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Research Article

Active Tectonic Features of Muong Te Zone from Geomophological Indicators

Nguyen Huu Tuyen[1, 2, *], Phung Thi Thu Hang[1]

[1]Tectonophysics Department -Institute of Geophysics (IGP), Vietnam Academy of Science and Technology (VAST), Hanoi, Vietnam

[2]The Earth's Science Faculty- Graduate University of Science and Technology (GUST), Vietnam Academy of Science and Technology (VAST), Hanoi, Vietnam

Abstract

The Muong Te fault zone is known as the active tectonic area in Northwest Vietnam, proved by earthquakes with the most recent one of Ms 4.9 on June 16, 2020 and hundreds of aftershocks accompanying with landslides. The neotectonic activities of the study area is asssessed by analysing 61 sub-basins in term of geomorphological indices: Ratio of valley floor width to valley height (V_f), Stream-Length gradient index (SL), Hypsometric integral index (HI), Hypsometric curve (HC) and Index of Relative Active Tectonics (IRAT). As a results, this are has: relative lowV_f corresponding to the terrain of V-shape valleys; SL in large range from 10 to 7000 (gradient - m); straight – convex H ccurve and HI in the range of 0,422 – 0,51 corresponding to the developing phase of river basins; More than 50% of asymmetric basins (AF) due to tectonic impacts. IRAT ranging from 1.25 to 2.5 divided into 3 classes according to the tectonic levels: (1) – strong uplift with - IRAT ≤ 1.5, (2) moderate uplift with IRAT from 1.5 to 2.0 (strong) and (3) weak uplift with IRAT more than 2. The calculated values of the indices are seemed very consistent with the tectonic-geological features of the Muong Te area.

Keywords

Neotectonics, Geomorphological Indices, Morphotectonics, Muong Te, Song Da

1. Introduction

Muong Te area, located in the northwest part of the northwestern Vietnam, chracterized by a relatively complex topography of high terrain elevation, strongly deep dissection and strong differentiation. Generally, this is a mountain range in NW-SE direction, controlled by a fault system of the same direction, including; Thuong Song Da, Muong Te and Muong Nhe - Muong Toong faults. These faults have formed asubsidence structure with strong variation of height. The central part is very clear of the depressive state area that creat an axis with a gradually southeastward decrease in height [1, 2, 4, 10-12, 18, 20, 21]. Complex tectonic characteristics in accompanying with rather high of regional seismic activity have shown the active neotectonic state of the studied area (Figure 1).

In this paper, the authors determine the neotectonic characteristics in Muong T è area through the analysis of the geomorphological tectonic indicators. This morphotectonic indices are principally applied in study of regional tectonics,

*Corresponding author: geosolary@yahoo.com (Nguyen Huu Tuyen)

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neotectonics and seismotectonics. Applying the quantitative analysis of geomorphological indicators are fruitful method in determining active tectonic because of their close relationships which are accociated with the present relief and tectonic deformation processes [1, 3, 5-8, 13, 16-23]. The geomorphological indices reflect tectonic regime of the region through the characteristics of topography relief, geomorphological deformation and the shape of basins. In this study, these indices are calculated in detail for Muong Te area which covers mainly whole the hydrological system of the Song Da basins. The calculated data are integrated and classified according to the dominant degree of tectonic activities. Since then, the Muong Te geomorphology is clearly expressed in associating with determination of involved active tectonics implication.

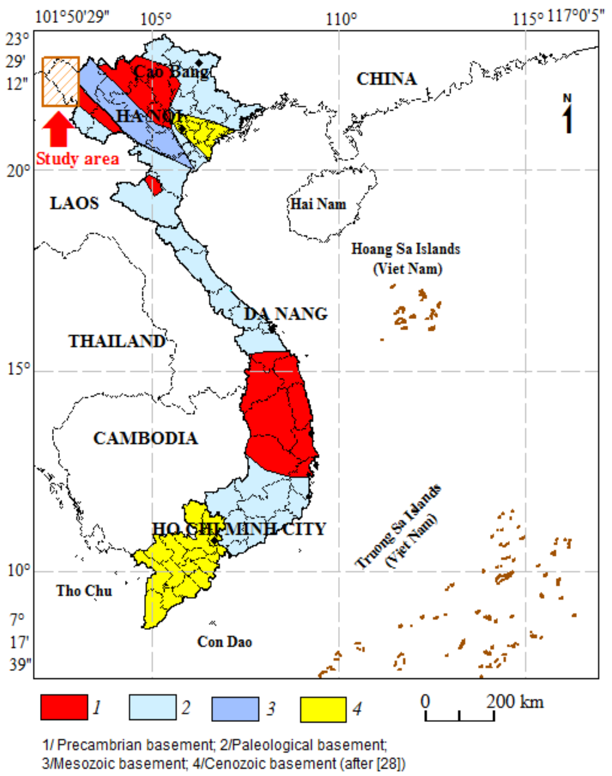


Figure 1*. The studied area (after [28]).*

2. Methodology

In this article, in order to clarify the neotectonic characteristics of Muong Te region, a number of geomorphological indicators are computed and analyzed for all hydrological systems of the Song Da basin. In general, the ArcGIS technology is applied for calculation, analyzing and mapping (*the Arcmap tool, Map Info software, Global Mapper*) with the following input data: DEM (*Digital Elevation Model*) made from SRTM (*Shuttle Radar Topography Mission*) with high resolution of 30m; Geological map (*at scale of 1/200.000*), Topographic map (*at scale 1/250.000*) and other relevant data of hot springs, earthquake catalogue, geophysical fields (*gravity, magnetic, magnetoluic*)…

The calculated and analyzed indicators include: the V_f index -*Ratio of valley floor width to valley height;* the SL - *Stream Length gradient index*; the AF - *Asymmetry of drainage factor*; the HC- *Hypsometric Curve;* and HI index - *Hypsometric Integral index*. Those above geomorphological indicators are widely applied in studying about regional and active tectonics [1, 3, 10, 17].

2.1. The Valley Index (V_f)

These parameters (Eq.1) should be computed at a certain distance from the mountain front for each valley. This ratio reflects the deep cutting level of the intrusion activity (*the height difference of the topography between the top and bottom of the valley*), therefore the ratio is used to assess the deep cutting process of the valley and the uplifted area and subsidence area [9-11]. The low values of V_f indicate deep valleys with rivers that are actively entrenching which are generally associated with uplifted process. In other word, the smaller the value of V_f the more positive the speed of the region is. In order to determine the state of tectonic regime of a region such as Muong Te, there for the total computation of V_f values carried out according to the Song Da Hydrological System, then the general values of V_f imply state of active tectonic.

Where V_f is the width/height ratio of valley, which can be expressed as follows:

$$V_f = \frac{2V_{fw}}{(E_{ld}-E_{sc})+(E_{rd}-E_{sc})} \quad (1)$$

In which: V_{fw} *– is the width of valley bottom;* E_{ld} *and* E_{rd} *- are the watershed boundary elevationon the left and right margin respectively;* E_{sc} *– is the elevation of the valley bottom* (Figure 2).

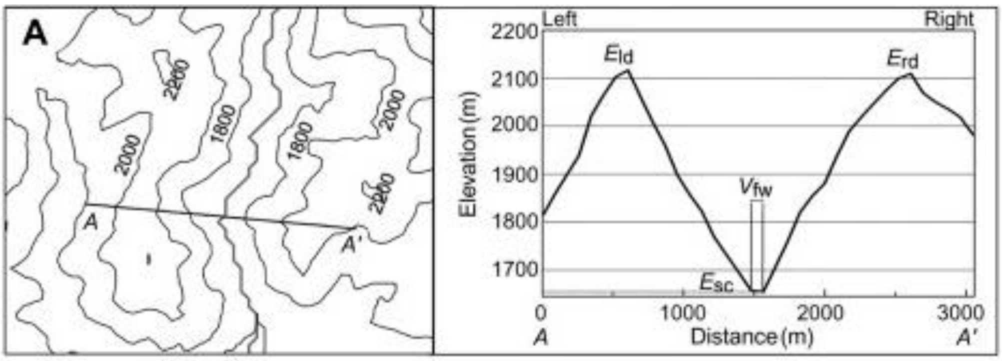


Figure 2. Schematic computation of V_f index.

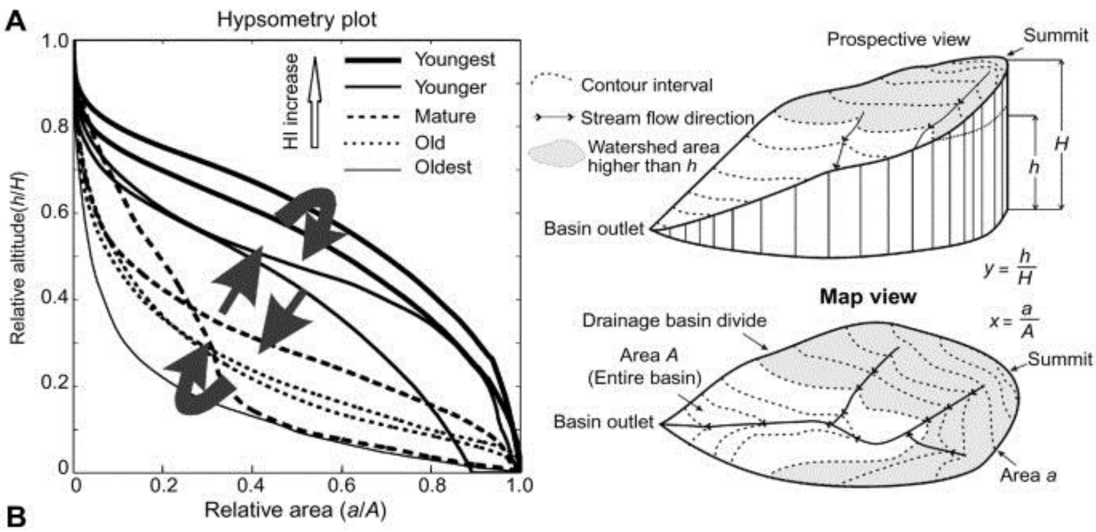


Figure 3. The Hypsometric Curve (HC) and progress of Geomorphological process in correlation with the Hypsometric Curve development, after [9, 11, 12].

In which: HI is a high measurement integral; Hmax is the highest height value; Hmin is the smallest height value and Hmean is the average height value.

2.2. Hypsometric Curve (HC) and Hypsometric Integral (HI)

The HC curve and HI index are very useful tools to determine the development stages of the river basin. Hypsometric analysis aims at developing a relationship between horizontal cross-sectional area of the water-shed and its elevation in a dimensionless form. Hypsometric curve isobtained by plotting the relative area along the abscissa and relative elevation along the ordinate. The relative area is obtained as a ratio of the area above a particular contour to the total area of the watershed encompassing the outlet. The plotted hypsometric curves are best fitted with a trend line to represent an equation of the curve having highest coefficient of determination (R^2) value. The equation was further integrated within the limits of 0 to 1 (due to the non-dimensional nature of the graph) for estimating the area under the curve. If the curve diagram of HC is convex that represents a relatively young terrain feature; The curve diagram of HC has an “S” shape that characterizes relatively eroded areas and when the curve diagram of HC is concave shaped that characteristic of the relatively old stream region.

The hypsometric integral (HI) (Eq. 2) has been used to explain the stages of landscape evolution and erosional processes. It is an important tool to investigate tectonics and lithological and climatic effects on topographic change. The HI distribution does not show clear spatial patterns of high and low HI values. However, when statistical methods of local indices of spatial autocorrelation were applied, it was possible to identify clear clusters of high and low HI values. Trend surface analysis is carried out to distinguish areas with anomalously high and low elevations, and to observe their spatial correlation with the HI and regional geological structures. The results indicated that the high HI values correlated with the areas of high tectonic activity and along the regional structures [1, 5, 14].

$$HI = \frac{H_{mean} - H_{min}}{H_{max} - H_{min}} \quad (2)$$

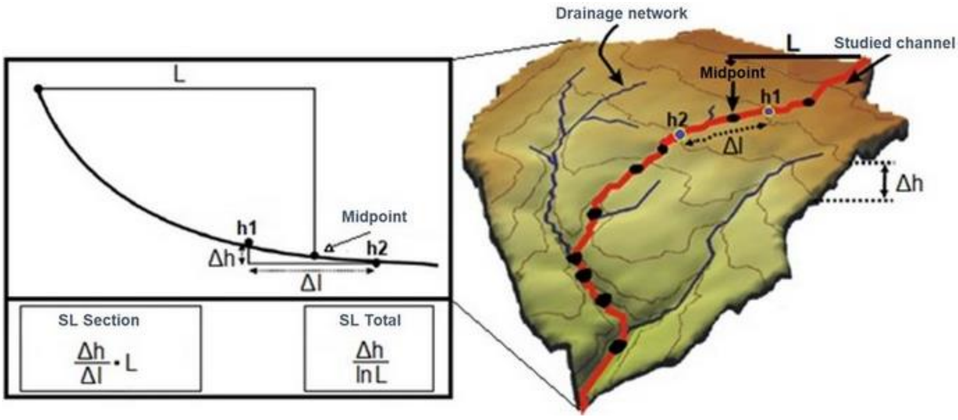
2.3. Spatial Analysis of Stream Length-Gradient Index (SL)

Among the geomorphic indices, the SL (Eq. 3) represents a practical tool to highlight anomalous changes in river gradients. The perturbations of SL are usually indicative of (1) differences in the resistance of outcropping-lithological units to erosion, (2) sub-surface processes, such as active faulting, and (3) slope failures that directly reach the stream channels, particularly in small catchments.

$$SL = (\Delta H|\Delta L)L \quad (3)$$

Where: *SL is the flow length gradient index; ΔH/ΔL is the slope of the flow on the segment ΔL or the gradient (ΔH is the change in the height of the flow section ΔL), L is the length of the flow, calculated from the highest point of the line flows to the point of calculating the SL value.*

The SL index relates to the energy of flow and the sensitivity to changes in slope of streams valley. It is this sensitivity that allows to assess the relationship between tectonic activity in correlation with rock strength and regional topography.



Stream length index along stream (*On the left*) / Watersheds objects needed for SL processing (*On the right*) [after Hack, 1973].

Figure 4. *Measurement of SL.*

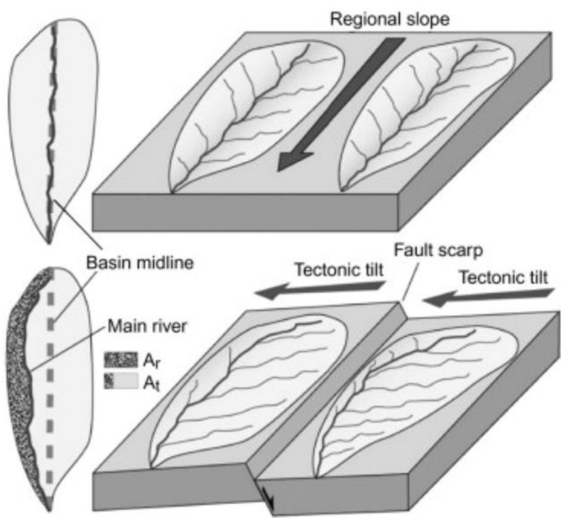


Figure 5. *Sketch of The asymmetry of drainage.*

2.4. The Asymmetry of Drainage Factor (AF)

To make this investigation it is necessary to analyze in detail the relationship between the intensity of erosional processes and the asymmetry running along both sides of the basin. The basin was divided into relatively small sectors that segmented the main axis of the basin, from the outlet to the most distant point of the head-stream, into segments all of 700 m length. Starting from the sides of each segment, lines were created perpendicular to the mainaxis of the basin, terminating at the left and the right watersheds of the basin. The perpendicular lines created start from the beginning and end of each segment and then enclose a sector.

$$AFs = 100(A_r/A_t) \quad (4)$$

Where: *Ar is the area on the hydrographic right and at is the total area of the sector.*

The AFs of each sector were plotted against distance along the river basin

The asymmetric factor is considered to determine the tectonic direction of each position and the area of the drainage basins. Geometric characteristics of river and stream networks often show the presence of tectonic deformation: The rivers and streams that have formed and continue to flow in stable conditions with AF values is in the range of fluctuation 50; The drainage basin is inclined to the left flank if the AF value is large then 50 and the flows are more concentrated in the right side; The drainage tank is inclined to the right flank if the AF value is less than 50 and the currents flows are more concentrated in the left flank.

2.5. The Index of Relative Active Tectonic (IRAT)

From the results of 5 geomorphological indexes are decentralized depending on the degree of sensitivity to tectonic activities of each area. We apply the method of IRAT [1, 6, 9, 11, 14, 17], in which, each index is divided into 3 to 6 levels depending on the each index and the level of modern tectonic activity of the area, the level decreases (i.e.first level is the most active). Since then, the strong tectonic movements is match up with the lower level (the first level) and the higher the level is the more tectonic activity reduced (i.e. the higher level - sixth). Then the matrix is set up to evaluate the correlation between the geomorphological indicators where the (IRAT) value is the average value of the level of those indicators. Finally the IRAT conducts the geomorphological tectonic characteristics and assess the nature of tectonic activity of studied area.

3. The Main Characteristics of Muong Te Region

3.1. Introduction to Geotectonic-Geomorphology of Muong Te

On remote sensing image and Digital Elevation Model (DEM) of terrain, Muong Te area can be regconized by a very clear separation on topography which formed the by high topography in the northern part and sharptly elevated relief caused tectonic movement (*Figure 6*). The main structure region is expressed in dome shape with the elevational amplitude reached approximatly 3.3 km in the northern-part, southwardly descending to less than 2.3 km. Going along the Thuong-Song Da valley, there is a system of small basins which are filled up with Quaternary sediments mainly of alluvia, proluvia. The south of Muong Te area has a slightly moderate uplift with an elevational amplitude lower than 1.8 km, interspersing with the uplift zones of NW-SE horst strutures having an elevation from 2.3 km to nearly 3.0 km (such as the Phu Den Dinh mountainous range). The above mentioned uplifted range gradually changes into the meridian direction as getting close to the main fault of Lai Chau-Dien Bien (LC-DB) with the elevated amplitude of 2.3 km which formed some of differentiate scattering domes in the smaller scale [2, 4, 13, 18, 20-29].

The main faults system in Muong Te region develope in the Northwest - Southeast direction except the deep seated LC-DB fault in meridian direction. In which, the LC-DB is a deep-seated fault, playing an important boundary in the structure of Southeast Asia. The N–S-trending LC-DB Fault Zone is located in northwestern Vietnam, extending about 500 km in length between China through Vietnam and Laos. The movement of this fault has caused a deformation of the crust and a large destruction zone in the Dien Bien Basin [4]. Besides the LC-DB Fault Zone, the width of the deformation zone also depends on the NW–SE-trending faults observed in the study area. Movement along these two structural zones has created a large deformation.

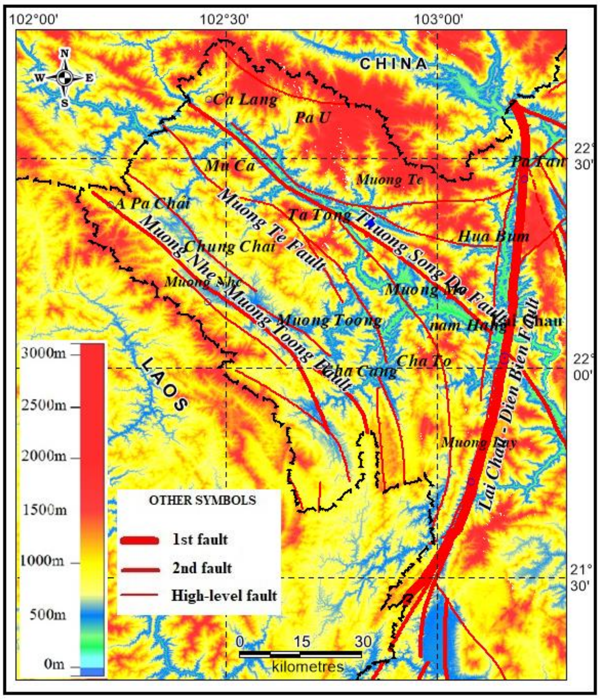


Figure 6. The Digital Elevation Modal (DEM) of Muong Te and adjacent area.

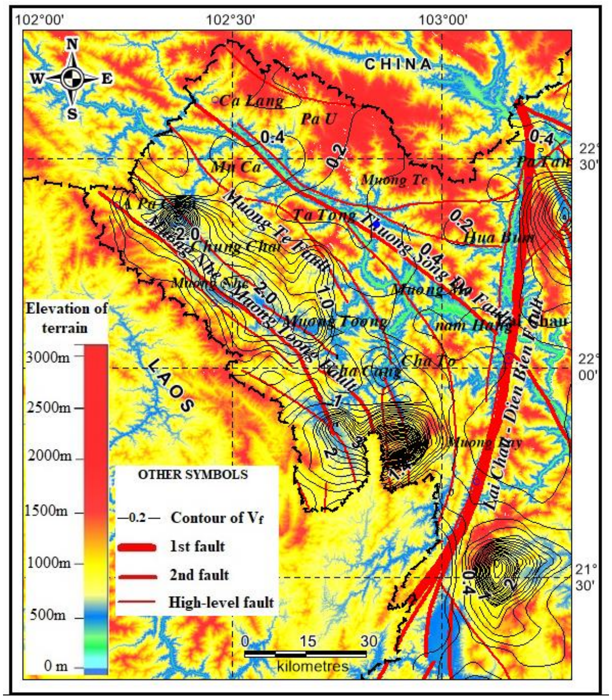


Figure 7. The sketch distribution of V_f values in Muong Te area.

The current tectonic activity of LC-DB fault is expressed in a many ways, but the most importantly by the earthquakes and the formation of Quaternary subsidence structures. The degree of active deformation of the LC-DB Fault Zone is clearly shown in the geological formations distributed along this zone. During the Cenozoic tectonic activity resulted in two main phases of deformation [4, 10-12, 23]: (a) the Oligocene–Miocene phase and (b) the late Pliocene–Quaternary phase. The Oligocene–Miocene phase was subjected to tectonic compressive forces oriented in sub-parallel direction with the maximum compressive axis σ1. Due to the impacted by this force, the deep seteed faults splays in NW–SE direction that moved sinistrally and oriented in a sub-parallel trend with the latitudinal dextral fault. Different movements of these faults systems resulted in compressing and separating the blocks. Along the faults, the geological formations were broken, forming the shear zones in different scales, the late Pliocene–Quaternary phase was impacted by tectonic forces with maximum stress direction oriented sub-parallel to the compressive axis. The largest left-lateral displacement along the LC-DB is approximately 12.5 km which records the entire fault movements in the later left-lateral phase with the probable age of the onset of sinistral motion (≈ 5 Ma), since the longterm slip rate of LC-DB from the Pliocene up to the present estimated approximately of 2.5 mm/yr [22]. Along the faults, deep NW–SE-oriented structures moved dextrally and the subparallel faults moved sinistrally, resulting in formation of the compressed/crushed areas. The interaction also formed the basin which filled up with Quaternary sediments of slight consolidation and high efficient porosity [22].

The Thuong Song Da is also another deep fault zone, elongated in NW-SE direction, which cut throught out the core of Muong Te anticline complex. This fault zone is clearly detected on satellite images and present terrain. In addition, the its current activity is expressed by a series of earthquake activities for years. The major fault in the study area is the Muong Nhe - Muong Toong fault zones, consisting of 2 parallel faults in NW-SE direction: Muong Nhe and Muong Toong. In general, Muong Te is an area of relatively high seismicity in Vietnam.

3.2. The Neotectonic Features of Muong Te from Analyzing Geomorphological Indicators

3.2.1. The Ratio of V_f

The value of V_f in Muong Te area is relatively low ranging from 0.07 to 8.475. The value V_f <0.5 accounts for 60% of the total 179 points of V_f; There are only 11 points with V_f > 2.0. The low values V_f is concentrated in the northern basins (basin 1 to basin 19). High values are concentrated in the southern basins from Muong Nhe to Muong Lay. In the left area of Song Da basin (from Ca Lang to Muong Te) the branch valleys have a low value in the range of 0.07 - 0.3. The V_f values gradually increases towards the right of Song Da, especially in the area from Muong Nhe to Muong Lay. The highest concentration is found in the tributaries of the branches numbers 49 and 61. It can be seen that in the right part of the basin, the hydrological system developes extensively in accompanying with the strong development of the Middle valley terrain. In contrast, the Muong Te branch basins developed the complex terrain which strongly separated with the typical V-shaped valley. It is notable that the V-shaped valleys correspond to areas with low V_f values, and the wider or U-shapes valleys do the higher V_f value.

It can be clearly observed that the high V_f values fall in the sub-basins having the same NW-SE direction with Muong Nhe fault zone (*Figure 7*). On the structure plan of the area, there is a range of low basin system - grabens, alternated with relative uplifts of Pusilung and Muong Toong.

Based on V_f values, the basins could be divided into 3 classes with descending influence of tectonic activity as follows: class 1 (V_f = 0.07 - 0.5), class 2 (V_f = 0.51 – 1.0), class 3 (V_f > 1.0) (*Figure 8*).

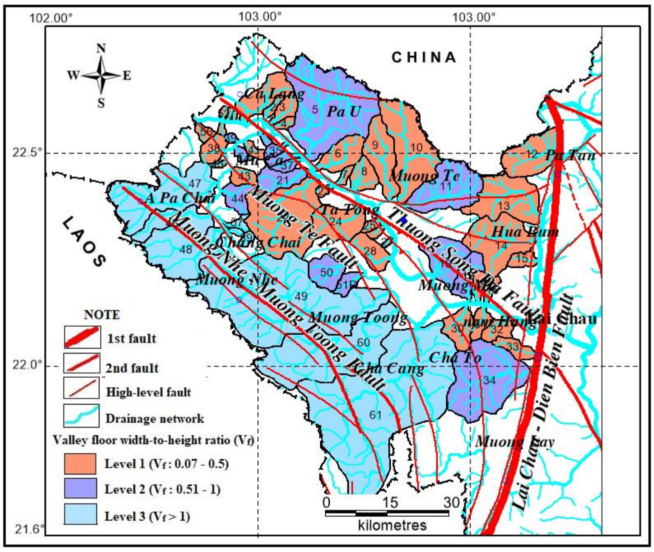


Figure 8. *The sketch distribution of V_f along the Sub-basin of the Song Da (Muong Te area).*

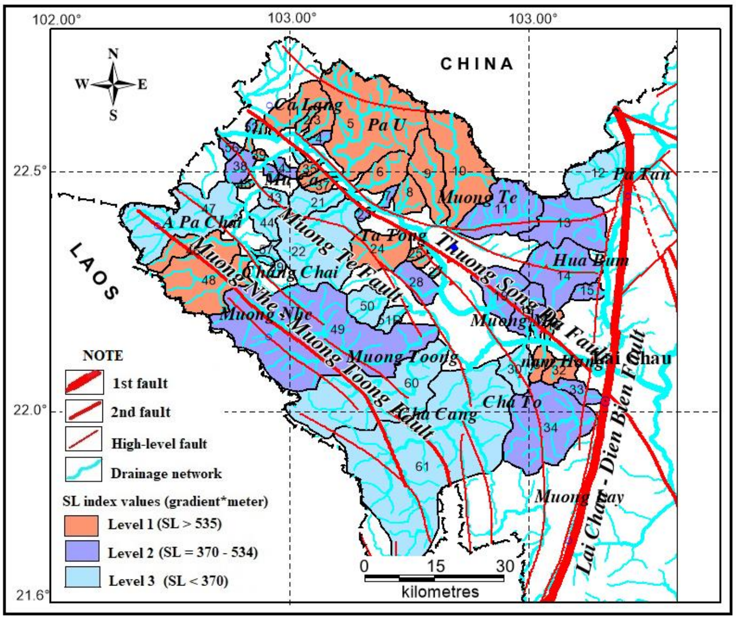


Figure 9. *The values of SL index computed for whole separate basins in Muong Te area.*

3.2.2. The Stream Length-Gradient Indicator (SL)

In the study area, the SL calculation from 847 points in the sub-basins of the Song Da basin with a height interval of 100m (ΔH = 100m) gives the values in range from 10 to 7000 (gradient - meters), the average value of the basins from 118.89 (sub-basin 58) to 843.01 (sub-basin 25). The standard average SL values of branch basins are divided into 3 classes according to the gradual tectonic activity level: class 1 (SL> 535), class 2 (SL = 370-534), class 3 (SL <370) [1, 9] (*Figure 9*). The results of this classification shows that, class 1 with high SL index, mainly concentrated in the left part Song Da basin (Muong Te area), is quite consistent with the topographic features of steep terrain.

However, the SL values also depend on the strength of rock. The north of the study area is intruded by granodiorite complexes of Dien Bien (δ- γP_{3}*đb*), followed by Paleozoic sedimentary and metamorphicrocks mainly components of schist, quartzite sandstones and thin layers of limestones in flysch structures (Nam Cuoi formation), overlaid in somewhere by late Paleozoic carbonate sediments [2, 20]. So it can be seen that the rocks in the north of Song Da area have relative high strength. In addition, the crystallized basement in this northern area is folded and strongly deformed with a vertically uplift reaching to 3.3 km (at the center) and gradually reducing towards the "*relatively low trough*" connecting along the Lai Chau - Dien Bien faults (with the trough latitude less than 1.3 km) and Muong Te (with the trough latitude is less than 2.3 km) [18, 19].

The south of the Song Da basin of Muong Te area is covered by Late Carbonaceous - Early Triassic sedimentary rocks (Song Da and Bo Lech formation) in the area close to the main river valley and by Late Triassic terrestrial molasse (with Norian - Rhaetian coal-bearing sediments) in the others, continuously overlaid by Jurassic and Cretaceous and even Paleogene rock [20]. The geological characteristics show low strength of rocks, easily eroded by exogenous activities affection from the river lowing processes, and therefore, reflecting the extensive development of hydrological system with the low SL values in this southern area.

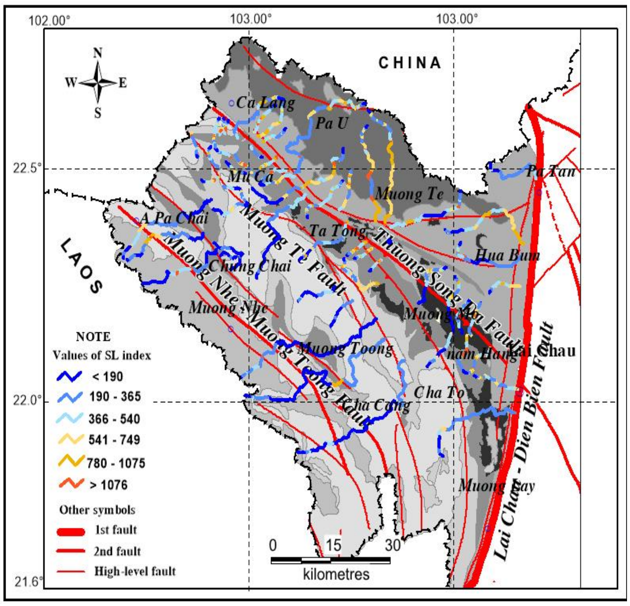


Figure 10. *The values of SL index computed for Muong Te area.*

The SL values depend on rock strength, lithologic creation and tectonic condition (*Figure 10 and Figure 11*). When the increase in SL value can be related to lithological change (between rock with high stable and low stable) or due to faults appearance which changed shartly the slope. The computed of SL values (*figure 10*) are almost adequate in comparison with the shear resistance of rocks, the faults distribution and the results of profile along the river (*figure 11*).

3.2.3. The Values of the Hypsometric Curve (HC) and the Hypsometric Integral Index (HI)

In Muong Te area, the HI values is not much differentiated and in range from 0.422 to 0.511, denoting an intermediate environment. For the Hindu Kush area (India) the HI ranging from 0.37 to 0.78 is divided into 3 classes corresponding to HC curves as follows: The 1st Class with high HI from 0.51 to 0.78 and convex HC curve, indicating the basins in young stage; The 2nd Class with intermediate HI from 0.37 to 0.50 and S-shaped curve, typical standing for the developing phase of the basin; and The 3rd Class withlow HI, less than 0.37 and concave curve, typical for the mature and developed phase of the basin [14].

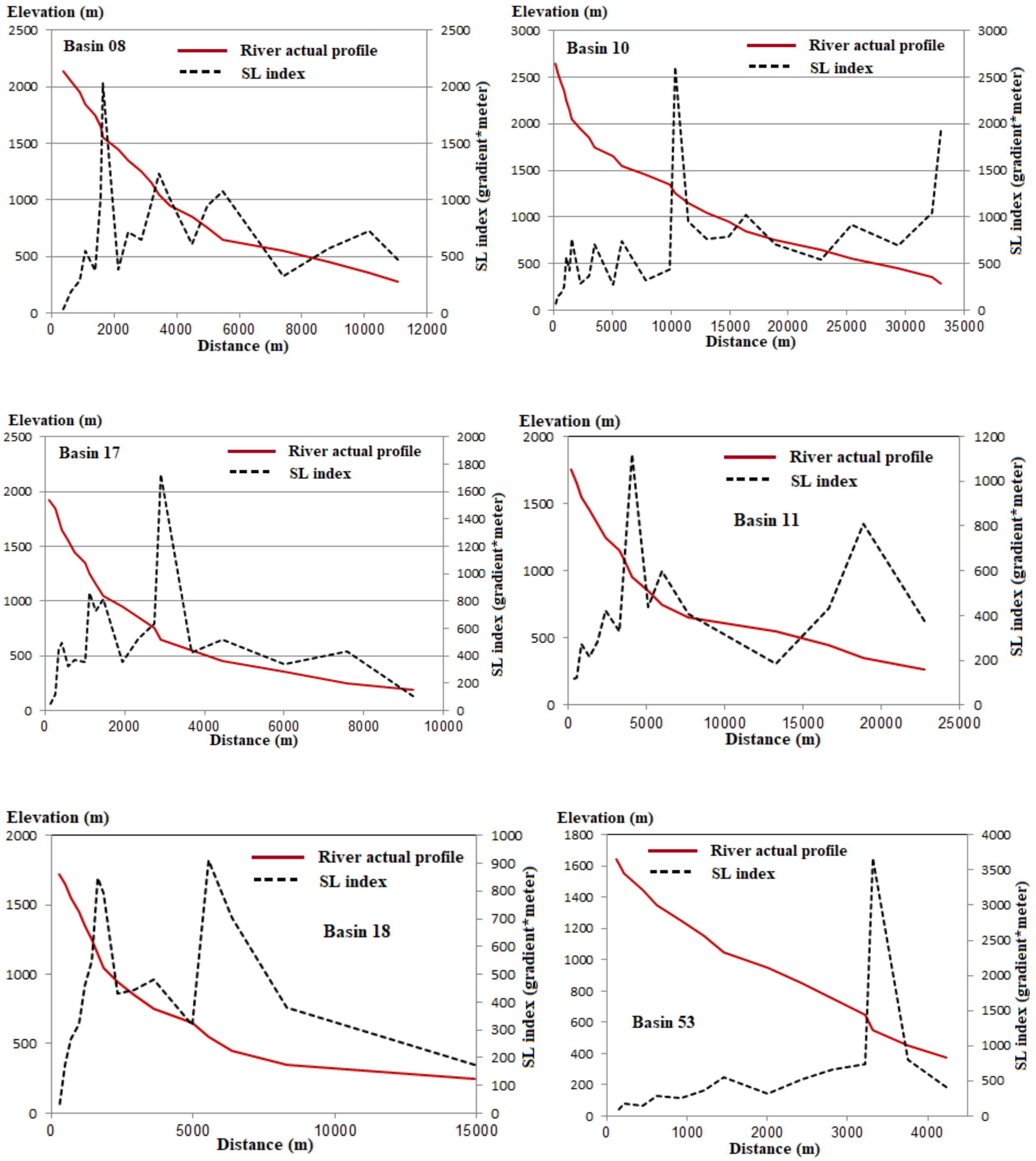


Figure 11. *The profile along the river and SL index, examples from some basins in Muong Te.*

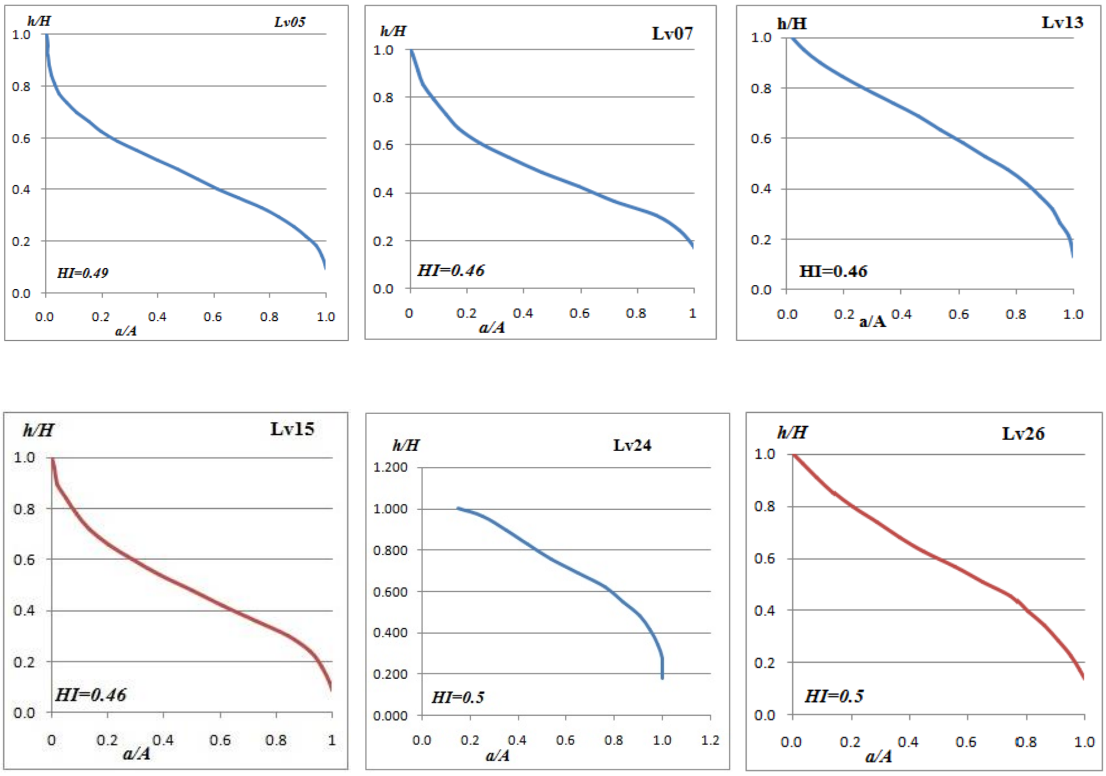


Figure 12. *The values of the hypsometric curve (HC) of separated basins a long Song Da river.*

The privious studied [1, 3, 4] shown that within such 3 classes of HI values which correspond to the specific types of HC curves: The 1th Class with HC curve is convex, high HI values describe the basins at the young stage; The 2nd Class with HC cuve is an S-shaped, this typical standing for for the developing phase of the basin; The 3th Class with HC curve is concave, low HI value and this typical for the mature and developed phase of the basin. For the Red River, Song Lo and Song Chay basins, HI is classified in 5 groups: (1) HI = 0.5 - 0.59 corresponding to convex HC curve; (2) HI = 0.4 - 0.5 with straight - convex HC curve; (3) HI = 0.3 - 0.4 with S-straight HC curve; (4) HI = 0.2 - 0.3 with S-concave HC curve; and (5) HI <0.2 with HC curve [1, 3, 4]. For the study area, HI value belongs to the intermediate group (HI = 0.422-0.511), HC curve is in straight – convex shape, meaning this part of Song Da basin is in the developing stage (*Figure 12*). Most of HC curves of the sub-basins are straight-convex, except some only convex. The HI could be divided into 3 classes in decreasing order of tectonics: (1) with HI ≥ 0.5; (2) with HI = 0.45-0, 5; and (3) with HI = 0.422-0.44.

3.2.4. Asymmetry of the Drainage Factor (AF)

In the study area, the AF values, calculated for all 61 sub-basins, varies from 17.76 to 76.74, separated into 2 groups: (1) - AF > 50; and (2) - AF <50. The AF calculation shows that the Song Da sub-basinsin Muong Te area are generally asymmetric. This asymmetry may be expressed by absolute value of the difference between AF and 50, i.e. |AF-50|, ranging 0.27 to 32.24 for the study area (*Figure 14*), divided into 3 classes corresponding to the decreasing activity of tectonics: (1) -|AF-50|> 5,91; (2)- |AF-50| = 2.96 to 5.91; and (3) -|AF-50| < 2.96.

According to the calculation results, the number of asymmetric sub-basins, strongly influenced by tectonic activity, accounts for more than 50% of the total in the study area. However, the basin asymmetry characteristics is also influenced by lithological factors and exogenous processes such as erosion. The topographic relief is effected by tectonic processcess in which consists of a numerous steep mountains and hills. The slopes are formed by the tectonic process such as the faults movement that cause of the relatively displacement of the valleys to the vicinity edges. This activity leads to the inclination of the basin, directly making the river slowly moves and deviate away from the basin center.

3.2.5. Tectonic Activities from the IRAT Index

The IRAT index expressing current tectonic activities is obtained by integration of 4 geomorphologic indices (V_f, SL, HI, and AF) in following formula:

$$IRAT = S/N \tag{5}$$

Where: *S represents the sum of the previous indices, and N represents the number of selected indices [1].*

The synthetic IRAT from all 4 indicators are divided into 3 levels with a gradually decrease of tectonic activity according to the average values of each basin. The synthetic IRAT value is the average of 3 these above divided levels. In the study area, the average IRAT values ranging from 1.25 to 2.5 could be divided into 3 classes corresponding to the relative level of tectonic activity (*figure 15*): (1) - IRAT < 1.5 (active); (2) - IRAT= 1.5 to 2.0 (average), and (3) - IRAT > 2.0 (low). Generally in the north (or the left) Song Da basin in Muong Te area exhibits an active activity (*Figure 15*). The influence of tectonic activity decreases gradually from The North to the South and from Northwest to Southeast of studied area. In general, the level of current tectonics along the two sides of the Song Da main stream or along the Thuong Song Da fault zone are active area. It is moderate and weak of tectonic activities in the area along the Muong Nhe and Muong Te fault zones.

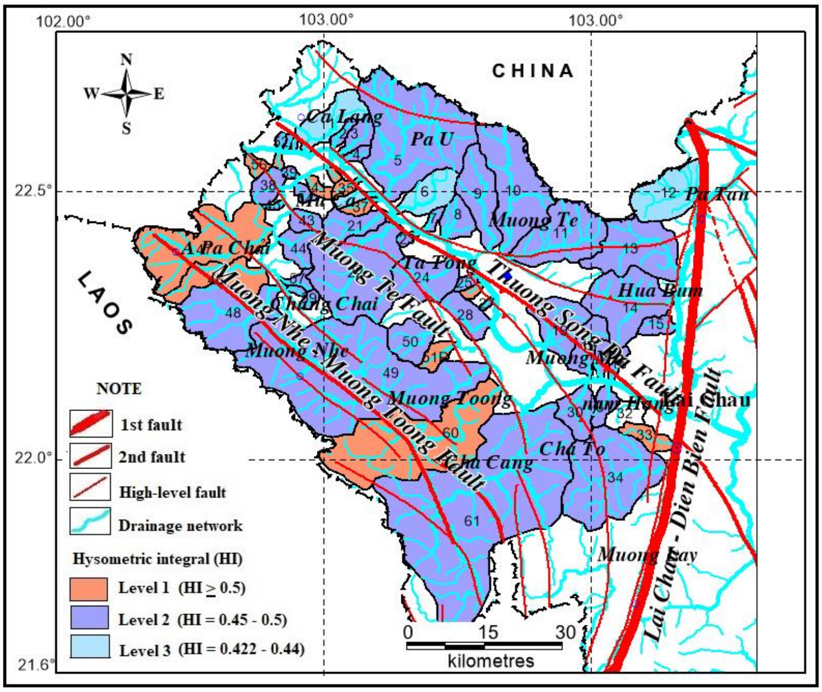


Figure 13. *Sketch of Hypsometric integral index of Song Da branch basin.*

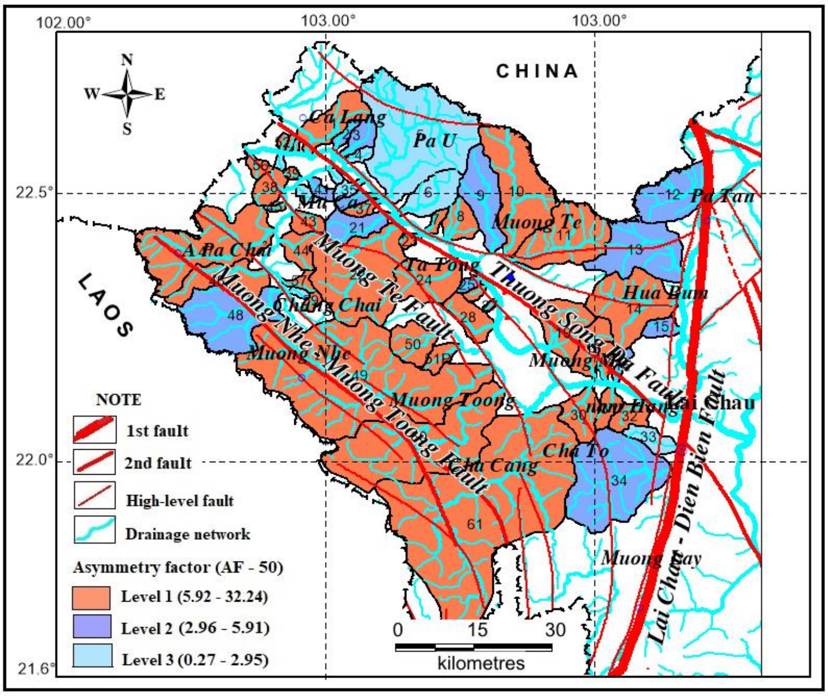


Figure 14. *Sketch of asymmetry of the drainage basin for Song Da area (values of AF-50).*

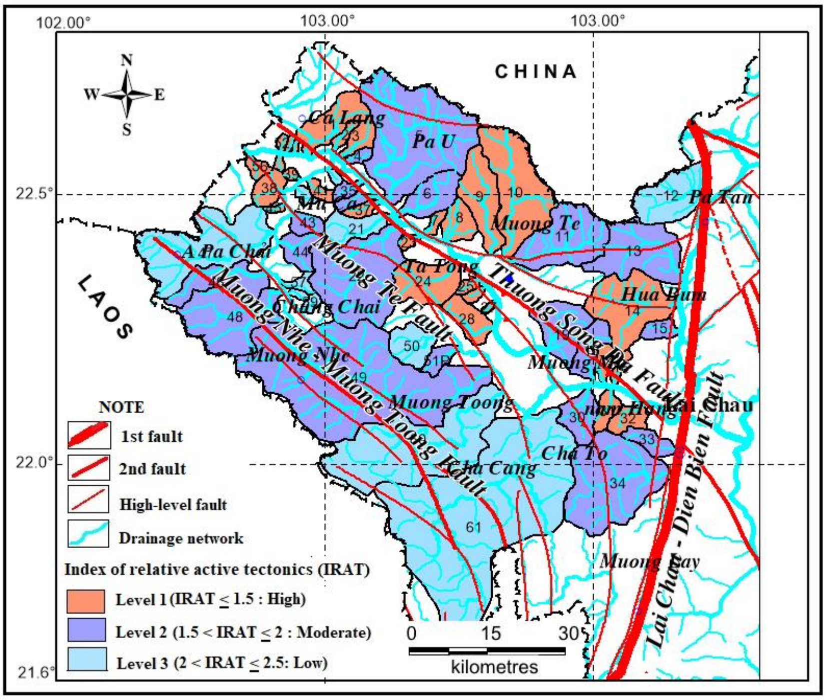


Figure 15. *The distribution of the index of Relative Active Tectonics (IRAT) In Muong Te and vicinity area.*

Table 1. *Values and classes of geomorphic indices and IRAT.*

Basin number	Class of geomorphic indices				IRAT value	IRAT class
	SL	AF	HI	V_f		
1	1	1	3	1	1.5	1
2	1	2	2	1	1.5	1
3	1	2	2	1	1.5	1
4	2	3	2	1	2	2
5	1	3	2	2	2	2
6	1	3	3	1	2	2
7	2	1	2	1	1.5	1
8	1	1	2	1	1.25	1
9	1	2	2	1	1.5	1
10	1	1	2	1	1.25	1
11	2	1	2	2	1.75	2
12	3	2	3	1	2.25	3
13	2	2	2	1	1.75	2
14	2	1	2	1	1.5	1
15	2	2	2	1	1.75	2
16	1	2	2	1	1.5	1
17	2	1	2	1	1.5	1
18	2	1	2	2	1.75	2
19	2	1	2	2	1.75	2
21	3	2	2	2	2.25	3
22	3	1	2	1	1.75	2
23	2	1	2	1	1.5	1
24	1	1	2	1	1.25	1
25	1	2	2	1	1.5	1
26	1	1	2	1	1.25	1
27	1	1	2	1	1.25	1
28	2	1	2	1	1.5	1
30	3	1	2	1	1.75	2
31	1	1	2	1	1.25	1
32	1	1	2	1	1.25	1
33	2	3	2	1	2	2
34	2	2	2	2	2	2
35	1	3	1	2	1.75	2
36	1	2	3	2	2	2
37	1	1	2	2	1.5	1
38	2	1	2	1	1.5	1
39	1	1	2	2	1.5	1

Basin number	Class of geomorphic indices				IRAT value	IRAT class
	SL	AF	HI	V_f		
40	3	3	2	2	2.5	3
41	2	2	1	1	1.5	1
42	2	3	2	2	2.25	3
43	3	1	2	1	1.75	2
44	3	1	2	2	2	2
45	1	1	2	1	1.25	1
46	1	1	2	3	1.75	2
47	3	1	2	3	2.25	3
48	1	2	2	3	2	2
49	2	1	2	3	2	2
50	3	1	2	3	2.25	3
51	3	1	1	2	1.75	2
52	2	1	2	1	1.5	1
53	1	1	2	1	1.25	1
54	1	1	2	1	1.25	1
55	1	3	1	1	1.5	1
56	2	1	2	1	1.5	1
57	3	1	2	3	2.25	3
58	3	3	2	2	2.5	3
59	3	1	2	3	2.25	3
60	3	1	2	3	2.25	3
61	3	1	2	3	2.25	3

4. Conclusion

Analyzing morphotectonic indicators allows to clarify some tectonic features in Muong Te area. Their current tectonic activities are expressed by these indicators as follows:

1) The V_f value is relatively low, ranging from 0.07 to 8.475, V_f value <0.5 accounts for 60% of the total.
2) The SL values vary greatly from 10 - 700 (gradient - m) and their average value of basins ranges from 118.89 to 843.01.
3) HC and HI analyses show straight – convex, corresponding to the developing phase of river basins.
4) AF values show the asymmetric characteristics of the Song Da sub-basins in Muong Te area are asymmetric.

The IRAT, averaging four above indices (Vf, SL, AF and HI), reflects the differentiation of activetectonic influences on the present relief. Based on geomorphological indicators, the Thuong Song Da fault zone is more active; and the Muong Te and Muong Nhe faults are rather less active. The morphotectonic indices have not been fully computed, but the previous works have proved a left movement approximately 12.5 km (*during 5 Ma*) with slip rate approximately 2.5 mm/yr (*from the Pliocene up to the present*) along the Lai Chau - Dien Bien fault zone. Therefore this fault zone should be paid morphotectonic attentions in the future.

Abbreviations

IGP	Institute of Geophysics
VAST	Vietnam Academy of Science and Technology
GUST	Graduate University of Science and Technology
V_f	Ratio of Valley Floor width to valley height
SL	Stream-Length Gradient Index
HI	Hypsometric Integral Index
HC	Hypsometric Curve
IRAT	Index of Relative Active Tectonics
AF	Asymmetric Basins

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Conflicts of Interest

The authors declare no conflicts of interest.

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