ISSN 0747-9239, Seismic Instruments, 2020, Vol. 56, No. 3, pp. 290–298. © Allerton Press, Inc., 2020.
Russian Text © The Author(s), 2019, published in Voprosy Inzhenernoi Seismologii, 2019, Vol. 46, No. 3, pp. 46–56.

Features of the January 8, 2018, Muong Ang Earthquake in Northwest Vietnam

Ngo Thi Lu[a,b], V. Yu. Burmin[c,] *, Phung Thi Thu Hang[a, b], Nguyen Huu Tuyen[a], Mai Xuan Bach[a], and Ha Thi Giang[a]

[a] *Institute of Geophysics, Vietnam Academy of Sciences and Technologies, Joan Quoc Viet st., 18, Hanoi, Vietnam*
[b] *University of Science and Technology, Vietnam Academy of Sciences and Technologies, Joan Quoc Viet st., 18, Hanoi, Vietnam*
[c] *Schmidt Institute of Physics of the Earth, Russian Academy of Sciences, Moscow, 123242 Russia*
**e-mail: burmin@ifz.ru*

Abstract—Macroseismic and instrumental data on the January 8, 2018, Muong Ang earthquake in northwestern Vietnam are comparatively analyzed. Good agreement is found between the macroseismic and instrumental data, which in turn correlate perfectly with the tectonic data. The Muong Ang earthquake consisted of foreshocks, the mainshock, and three series of aftershocks. The first series of aftershocks occurred on the left wall of the Tuan Zao fault, at its terminus in Sha Zung, Muong Ban. Then, aftershocks gradually migrated north-northeast. Finally, aftershocks migrated south. The migration process of aftershocks not only indicates that the seismic activity is largely related to tectonic elements, but also confirms the notion that the Tuan Zao and other faults in this area are active. It can be also assumed that the Tuan Zao fault extends rather far south to the area of Chieng Sho, instead of terminating in Sha Zung and Muong Ban, as shown on modern tectonic maps.

Keywords: macroseismic and instrumental data, earthquakes, Vietnam, foreshock, aftershock, tectonic fault
DOI: 10.3103/S074792392003007X

INTRODUCTION

There are two tectonic faults in Dien Bien Province, northwest Vietnam: the Lai Chau–Dien Bien and Ma River–Shon La faults. Generally, northwest Vietnam is a region with complex tectonics and intense seismic activity. Recently, earthquakes have occurred quite frequently in Dien Bien; an unusually large number of events have been recorded since the beginning of 2017. One of the latest earthquakes ($M = 4.7$) occurred in Muong Ang District, Dien Bien Province, on January 8, 2018, at 23:21:21.8 GMT. This earthquake stirred great public interest in the possible devastating effects to the population of the province.

Shortly before the earthquake, the dense network was deployed in the epicentral zone to provide recording of earthquakes with magnitudes less than 1.0 without omission (Burmin et al., 2010, 2018). Immediately after the Muong Ang earthquake, the Geophysical Institute, Vietnam Academy of Sciences and Technologies, sent a group of researchers to collect macroseismic data, i.e., information about how seismic oscillations were perceived by people and to what extent civilian facilities were damaged.

The Vietnam seismic network recorded the foreshocks and aftershocks of this earthquake from January 2018 through May of 2018. Comparative analysis of the macroseismic and instrumental data makes it possible to study in the Muong Ang earthquake in sufficient detail and characterize the seismic process in the earthquake zone. The study area lies between 20.70° and 22.80° N and between 102.10° and 105.30° E (Fig. 1).

Instrumental data were collected in this area through May 2018, so that a catalog of foreshocks and aftershocks of the Muong Ang earthquake could be produced for further research. Importantly, the foreshocks, mainshock, and aftershocks were recorded not only by the Vietnam seismic network, but also by foreign seismic stations (see Seismological Bulletin of the International Seismological Centre, 2001. URL: http://www.isc.ac.uk/iscbulletin/search/bulletin/) and a temporary seismic network (23 stations) set up under the project "Investigation into the Issue about Deployment of a Seismic Monitoring Network and Assessment of Features of Earthquakes Triggered by Reservoirs of the Song Da Hydroelectric Power Stations" (Le Van Zung et al., 2018) (Table 1).

This paper analyzes the spatiotemporal distribution of earthquakes in Dien Bien Province and neighboring areas using data on foreshocks and aftershocks. Their spatiotemporal interrelationship is also examined, as well as their correlation with the tectonic and geomorphic features of Dien Bien Province. Similar analyses can be found in publications on earthquakes in Viet-

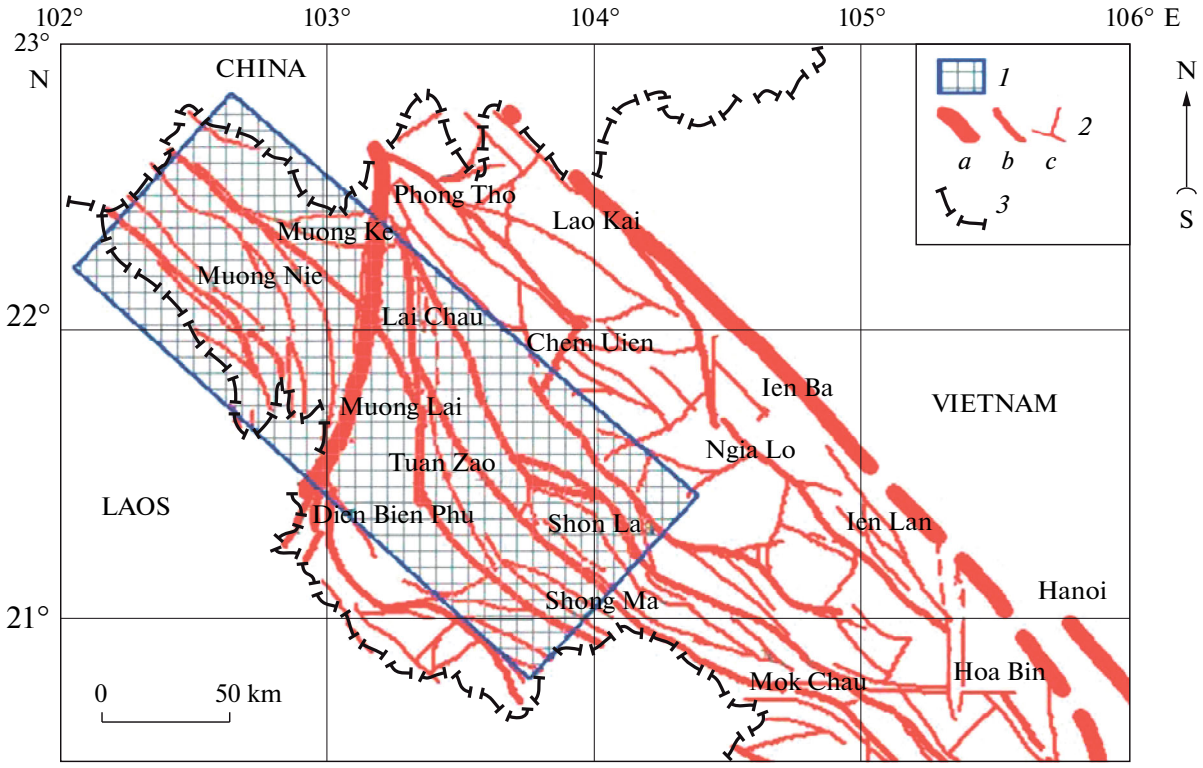

Fig. 1. Map of study area: (*1*) study area; (*2*) faults of different levels: (*a*) level I, (*b*) level II, (*c*) level III; and (*3*) state borders.

nam and Southeast Asia (Kondorskaya and Ngo Thi Ly, 1994; Ngo Thi Lu, 1990, 1998, 1999, 2003; Ngo Thi Lu and Nguyen Quang, 1997; Ngo Thi Lu et al., 2000, 2010).

MACROSEISMIC DATA

Table 2 presents macroseismic data on the January 8, 2018, Muong Ang earthquake. These data describe a wide range of local seismic impacts. Only those events felt by highly sensitive people are presented (shocks of intensity $I \geq$ III on the MSK-64 scale (Medvedev et al., 1965)). Table 3 describes the perceptions of people and phenomena observed in the study area during the Muong Ang earthquake. Based on the macroseismic data, an isoseismic map was compiled for the January 18, 2018, earthquake (Fig. 2).

INSTRUMENTAL DATA

As noted above, the January 18, 2018, Muong Ang earthquake with magnitude $M = 4.708$ occurred in Muong Ang District of Dien Bien Province in northwest Vietnam at 23:21:21.8 GMT. The coordinates of the earthquake were 21.3740° N, 103.290° E; the source depth was ~10 km.

The isoseismic map of the January 8, 2018, Muong Ang earthquake is based on data collected in the epicentral zone (see Fig. 2). The elongated axes of the isoseismal lines are generally oriented north–south, deviating northeast-southwest parallel to the trend of the Tuan Zao fault.

From January to April 2018, the Vietnam seismic network recorded four foreshocks with magnitudes of $M = 1.7$–4.1, the main shock, and 23 aftershocks with magnitudes of $M = 1.5$–4.0. The main parameters of the Muong Ang earthquake, its foreshocks, and aftershocks are presented in Table 4.

CHARACTERISTICS OF THE MUONG ANG EARTHQUAKE

The spatiotemporal evolution of foreshocks and aftershocks of the Muong Ang earthquake (Fig. 3) shows that their epicenters are concentrated along the same direction as the trend of the Tuan Zao fault where the latter intersects the Shong Ma fault. The period of foreshock and aftershock activity can be divided into three time intervals.

Interval 1 includes foreshocks, the main shock, and the first aftershocks concentrated in an ellipsoidal region with an area of about 9.52 km^2 (the major axis is 5.48 km, and the minor axis, 2.20 km). The major axis is oriented northeast–southwest (Fig. 3). Note that the aftershock epicenters of Interval 1 lie in the area bounded by the intensity VI isoseism with the

Table 1. Vietnam seismic stations that recorded the January 8, 2018, Muong Ang earthquake

Station	Station Code	Coordinates		Absolute elevation, km	Year of station installation
		N	E		
Temporal seismic stations					
Tu-Li	TLY	20.933	105.105	408	2016
Mai Chau	MAC	20.5238	105.065	157	2016
Yen Chau	YCH	21.057	104.271	320	2016
Chieng Lao	CLA	21.613	103.937	220	2016
Ngok Chien	NCH	21.65	104.237	507	2016
Quin Nyai	QNH	21.656	103.601	394	2016
Phu Yen	PYE	21.315	104.689	432	2016
Tua Chua	TCH	21.931	103.422	831	2016
Chan Nya	CNU	22.194	103.154	237	2016
Pu Dao	PUD	22.136	103.162	752	2016
Muong Mo	MMO	22.207	102.938	395	2016
Muong Nie	MTO	22.035	102.668	450	2016
Kan Ho	KHO	22.292	102.834	382	2016
Hua Wum	HUB	22.393	102.954	557	2016
Phong Tho	PHO	22.394	103.451	966	2016
Tan Uien	TAN	22.175	103.715	525	2016
Muong Te	MTE	22.379	102.825	296	2015
Cha Kang	CCA	21.971	102.868	433	2015
Nam Nyun	NNU	22.144	103.000	330	2015
Nam Na 3	NNA3	22.291	103.16	281	2015
Ban Chat 1	BC1	21.846	103.846	429	2015
Ban Chat 3	BC3	21.954	103.758	503	2015
Ban Chat 2	BC2	21.954	103.878	603	2015
Permanent seismic stations					
Muong Lai	MLAV	22.042	103.154	270	1990
Shon La	SLV	21.325	103.907	607	1997
Tuan Zao	TGVB	21.592	103.418	574	1997
Hoa Bin	HBVB	20.842	105.327	55	1970
Sha Pa	SPVB	22.338	103.835	1550	1957
Mok Chau	MCVB	20.844	104.636	825	2002
Van Chan	VCVB	21.575782	104.59433	357	2016

major axis oriented in the same direction as the general trend of the isoseisms in the epicentral region.

Interval 2 includes aftershocks concentrated in a narrower area, also shaped like an ellipse about 5.17 km^2 in are (the axes are 3.8 and 1.7 km). The major axis of the ellipse is oriented in the same direction as the trend of the Tuan Zao fault where this fault intersects the Shong Ma fault. Note that the aftershock epicenters of Interval 2 are located north of the mainshock epicenter and the zone of foreshocks and aftershocks of Interval 1 (see Fig. 3). This area is bounded by the intensity V isoseism, whose major axis is oriented in the same direction as the general trend of isoseisms in this area.

Interval 3 comprises the latest series of aftershocks that occurred in the epicentral zone of the Muong Ang earthquake from mid-2018 to mid-2019. This series includes six aftershocks with epicenters concentrated in a narrow ellipsoidal zone about 8.40 km^2 in area (the axes are 5.75 and 1.80 km). The major axis is oriented north–south, in the same direction as the trend of the Tuan Zao fault where this fault intersects the

Table 2. Macroseismic data on January 8, 2018, Muong Ang earthquake

Coordinates of observation stations, degrees		Place	Seismic intensity on MSK-64 scale
N	E		
21.59057	103.42301	Town of Tuan Zao, Tuan Zao District, Dien Bien Province	III
21.59306	103.40778	National seismic station Tuan Zao, Town of Tuan Zao, Tuan Zao District, Dien Bien Province	III
21.51845	103.35537	Kuet Thien 2 village, Bung Lao community, Muong Ang District, Dien Bien Province	IV
21.51774	103.34016	Ho village, Bung Lao community, Muong Ang District, Dien Bien Province	IV–V
21.48816	103.33496	Ke village, Suan Lao community, Muong Ang District, Dien Bien Province	IV–V
21.45255	103.30257	Lan village, Muong community, Muong Ang District, Dien Bien Province	V–VI
21.44529	103.2777	Ho Muong village, Muong Lan community, Muong Ang District, Dien Bien Province	VI
21.42813	103.26354	Hua La village, Muong Lan community, Muong Ang District, Dien Bien Province	V–VI
21.43037	103.27481	Hua La village, Muong Lan community, Muong Ang District, Dien Bien Province	V–VI
21.46736	103.3413	Lao village, Suan Lao community, Muong Ang District, Dien Bien Province	IV–V
21.44325	103.34932	Ko Muong village, Suan Lao community, Muong Ang District, Dien Bien Province	IV–V
21.40065	103.3848	Ha Kau village, Muong Be community, Tuan Chau District, Shon La Province	IV–V
21.40565	103.38023	Ha Zen village, Bung Lao community, Muong Ang District, Dien Bien Province	IV–V
21.52032	103.22473	Ho Hang Kang village, Muong Ang Town, Dien Bien Province	IV–V
21.4853	103.2623	Thuoy Shu Quong village, Ang Kang community, Muong Ang District, Dien Bien Province	V
21.53014	103.14683	Ta Kang 1 village, Na Tau community, Dien Bien District, Dien Bien Province	IV–V
21.51401	103.12774	Na Kay 1 village, Na Tau community, Dien Bien District, Dien Bien Province	IV–V
21.47039	103.06971	Na Nhan village, Na Nhan community, Dien Bien District, Dien Bien Province	IV
21.38694	103.01556	Center of Dien Bien Phu, Dien Bien Province	III
21.21683	103.25025	Town of Dien Bien Dong, Dien Bien Province	IV–V
21.30254	103.32891	Group 2, Town of Dien Bien Dong, Dien Bien Province	IV–V
21.32282	103.2412	Na Pat S village, Na Shon community, Dien Bien Dong District, Dien Bien Province	IV–V
21.35497	103.23917	Pa Chuong village, Na Shon community, Dien Bien Dong District, Dien Bien Province	IV–V
21.38936	103.24362	Bo village, Na Shon community, Dien Bien Dong District, Dien Bien Province	V
21.40402	103.24186	Shy Ly village, Na Shon community, Dien Bien Dong District, Dien Bien Province	V–VI
21.40339	103.24512	Shy Ly 1 village, Na Shon community, Dien Bien Dong District, Dien Bien Province	V–VI
21.31019	103.41038	Center of Chieng Sho community, Dien Bien Dong District, Dien Bien Province	IV
21.3799	103.202	Pu Nung community, Dien Bien Dong District, Dien Bien Province	V
21.1782	103.227	Fin Zang community, Dien Bien Dong District, Dien Bien Province	IV–V
21.3594	103.196	Pu Nyi community, Dien Bien Dong District, Dien Bien Province	V
21.4915	103.293	Nam Lich community, Muong Ang District, Dien Bien Province	V
21.2765	103.232	Center of Dien Bien Dong District, Dien Bien Province	V
21.3839	103.142	Pu Nyi community, Dien Bien Dong District, Dien Bien Province	IV
21.2045	103.333	Muong Luan community, Dien Bien Dong District, Dien Bien Province	IV

Table 3. Scale of earthquake intensities (Medvedev et al., 1965)

Local effects of earthquake on people and observed phenomena	Seismic intensity on MSK-64 scale
A few felt that their beds slightly shake. A few asleep woke up as if from sound of truck rumbling along. Most people felt nothing.	III
People at rest felt bed shaking. Unclosed windows and doors rattle. Noise was heard as if a car was driving nearby. Some awake due to feeling that bed was swaying. No one was frightened. Many stayed asleep.	IV
Many sleeping people woke up. Buildings shook, floor vibrated. Sound like explosion heard. A few houses slightly damaged, walls covered with small cracks.	IV–V
Most sleeping people woke up, children were crying. In rural areas, all people felt earth shaking. Wooden houses shook and some collapsed. Dogs were barking.	V
All people living in countryside felt earth quaking. Sleeping people heard loud explosion; roof vibrated; everyone woke up in panic; children were awake and crying; dogs were barking. Isolated cracks appeared on ground. Wooden houses shook and collapsed.	V–VI
All people living in countryside felt quaking. People sleeping on floor felt house shaking violently; loud sounds heard, similar to cracks of thunder. People lost balance. Total panic; children were awake and loudly crying. Walls of some houses suffered cracks. Dog was barking.	VI

Shong Ma fault. The aftershock epicenters of Interval 3 are located east of the main shock epicenter and the zone of foreshocks and aftershocks of Intervals 1 and 2 (see Fig. 3). This zone is bounded by the intensity VI isoseism with the major axis oriented in the same direction as the general isoseismic trend.

The above considerations show that there are three stages of the aftershock generation process. The first series of aftershocks occurred at the end of the left wall of the Tuan Zao fault in Muong Bam, Sha Zung. Afterward, aftershock activity gradually migrated north and northeast, then, at the third stage, to the south. This type of the evolution of seismic activity perfectly fits the seismic and tectonic data and confirms the modern tectonics of the Tuan Zao and other faults in this area. This also explains why strong earthquakes followed by a series of aftershocks most often occur in Dien Bien Province and neighboring areas.

Note that, according to the tectonic data, the Tuan Zao fault can be traced only to Muong Bam and Sha Dung. However, the aftershock distribution, the isoseismic pattern, and the specifics of the focal process of the Muong Ang earthquake indicate that the Tuan Zao fault extends further south to Chieng Sho, not to Muong Bam and Sha Dung (see Figs. 2 and 3), as shown on the tectonic map (Nguyen Ngok Thi et al., 2005).

CONCLUSIONS

Analysis of macroseismic and instrumental data on the January 8, 2018, Muong Ang earthquake in northwest Vietnam not only revealed some specific characteristics of this earthquake, but also showed good agreement between the macroseismic and instrumental data and the tectonic structure of the region.

Based on a detail study of the Muong Ang earthquake, the following can be stated.

The evolutionary process of the Muong Ang earthquake took place in three stages. The first stage comprises foreshocks, the main shock, and aftershocks on the left wall of the Tuan Zao fault in Muong Bam and

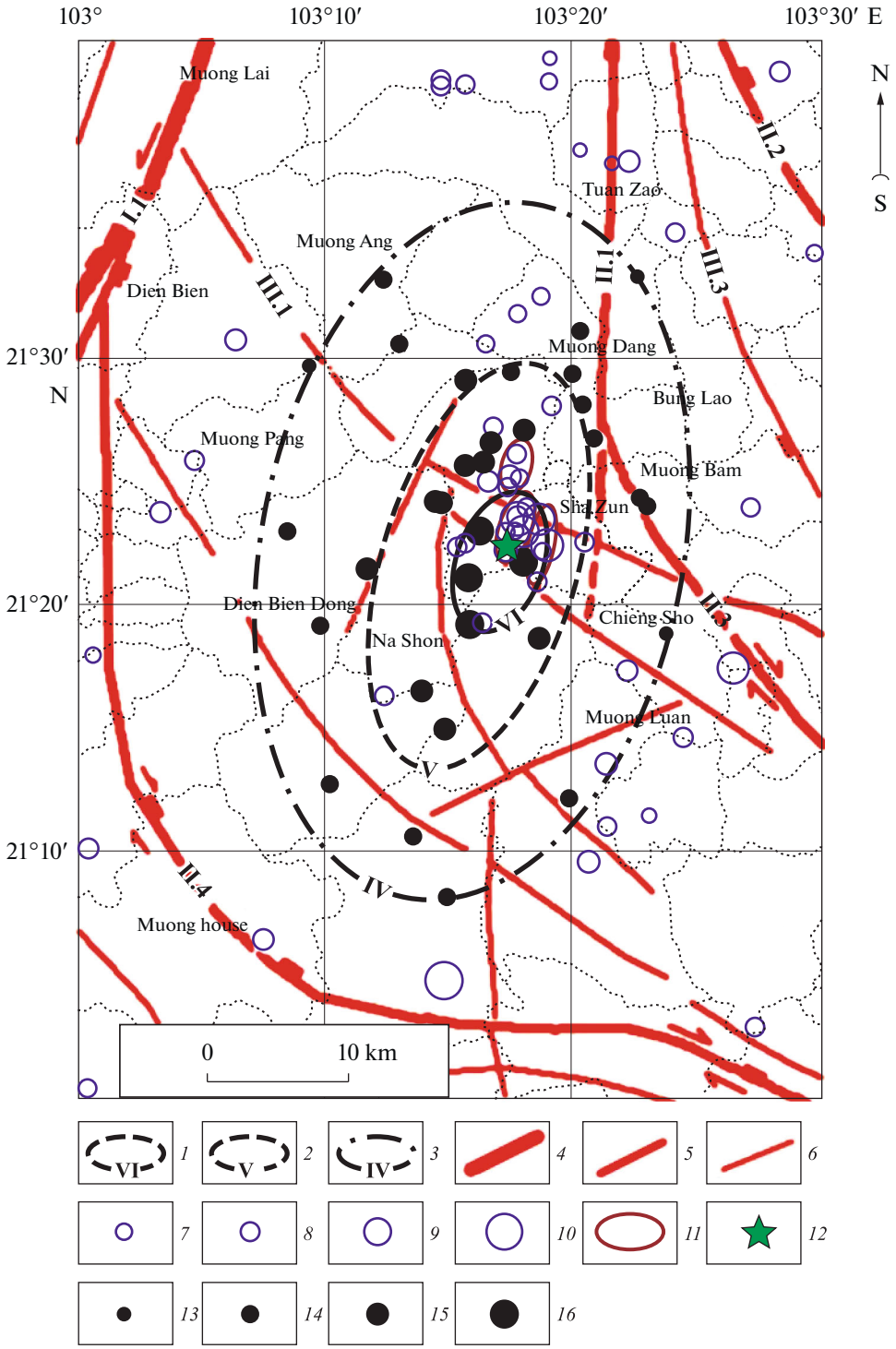

Fig. 2. Isoseismic map of January 8, 2018 Muong Ang earthquake: (*1–3*) Isoseismals of (*1*) I = VI, (*2*) I = V, and (*3*) I = IV; (*4*) level I fault; (*5*) level II fault; (*6*) level III fault; (*7*) earthquake epicenter with magnitude $M < 3.0$; (*8–10*) epicenters of earthquakes with (*8*) $M = 3.0–3.9$, (*9*) $M = 4.0–4.9$, and (*10*) $M > 5.0$; (*11*) boundary of the aftershock zone; (*12*) the main shock; (*13–16*) reported seismic intensities of (*13*) I = III, (*14*) I = IV, (*15*) I = V, and (*16*) I = VI. Faults of different levels: **I.1** Lai Chau Dien Bien; **II.1** Tuan Zao; **II.2** Shon La; **II.3** Shong Ma; **II.4** Fumaitun; **III.1** Chieng Hyong; **III.2** Than Nua-Sop Kop; **III.3** Muong Chung-Nam Tu.

Table 4. Main parameters of January 8, 2018, Muong Ang earthquake

No.	Date	Time			Coordinates, degree		Focal depth, km	Magnitude (M_S)
		hour	min	s	E	N		
Foreshocks								
1	January 6, 2018	21	54	11.2	21.968	103.441	14.3	1.7
2	January 7, 2018	20	14	19	21.391	103.298	10	4.1
3	January 7, 2018	21	28	57.3	21.401	103.304	8.1	2.5
4	January 8, 2018	22	7	25.2	21.372	103.287	8.2	1.7
Main shock								
Main shock	January 8, 2018	23	21	21.8	21.374	103.29	10	4.7
Aftershocks								
1	January 8, 2018	23	27	18.7	21.384	103.291	8.1	2.8
2	January 9, 2018	14	44	21	21.435	103.298	8.1	2.8
3	January 11, 2018	16	4	1.9	21.322	103.274	25.3	2
4	January 13, 2018	4	50	25.3	21.419	103.293	8.1	3.4
5	January 14, 2018	15	16	59.7	21.392	103.298	8.1	3.1
6	January 20, 2018	18	14	44.9	21.421	103.299	8.2	2.3
7	February 3, 2018	14	48	17.2	22.147	103.384	8.2	1.9
8	February 8, 2018	22	1	41.7	20.889	103.348	8.1	2.3
9	February 9, 2018	12	49	39	21.384	103.3	11.4	4
10	February 18, 2018	17	50	9.2	21.911	103.784	10.1	1.6
11	March 6, 2018	17	2	46.6	21.97	103.465	13.7	2
12	March 26, 2018	4	39	56.4	21.582	103.93	21.1	2.6
13	March 27, 2018	9	25	4.7	21.349	103.311	8.2	2.4
14	April 3, 2018	3	2	49.5	21.418	102.974	10	1.7
15	April 15, 2018	11	33	59	20.715	103.064	8.1	3.2
16	April 15, 2018	18	19	10.2	21.336	102.981	10	1.9
17	May 1, 2018	19	8	37.1	21.413	103.292	8.1	1.5
18	June 6, 2018	17	19	41	21.167	102.994	8	3.9
19	March 26, 2019	8	12	33	21.05	103.458	12.1	2.5
20	May 21, 2019	17	49	28.8	21.374	103.318	8.1	4
21	May 22, 2019	1	19	57	21.377	103.343	9.7	2.5
22	June 17, 2019	8	17	57	21.37	103.314	8.1	2.5
23	June 22, 2019	17	42	30	21.391	103.312	17.1	4

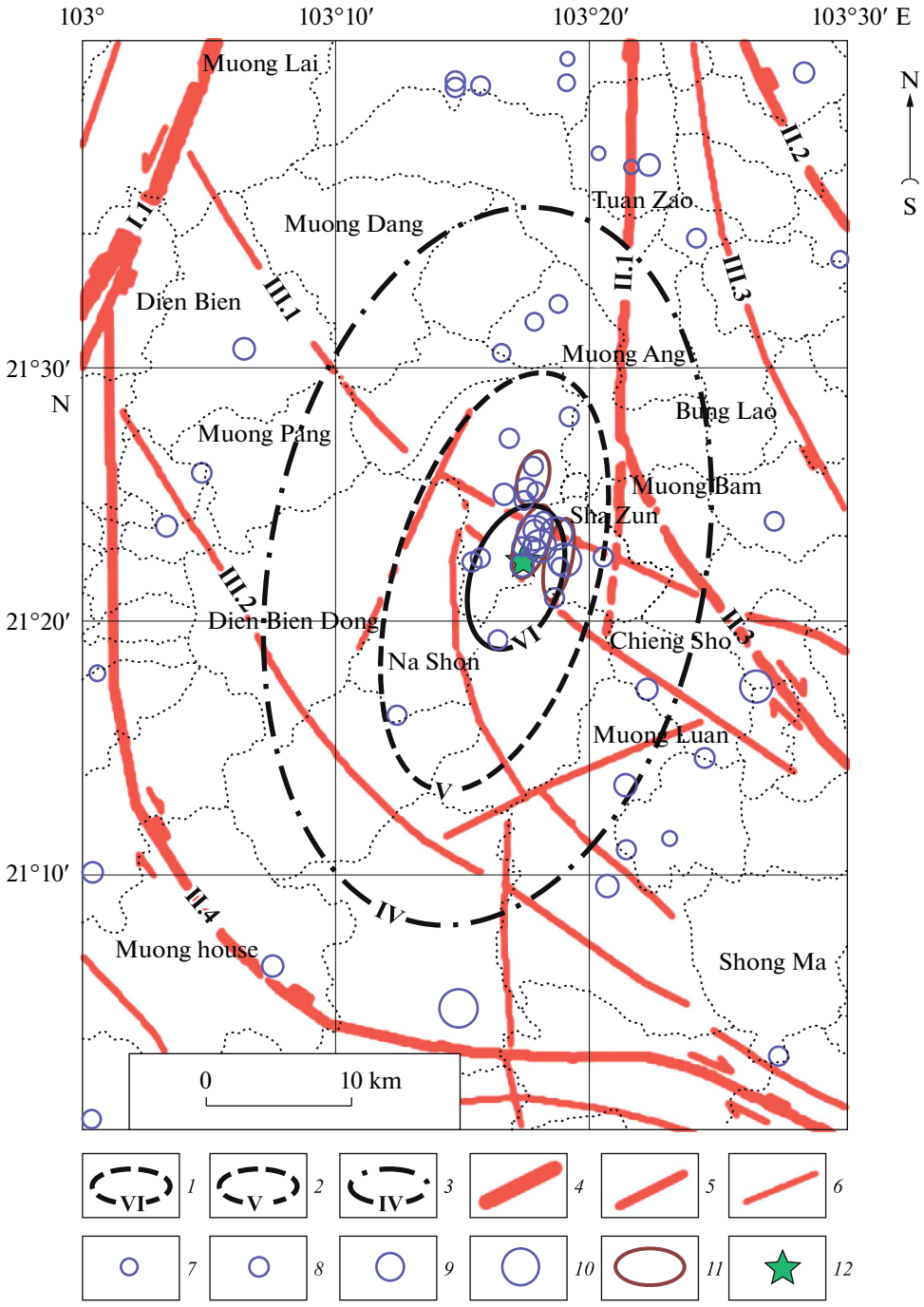

Fig. 3. Spatial distribution of foreshocks and aftershocks of January 8, 2018, Muong Ang earthquake. For legend see Fig. 2.

Sha Zung Ban. Then aftershock activity gradually migrated north and northeast. The third stage comprises aftershocks that migrated south, as opposed to the events of the previous stages. This confirms that the Tuan Zao and other faults in this region are active. It can therefore be suggested that the Tuan Zao fault extends rather far south to the Chieng Sho District, instead of terminating in the Sha Zung and Muong Ban Districts, as shown on modern tectonic maps.

FUNDING

The study was carried out under a state-financed project of Schmidt Institute of Physics of the Earth, Russian Acad-

emy of Sciences (project no. 0144-2019-0011), and was supported by the Vietnam Academy of Sciences and Technologies (project NVCC12.01/19-19).

CONFLICT OF INTERESTS

The authors declare they have no conflict of interest.

REFERENCES

Burmin, V.Yu., Ngo Thi Lu, and Tran Viet Phuong, Estimation of efficiency of the modern and planning optimal network of seismic stations within the Vietnam territory, *Seism. Instrum.*, 2010, vol. 46, no. 1, pp. 27–37.

Burmin, V.Yu., Ngo Thi Lu, Phung Thi Thu Hang, and Le Quang Khoi, Estimating the efficiency of the new seismic network in Vietnam, *Seism. Instrum.*, 2018, vol. 54, no. 3, pp. 281–292.

Kondorskaya, N.V. and Ngo Thi Ly, Determination of basic source parameters in North Vietnamese earthquakes, *Phys. Solid Earth*, 1994, vol. 30, no. 4, pp. 349–353.

Le Van Zung et al., *Investigation into The Issue about Deployment of a Seismic Monitoring Network and Assessment of Local Effects of Earthquakes Triggered by Reservoirs of the Song Da Hydroelectric Power Stations: Project Report*, 2018 (in Vietnamese). Available from the Institute of Geophysics, Academy of Sciences and Technologies, Hanoi, Vietnam, Code ĐTĐLCN.27/15.

Medvedev, S.V., Shponkhoier, V., and Karnik, V., *Shkala seismicheskoi intensivnosti MSK-64* (MSK-64 Scale of Seismic Intensity), Moscow: Mezhduved. Geofiz. Kom. Akad. Nauk SSSR, 1965.

Ngo Thi Lu, Kinematic and dynamic parameters of earthquake sources in North Vietnam, *Cand. Sci. (Phys.-Math.) Dissertation*, Moscow: Inst. Phys. Solid Earth Acad. Sci. USSR, 1990.

Ngo Thi Lu, Strong earthquakes on the territory Southeast Asia and peculiarities in their manifestation, *J. Earthquake Predict. Res.*, 1998, vol. 7, pp. 170–185.

Ngo Thi Lu, Seismicity peculiarities and main characteristics of earthquake sources in Southeast Asia from the perspective of revealing new tectonic structures, *Doctoral (Phys.-Math.) Dissertation*, Moscow: Inst. Phys. Solid Earth Russ. Acad. Sci., 1999.

Ngo Thi Lu, Strong earthquakes and features of tectonic activities in Southeast Asia region, *J. Geol., Ser. B*, 2003, no. 22, pp. 54–60.

Ngo Thi Lu, Features of activities of the Andaman-Nicobar earthquake and tsunami 26.12.2004 and aftershock sequence, *J. Geol., Ser. A*, 2005, no. 286, pp. 1–10.

Ngo Thi Lu and Nguyen Quang, Large earthquakes in SE Asia in 1970–1993, *Volcanol. Seismol.*, 1997, vol. 19, pp. 235–246.

Ngo Thi Lu, Gatinskii, Yu.G., and Kondorskaya, N.V., Seismicity and recent geokinematics of Southeastern Asia, *Dokl. Earth Sci.*, 2000, vol. 374, no. 7, pp. 1153–1157.

Ngo Thi Lu, Le Van Dung, Nguyen Huu Tuyen, Vo Le Nam, and Tran Viet Phuong, Seismicity on the Vietnamese territory and adjacent regions during the period 1137–2008 ($M \geq 3.5$), *J. Geol., Ser. B*, 2010, no. 35–36, pp. 99–110.

Nguyen Ngok Thi et al., *Report on Zoning and Detailed Earthquake Forecast for Northwestern Vietnam: Report on Government Project KS-08-10*, 2005 (in Vietnamese). Available from the Institute of Geophysics, Academy of Sciences and Technologies, Hanoi, Vietnam.

Translated by B. Shubik