dien Bien earthquake of 1935 with M_s =6.8.

With the aim to find out the distribution law of earthquake foci, within this study the authors determined the average density of focal with the use of a grid with interval of 1km. From the result of this calculation (fig. 7b) we can easily recognize that the earthquake focal in the Tuan Giao area and surroundings are concentrated mainly within the depth from 4km to 21km. The thickness of the seismic active layer is about 17 km. The maximum depth of over 15 km pertains to the earthquakes with large magnitudes such as: Dien Bien earthquake with Ms = 6.8 and H= 23 km; Tuan Giao earthquake with Ms = 6.7 and H = 18 km.

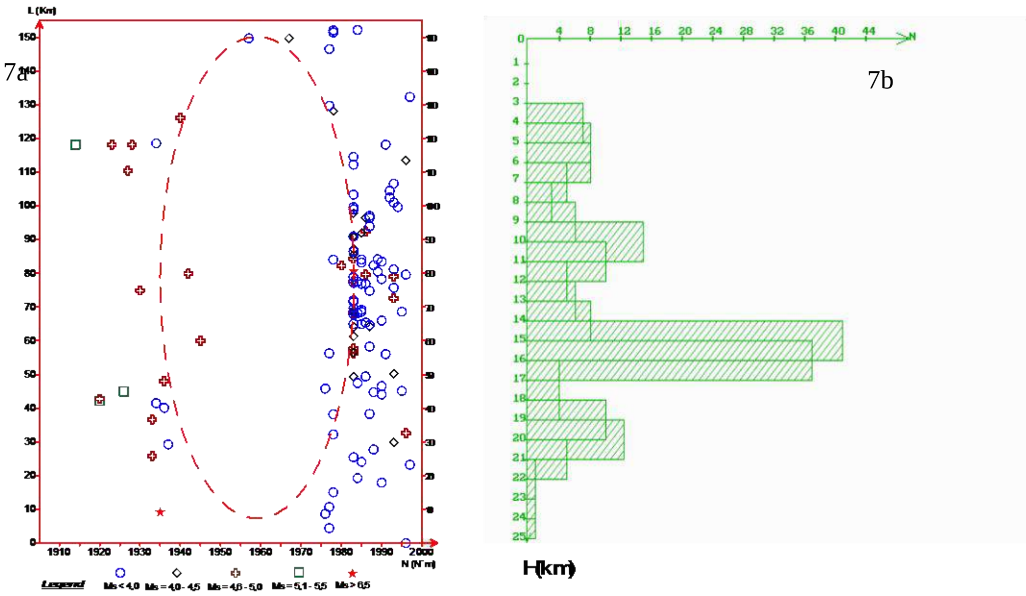


Fig 7. 7a) Time-space of epicenter area, 7b) Focal depth distribution in Tuan Giao area

Magnitude distribution of seismic activities, magnitude distribution law of seismic activities is expressed rather clearly for the strong earthquakes in the study area, especially the Tuan Giao earthquake of 1983. It shown that before the occurrence of Tuan Giao earthquake in 1983 with Ms = 6.7 there had occurred three earthquakes with Ms = 5.0 ÷ 5.9: one in 1914; one in 1920 and one in 1926. These three earthquakes tended to move counter-clockwise, in time sequence from the earthquake of 1914 through that of 1920 and then to that of 1926 with the most remote distance of about 50 km from the epicenter of Tuan Giao earthquake. Earthquakes with lower magnitude (Ms = 4.0 ÷ 4.9) and distance from the epicenter of Tuan Giao earthquake not exceeding 35 km showing similar trend of movement occurred in 1927, 1936 and 1945.

3.2.2. Time distribution law

A time distribution characteristic, the most prominent feature of this distribution is the manifestation of seismic activities with low frequency in the period before 1914 and from 1945 to 1976 (fig. 7a). Before the occurrence of Tuan Giao earthquake in 1983, there was in 1977 a manifestation of intensive seismic activities, and then it was decreased. If this is a premonition of a strong earthquake, we can use it in the future for long-term earthquake prediction in Vietnam.

Quiescence - activation law, the seismic quiescence in an area is determined clearly in the spatial and temporal distribution curve of the earthquake. On the basis of the earthquake spatial and temporal distribution of the Tuan Giao area and the surroundings one can make some remarks as follows: (fig. 7a): 1) The average seismic quiescence time before the maximum earthquake occurs s about 50 years; 2) Intensive seismic activities before the Dien Bien earthquake occurred were in the period from 1914 to 1945, i.e. about 30 years. The most prominent during this period of intensive seismic activities was the occurrence of the Dien Bien earthquake in 1935 (Ms = 6.8); 3) If the previous period of intensive seismic activities is deemed to characterize the present, then at present the Tuan Giao area and the surrounding is being subjected to a period of intensive seismic activities which may continue for another 10 years.

3.3. Model of Analogue Identification (MAI) for earthquake recognization

An extremely important task in studying seismotectonic, which is the premise for medium and long-term earthquake prediction, is the study and prediction of seismic sources. This is a long-term and urgent direction of research of a nation, the result of which will serve as the primary basis and foundation for the earthquake forecast in the future. The main methods used for evaluating the maximum earthquake occurrence in this study include forecasting maximum earthquake on the developed the Model of Analogue Identification (MAI) for earthquake location [5,6,8].

With the aim to find out the locations with the risk of maximum earthquake occurrence within the Tuan Giao area and the surroundings the authors have adopted an identification algorithm as presented in [6,13,14]. The data used included; vertical component vector of the magnetic field ΔTa, the vertical vector of Bouguer gravity field, lineament intersection density and lineament density. These data were taken from the standard samples and underwent processing to be entered into the identification program as follows:

- The data on vertical component of magnetic field (along the z-axis) were calculated from the component aeromagnetic field ΔT_a in the area of earthquake with defined magnitude.

- The data on vertical component vector of gravity field (vector along the z-axis) were calculated in the area of earthquake with respective magnitude.

- The data on lineament density and lineament intersection density were established from the results of space image and geological data interpretation.

The standard sample selected for the identification problem is an area around the epicenter of an earthquake with a radius of about 8 km.

Usually the standard samples selected are based on the task set forth for the identification problem. For the purpose of forecasting the seismic maximum of the Tuan Giao area and the surroundings the authors used two types of standard samples: 1) The standard samples of the first type are earthquakes with magnitude between 6.0 and 6.9 (Ms = 6.0 ÷ 6.9): Dien Bien 1935, and Tuan Giao 1983. 2) The standard samples of the first type are earthquakes with magnitude between 5.0 and 5.9 (Ms = 5.0 ÷ 5.9): Lai Chau 1914; Dien Bien 1920; Son La 1926; Tuan Giao 1983; and Luan Chau 1993.

The primary result of earthquake forecast by MAI shown in (fig. 8b) which identify some remarkable places with highs potential of earthquakes as: a) Earthquakes with maximum magnitude 6.0 ÷ 6.9 are likely to occur in Pa Ham; Tuan Giao; Luan Chau; Thuan Chau; Than Uyen; and Song Ma areas. b) Earthquakes with maximum magnitude 5.0 ÷ 5.9 are likely to occur in areas such as Pa Hang, Muong Lay, Tua Chua, Quynh Nhai, Mai Son, Muong Trai, Phu Ba.

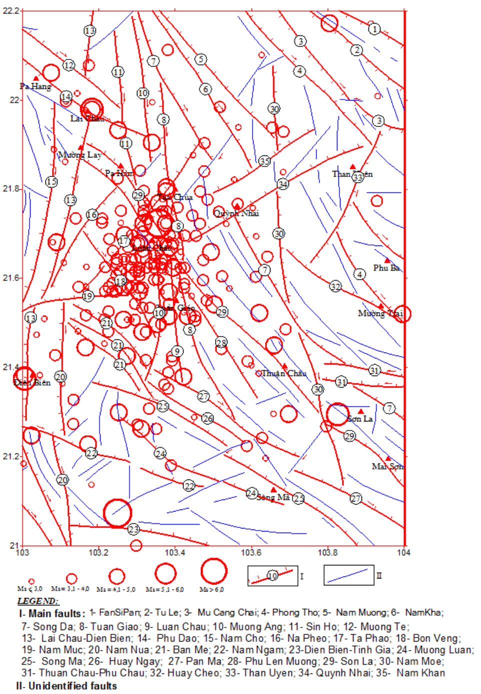
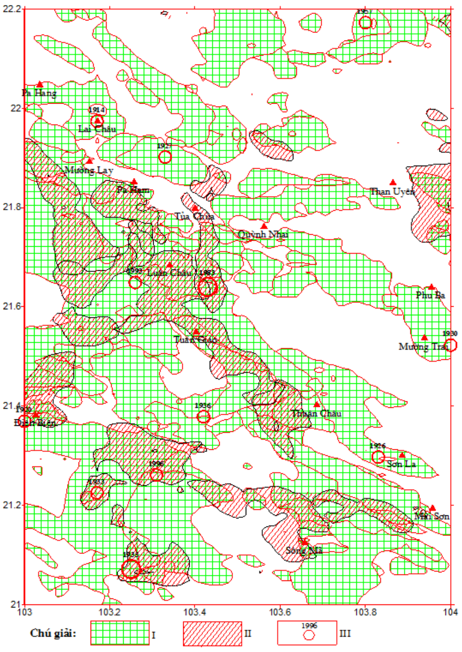


Fig 8: 8a) Earthquake and faults system;



I- Place with possible Earthquake Magnitude 5,0 - 6,0;
II- Place with possible Earthquake Magnitude 6,1 - 7,0
III- Time and place of Earthquake happened

8b) The possibility of occurrence earthquakes location with MAI

4. CONCLUSION

On the basis of the results obtained in this study about the Tuan Giao epicenter and adjacency area, some conclusions can be made as follows:

The crust - upper mantle boundary (Moho surface) in the area varies in a rather complicated manner and has a depth varying between 32 km and 36 km, increasing from East to West. The faults in the study area have a relatively great penetration depth (through the crust) and divide the earth crust into block structures with a clear variation of average density in lateral direction. Most of dominated these faults are NW - SE direction (Son La, Song Ma, Song Da, Thuan Chau, Fansipan, Tu Le) and others is sub-meridian faults (Lai Chau - Dien Bien and Tuan Giao).

Before the occurrence of Tuan Giao earthquake there had been in the epicenter area a long lasting seismic quiescence. The obvious manifestation of quiescence - activation law in the neighboring area before the main earthquake happened. The size of the Tuan Giao earthquake source is about 676.1 km^2, with their parameters of the source have been determined as; L = 33.1 km, W = 21.2 km, and focal height = 17 km.

Within the Tuan Giao and the adjacency area exist three of high seismogenic zones: Lai Chau- Dien Bien; Son La and Song Ma- Dien Bien - Tinh Gia. The thickness of the seismic activity layer is about 17 km; the earthquake epicenters are concentrated mainly within the range depth of 4 km to 21 km.

Based on the application of MAI shows possibility of earthquakes-prone area with maximum magnitude 6.0 ÷ 6.9 are likely in Pa Ham; Tuan Giao; Luan Chau; Thuan Chau; Than Uyen; and Song Ma. The possibility of earthquakes-prone area with maximum magnitude 5.0 ÷ 5.9 are likely to occur in areas such as Pa Hang, Muong Lay, Tua Chua, Quynh Nhai, Mai Son, Muong Trai, Phu Ba.

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REFERENCES

[1] Algermissen S. T., 1984. Seismic hazard and risk assessment. Some case studies. *The papers on risk and insurance*,Vol.9, No.30, p.8-26.

[2] Cao Dinh Trieu. 1995. Revelation of seismic zones after Geological and Geophysical data. *Journal of computer science and Cybernetic*, Vol. 12,2, Hanoi, p.41-45.

[3] Cao Dinh Trieu, 1997. Song Da and Phong Tho seismic active faults. *Journal of Sciences of the Earth, Volume 9, No 4, Hanoi, p* 270 - 278. (Vietnamese)

[4] Cao Dinh Trieu, Nguyen Xuan Binh, 1999. Crustal structure and Dynamics of the 1983 (Ms6.6) Tuan Giao Earthquake Epicentral Region. *Geology and Petroleum* in Vietnam, Hanoi, p. 107-118.

[5] Cao Dinh Trieu, 1999. Probable approach for long-term earthquake prediction in Vietnam based on the regulation of epicentral distribution. *Journal of GEOLOGY*, Series A, No 251,3-4, Hanoi, p 14-21.(Vietnamese)

[6] Cao Dinh Trieu, Nguyen Huu Tuyen etc..., 2001. Studying the geological, geodynamic and neotectonic conditions of the Tuan Giao earthquake area. Report of the Project of VAST 2000-2001 Years. Institute of Geophysics, Hanoi, pp. 80. (Vietnamese)

[7] Cao Dinh Trieu, Nguyen Danh Soan, 1998. Main fault systems on the territory of Vietnam based on the joint analysis of gravity, magnetic and satellite image data. *Journal of GEOLOGY*, Series A, No 247,7-8, Hanoi, p 8 - 17.(Vietnamese)

[8] Cao Dinh Trieu, Nguyen Thanh Xuan, 1997. Probability approach for long-term earthquake Ms>6.5 prediction in Tay Bac region based on the regulation of epicentral distribution. *Journal of GEOLOGY*, Series A, No 238,1-2, Hanoi, p 33 - 38.(Vietnamese)

[9] Cao Dinh Trieu, Nguyen Thanh Xuan, 1997. Main seismic faults in Tay Bac region. *Journal of Sciences of the Earth, Volume 19, No3, Hanoi, p* 214 - 219.(Vietnamese)

[10] Cao Dinh Trieu, Nguyen Thanh Xuan, 1999. Using remote sensing data and GIS to assess seismic

hazard in Tay Bac (Vietnam). Contribution of the Natural Hazard Monitoring in Vietnam in Hanoi, 15 - 20th October, Hanoi, p 192-204.(Vietnamese)

[11] Gibowicz S.I. and et al,1987. The Source of Tuan Giao 24-6-1983 earthquake. *Journal of Sciences of the Earth, Volume 9, No 2, Hanoi, p* 33-42. (Vietnamese)

[12] Le Duy Bach, Ngo Gia Thang, 1996. Tectonic setting of Tay Bac Vietnam. *Journal of GEOLOGY and Mining*, No 5, Hanoi, p 9 - 105.(Vietnamese)

[13] Nguyen Huu Tuyen, 2012. ''Study of geo-dynamics condition for Tuan Giao and adjacent area, establish the scientific criteria for earthquakes prediction''. PhD Dissertation, Hanoi Natural University (Vietnamese).

[14] Nikitin A.A., 1986. The basic theory of analysis geophysical information problem. Publish "Nedra", Masc¬va, 240 pp (Russia).

[15] Preliminary of epicenters. Monthly Listing.U.S. Department of the interior/*Geological Survey NEIS,* June 1983,p.9,10,16.

[16] Nguyen Dinh Xuyen, Cao Dinh Trieu and et al, 1990. The Tuan Giao, 24th June, 1983. *Publish House Science and tecnology*, Hanoi, pp 108.(Vietnamese)

[17] Nguyen Thanh Xuan, Cao Dinh Trieu, 1997. The application of Geographic Information System (GIS) to seismic hazard analys in Dien Bien - Son La area. *Journal of Sciences of the Earth, Volume 19, No 2, Hanoi, p* 119-123.(Vietnamese)

[18] Tran Dang Tuyet (in editor) 1976. Geological map of Northwest Vietnam at scale 1/200.000 (geological division)

[19] Robert s. Yeats, Kerry Sieh, Clarence R. Allen, 1997. The Geology of Earthquakes. *Oxford University Press*, New York, pp. 568.

[20] Utsu, T an A. Seki 1954. A relation between the area of aftershock region and energy of main shock, J. Seism. Soc. Japan 7, 233-240.

Index: After shock of the main event Tuan Giao (24 June, 1983)

No	Time		Coodinates		Depth of focal H (km)	Magnitude (Ms)
	Y, M, D	H, M, S	ψ	λ		
(1)	(2)	(3)	(4)	(5)	(6)	(7)
1**	1983 VI 24	07 18 22,3	21,71	103,43	18	6,7
2*	1983 VI 24	15 43 40,3	21,81	103,37	12	4,5
3*	1983 VI 24	21 25 11,6	21,69	103,40	12	4,7
4*	1983 VI 24	22 45 05,8	21,60	103,50	09	4,0
5*	1983 VI 25	10 52 07,0	21,61	103,33	07	4,6
6*	1983 VI 25	15 18 23,0	21,70	103,31	03	4,0
7*	1983 VI 25	19 55 23,3	21,50	103,41	09	4,2
8*	1983 VI 25	20 16 19,7	21,62	103,32	06	4,2
9	1983 VI 26	00 40 31,5	21,52	103,32	05	4,7
10	1983 VI 26	01 39 00	21,88	103,45	20	3,2
11	1983 VI 26	02 20 22,0	22,02	103,46	20	3,3
12	1983 VI 26	03 06 54,2	21,82	103,36	15	4,2
13	1983 VI 26	03 27 33,4	21,74	103,63	15	3,7
14	1983 VI 27	00 36 50,4	21,92	103,45	15	3,6
15	1983 VI 27	00 55 46,7	21,86	103,49	15	4,1
16	1983 VI 27	02 37 46,0	21,63	103,40	15	3,4
17	1983 VI 27	03 03 15,9	21,88	103,40	15	3,3
18	1983 VI 27	08 51 41,8	22,02	103,46	15	3,3
19	1983 VI 27	09 15 11,9	21,81	103,38	15	3,9
20	1983 VI 27	09 45 31,3	21,98	103,56	15	3,6
21	1983 VI 27	22 44 23,3	21,51	103,26	03	4,7
22	1983 VI 29	03 35 03,5	21,62	103,39	15	3,7
23	1983 VII 03	16 26 18,7	21,57	103,39	16	4,5
24	1983 VII 07	18 16 35,6	21,76	103,40	08	4,3
25	1983VII 11	17 32 01,4	21,78	103,33	04	4,3
26	1983 VII 15	11 48 51,6	21,75	103,44	03	5,0

** - Main shock; * -The after shock recorded in the epicenter area