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# INVESTIGATION AND RESEARCH OF LANDSLIDE GEOHAZARD IN NORTH-WESTERN PART OF VIETNAM FOR THE SUSTAINABLE DEVELOPMENT OF THE TERRITORY

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## Summary

The paper presents the results of investigation and research of landslide geohazard in North-Western part of Vietnam, including the following contents: the characteristics of scale, measures, distribution areas of landslides; the damages both in human life losses and in material losses caused by landslide geohazard. At the same time, the authors had defined the reasons that cause landslide geohazard in North-Western part of Vietnam.

By the results of investigation and research, the authors had established the Map of landslide in North-Western part of Vietnam. On this map the authors pointed out the danger levels of landslide occurring in various areas of North-Western part of Vietnam for the sustainable development planning of the territory.

## 1. Introduction

The natural hazards in general and the geohazards in particular all over the World are increasing more and more with higher intensity and complexity due to the global climate changes and the movements of the earth crust. During several past decades, especially in more ten years now the geohazards with large catastrophe have been occurring in man powerless in face of nature.

In Viet Nam, the geohazards are also occurring more and more with higher complexity. They have caused large damages both in human life (lives) and in social material losses.

Geohazards occur everywhere (from mountain areas to plain ones) and they may occur at any time both in day time and in night time. They are including about 20 geohazard types that belong to 4 genetic groups (by the reasons of causing geohazards). They are: endogenetic, exogenetic, artificial and combinational group. The main geohazard types are: earthquake, active fault, soil cracking, land subsidence, landslide, rock slide, land topple, rock topple, rock falling, rock dropping, rock rolling, flash flood, river bank erosion, sea bank erosion, sedimentary accumulation along river bottom and in river mouth areas, geohazard by exploiting and producing of minerals, geochemical geohazards, geohazards caused by geophysical fields,...

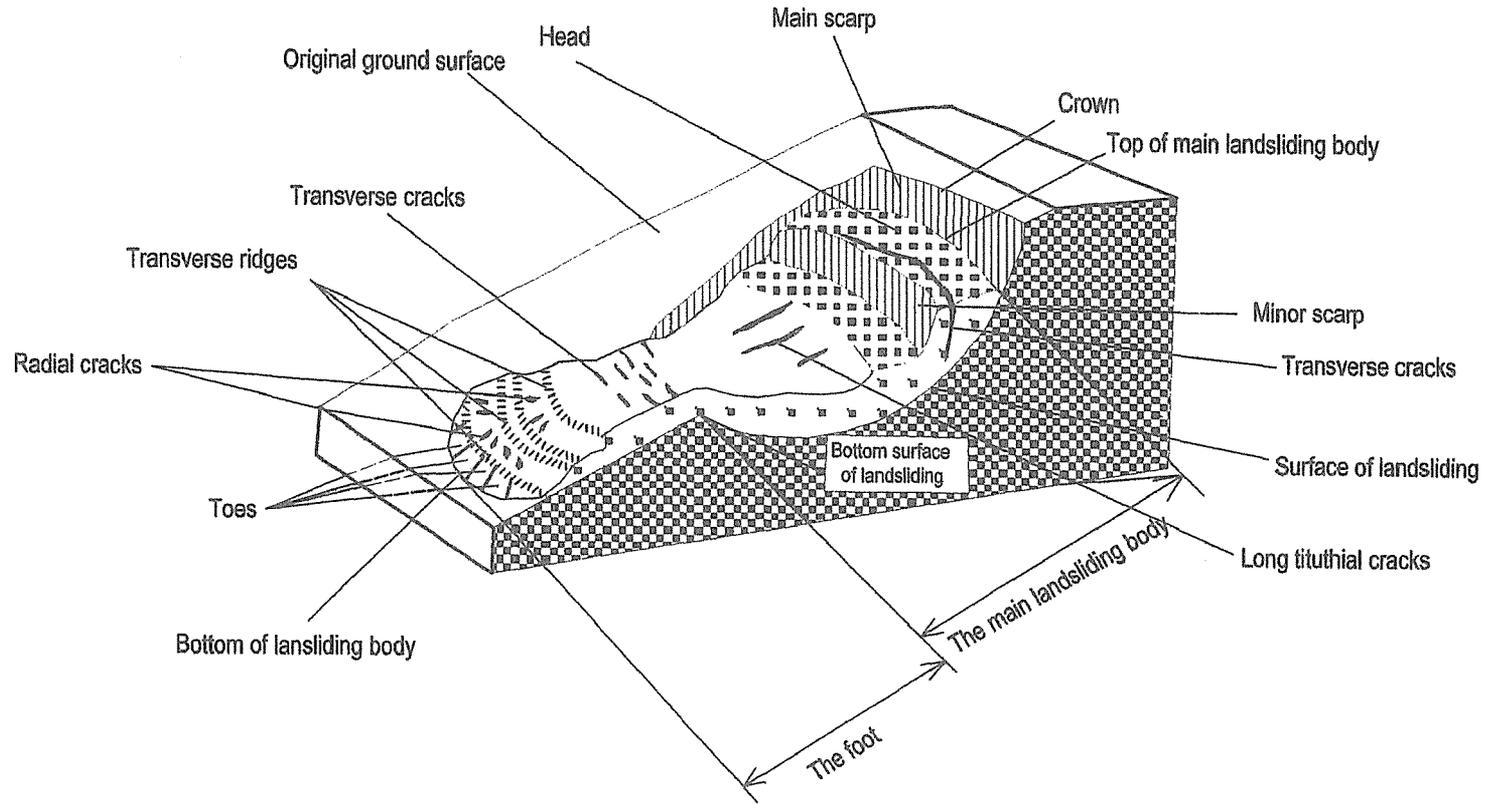
In general, North-Western part of Vietnam is in high level of geohazard danger, especially the geohazards that caused by various reasons such as: earthquake, active fault, landslide, flash flood, tube flood,... Among them, the hazards caused by landslide must be pay much attention.

## 2. The results of investigation and research of landslide geohazard in North-Western part of Vietnam

According to W. Varnes, 1978 "Landslide is the phenomena of rock and land replacing on relief surface from higher place to lower one by one definite sliding surface.

During recent years the investigation and research of landslide in N-W part of Vietnam was carried out along main roads, big rivers, in high populated areas and along tectonic faulting zone. Where landslides often occurred. The landslide points had been described according to landslide model of W. Varnes, 1978 (see, fig. N° 1).

**Fig.No-1: Block diagram of idealized complex landslides**  
(According to Varnes, 1978)



The investigation and research have brought sufficient results that may be used for planning the sustainable development of the territory.

## **2.1. General results**

The total number of the described landslide points is 772. They have different size and forms. They can be classified by dynamic regime, by sliding surface, by original material composition, by rock striking and dipping.

According to the landslide classification by Do Tuyet and others, among the above mentioned landslide points, there are 18 points of I<sup>st</sup> level of size (very big size) with body volume  $\geq 10,000\text{m}^3$ ; 144 points of II<sup>nd</sup> level of size (big size) with body volume =  $1,001-10,000\text{m}^3$ ; 148 points of III<sup>rd</sup> level of size (medium size) with body volume =  $501-1,000\text{m}^3$ ; and 391 points of IV<sup>th</sup> level of size (small size) with body volume  $< 500\text{m}^3$ .

By the results of investigation and research, the authors had established the map of landslide occurring in various areas of North-Western part of Vietnam for the sustainable development planning of the territory. This map was established on the basic of over-putting (integration) of different information layers (relief, slope, vegetation, rock types,...) by layer ration estimation and the distribution of investigated, studied landslide points (see fig. N<sup>o</sup>2).

## **2.2. Main properties of landslide hazard in North-Western part of Vietnam**

### ***a. Distribution***

The landslide points distribute everywhere. They concentrated mainly along big tectonic active fault; is such as: Dien Bien-Lai Chau; Tuan Giao-Tua Chua,... and in the areas where there is thick weathering crust.

### ***b. Occurring and influence***

Landslides happen at various speed: from very slow to very fast. The landslides caused by artificial reason often happen with low speed and small amplitude. Many landslides have the following characters:

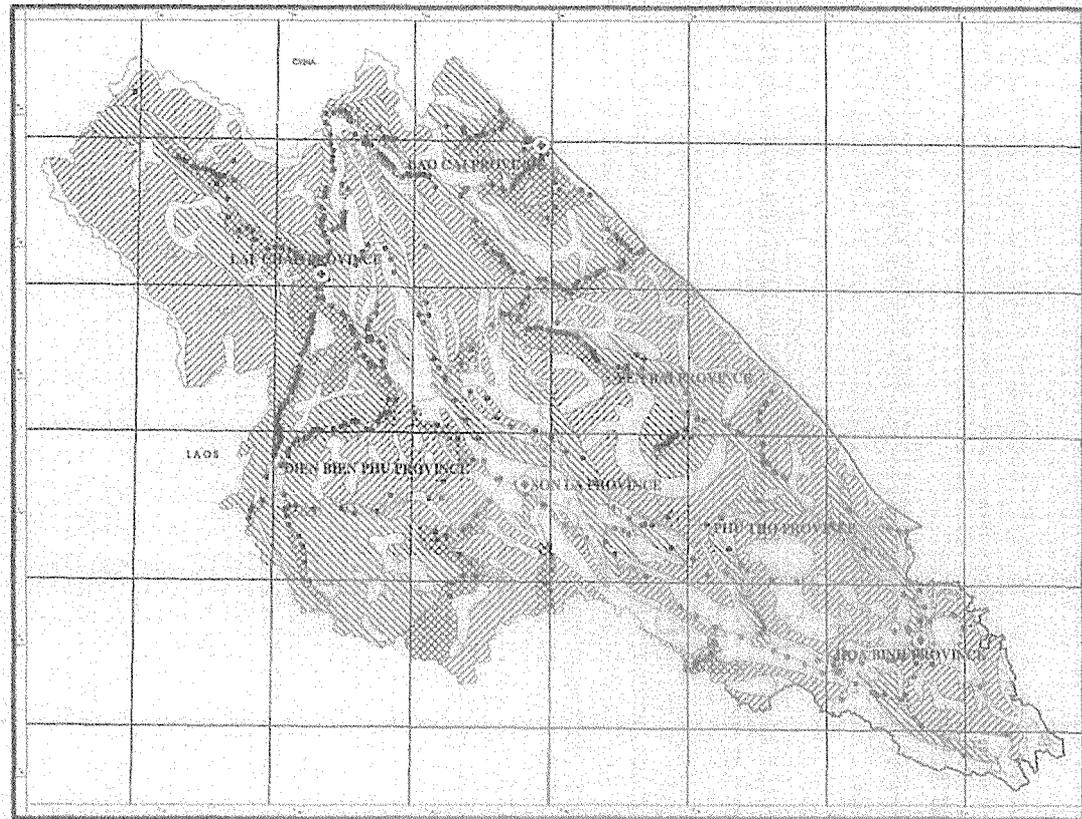
#### ***Very sudden character***

Landslides last from several seconds to 1-2 minutes. In comparison with other geohazards, landslides are the most sudden with the fast end.

#### ***Multi-time character***

In the weak geological zones, landslides happen not only in one time but they may re-happen in many time later. In Muong Lay and Sapa, landslides happened in 1966, 1990, 1992, 1994 and they re-happened at the same places in 2000, 2001, 2002 with bigger scale.

Fig No-2: Geohazard map of North-Western part of Viet Nam



**LEGEND**

-  Landslide point.
-  Area with extremely high danger level of landslide.
-  Area with high danger level of landslide.
-  Area with medium danger level of landslide.
-  Area with extremely low danger level of landslide.
-  District center.
-  Province center.
-  Roads.
-  Streams, rivers.

Compiled: by Dao Van Thinh and others.

SCALE 1:250,000  
 The form equivalent 2.5cm out field.  
 0 50 100km  
 kilometres

### *c. Destroying forms*

#### *Shattering (breaking up) form*

Landslides usually happen in high positions of relief that is why, they have very big dynamics. When they happened, they can break up strong, stable engineering works such as: bridges, sewerages, electrical poles, houses and other physical infrastructures. They cause big damages both in human life losses and in material losses. For example, landslides happened in 8/1986 had broken up many bridges, electrical poles, houses in the center of Muong Lay district, Lai Chau province. The rock blocks in debris flow have the measure of 5-6m and bigger.

#### *Burying character*

This is very common destroying form of landslides. Big massifs of rocks with land, big flows of rocks and mud may burry houses, engineering's, habitant areas in low parts. The people may be buried deeply by rocks and mud and it is very difficult to save the victims of landslides. The landslide's material can bury large areas of agricultural land. The buried agricultural land areas may reach some tens of hectare (in Muong Lay and Sapa for example).

#### *Sinking character*

This is the destroying form of landslides when they occur along rivers, streams and lakes. Big blocks of land with houses, gardens,... may sink and go away very fast with water flow. In sudden cases (in night time or in very sudden big flood) people and domestic animals also may sink together with houses and take away by water flow. For example, during one landslide happened in 7/2003 in Chu Va village, Tam Duong district, Lai Chau province, one American tourist had died by sinking of the water with rock flow.

#### *Rolling up to flow*

This is the common destroying form of debris and mud flows. People, animals and materials rolled up to these flows can not be saved on time.

#### *Deforming and destroying the functions of engineering works*

This is the direct destroying form of landslide bodies at the areas of engineering works (open mines, dams, roads, irrigation systems, construction works,...) The expenditures for repairing and rebuild of destroyed engineering works are very high.

#### *The landslide hazards make other geohazards to occur*

In may cases, landslides may make other geohazards to occur, such as soil cracking, explosions, fire accidents, distributing of poisoned elements,...

In North-western part of Viet Nam in some cases of landslides had caused the flash floods and sedimentary accumulation on bottom of rivers and lakes.

In some especially cases, landslides may form landslide lakes along river and streams. When landslide lakes broken up, the water in lakes flow very fast to lower parts of river. The flash flood had been formed. This is very dangerous hazard. The flood happened in 1990 caused much damages to the people of Lai Chau town has the landslide reason. This is the typical example for in combinational destroying form of some geohazards that occur at the same time.

In the limestone mountain areas with many caves and disappear rivers, the landslides may fill up windows of caves and rivers and as a result, the sudden flood happen.

### **2.3. The damages caused by landslide hazards in North-Western part of Vietnam**

Landslide hazards cause big damages in economics, human life, social materials and they destroy environment, cultivation land areas. In the following table some data of damages caused by landslide hazards in North-Western part of Vietnam.

**Table No 1. Some damages in main landslides (according to DMU, 2000 and other data)**

Year	Place	Losses houses	Dead people	Mounded people	Burried cultivated areas (ha)
1990	Lai Chau town	500	82	200	380
1991	Son La town	100	32	29	430
1994	Muong Lay Lai Chau	18	11	23	321
1996	Lai Chau province	872	106	26	511
2003	Lai Chau province	3	2		15
2003	Lao Cai province	39	6	1	175
2004	Lao Cai province	5	30	3	10
2005	Yen Bai province	127	59	23	500

#### 2.4. Some typical landslide points in North-Western part of Vietnam

**a. The first landslide point** at Mong Sen II bridge on road of 4D, 22km far away from Sa Pa center.

*Coordinates:* X= 22°22'48"; Y= 103°53'46".

*Position:* near the bridge; in positive wall of road.

*The main parameters of landslide:* original slope: 25°; slope of main body: 25°; slope of sliding surface: 30°;

*Time of occurrence:* 1990, 1994, 1996, 1998, 10/2000, 10/2001, 6/2002 (multi-time landslide).

*Reason:* by road making; rain; thick weathering crust; underground water (there is one water out-crop near the foot of main body). Landslide is in thick weathering crust (>5m) from granite rocks of Po Sen complex. The foliation of granite is 130<45. The vegetation is thinly populated.

*Sliding direction:* 130° (NE) and is coinciding with granite foliation.

*Type of sliding:* fast sliding on one plain surface. Material of main body is: broken up rocks, soil of weathering crust (silt, clay with dark brown, red-brownish color), soil layer (0,5-0,8m) and vegetation layer. Main body has the shape of semicircle with length of 150m; width of 130m; high of 50m; depth of 2-3m (according to electrical sounding the depth of weakened zone is >10m); main scarp of 3m. Area of main body is ~ 41.458m<sup>2</sup>; the volume of main body is ~ 207.290m<sup>3</sup>;

*Scale:* very big (I level).

*Damages:* 2 persons died before 1998; expenditure for repairing alone in 2000 was 10 billions VND. The engineering works for sliding protection (such as: wall, rock-baskets, water drainage canals) build in 2000. But they had been destroyed in 6/2002 because of a new landslide.

At present time this point is being repaired by transport Administration of Lao Cai province. This is the most typical multi-time landslide in NW part of Vietnam occurring in thick weathering crust from granite.



**Pic. No1. The typical landslide point at Móng Sến II bridge, Sa Pa district, Lào Cai province occurred several times in recent years and caused large material damages and human losses (taken by Đào Văn Thịnh, 2002)**

**b. The second landslide point is in South of Huoi Leng about 1 km**

On road of 12,15km far away from Muong Lay center.

*Coordinates:* X= 21°52'48''; Y=103°07' 18''. Position: in positive wall of road.

*The main parameters of landslide:* original slope: 30°; slope of main body: 30°; slope of sliding surface: 35°;

*Time of occurrence:* 1994, 1996, 1998, 8/2000 (multi-time landslide).

*Reason:* by road making; rain; thick weathering crust; steep slope of relief; strongly broken up rocks; active fault (Dien Bien-Lai Chau fault); underground water (there is one water out-crop near the foot of main body with the water recharge = 0,02l/s). Landslide is in thick layer of broken up. The vegetation is thinly populated.

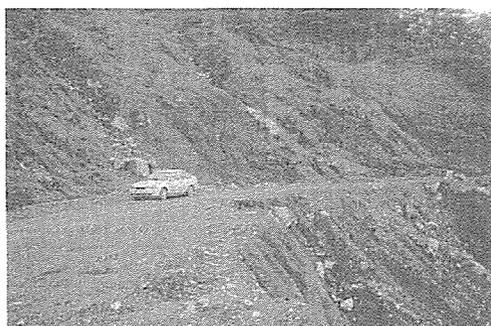
*Sliding direction:* 270° and is coinciding with rock dipping.

*Type of sliding:* fast sliding on one plain surface. Material of main body is: broken up rocks, soil of weathering crust (silt, clay with dark brown, red-brownish color), soil layer (0,2-0,5m) and vegetation layer. The original rocks are yellowish gray, dark gray clayish shale of Lai Chau formation. Rocks were under-gene mechanic weathering and strongly broken up. The striking and dipping of rocks: 260-270<60. Main body has the shape of semicircle with length of 80m; width of 150m; high of 40m; depth of 3m; main scarp of 5m. Area of main body is ~ 9430m<sup>2</sup>; the volume of main body is ~ 28.290m<sup>3</sup>;

*Scale:* very big (I level).

*Damages:* Destroyed 200m of 12 road and caused traffic jams for many days.

This is a typical multi-time landslide occurring in fine-grained terrigene sediments with sliding direction coinciding with rock dipping.



**Pic.No2. The landslide point in South of Huổi Lềng, Mường Lay district, Dien Bien province.**

(taken by Đào Văn Thịnh, 2001)

**c. The third landslide point**

Near culture house of Lai Chau town, at the low slope of one mountain; 500m far from the town in SE direction; 1km far from road of 12.

*Coordinates:* X= 22°03'06''; Y= 103°09'26''.

*The main parameters of landslide:* original slope: 50°; slope of the main body: 35°; slope of the sliding surface: 40°.

*Time of occurrence:* 7/2000 (old landslide).

*Reason:* rain; thick weathering crust; deep slope; active fault (Dien Bien-Lai Chau fault). Landslide is in thick weathering crust (>5m). From strongly broken up rocks of Lai Chau formation. The striking of rocks is: 270<35. The vegetation is thinly populated.

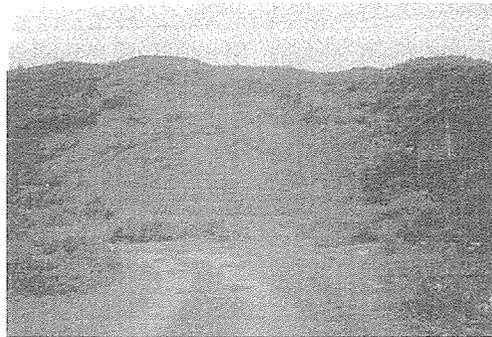
*Sliding direction:* 90° (E) and is against the rock dipping.

*Type of sliding:* fast sliding on one plain surface. Material of main body is: broken up rocks from dark gray shale of Lai Chau formation, soil of weathering crust, soil layer and vegetation layer. Main body has the shape of semicircle with length of 50m; width of 100m; high of 15m; depth of 5m (according to electrical sounding the depth of weakened zone is >50m); main scarp of 10m. Area of main body is ~ 3925m<sup>2</sup>; the volume of main body is ~ 19.625m<sup>3</sup>;

*Scale:* very big (I level).

*Damages:* Destroyed one part of forest with the area of 3925m<sup>2</sup>.

This is the typical old landslide occurring in terrigenous sediments with the sliding direction against to rock dipping.



**Pic.No 3. The landslide point near Culture House at old Lai Châu town,  
(now Mường Lay town ,Dien Bien province).  
(taken by Đào Văn Thịnh, 2001)**

**d. The fourth landslide point**

At Nga village, Ching Pha Commune, Thuan Chau district, Son La province.

*Coordinates:* X= 21°29'40''; Y= 103°39'20''.

*Position:* 500m far from road N° 6; on the slope of one gentle low mountain.

*The main parameters of landslide:* original slope: 25°; slope of main body: 15°; slope of sliding surface: 15-45°;

*Time of occurrence:* 5/2001 (new landslide).

*Reason:* rain; thick weathering crust; underground there may be limestone rocks with karst. Landslide is in thick weathering crust (>5m) from basalt rocks of Cam Thuy formation. The vegetation is thinly populated. Sliding direction: 130° (NE). Type of sliding: subsidence sliding on one curve, rolling surface.

Material of main body is: soil of weathering crust (silt, clay with dark brown, red-brownish color), soil layer (0,5-0,8m) and vegetation layer. Main body has the shape of accimetrical oval with length of 20m; width of 10m; high of 5m; depth of 2,5m; main scarp of 5m. Area of main body is ~ 245m<sup>2</sup>; the volume of main body is ~ 612,5m<sup>3</sup>;

*Scale:* medium (III level). On the surface of the main body there are many cracks.

*Damages:* Destroyed about 300m<sup>2</sup> of cultivated land. This is the landslide with subsidence-sliding dynamics by a rolling curve surface in the weathering crust from basalt with the existence of many cracks.



Pic.No4. The landslide point in Bản Ngà village ,Chiềng Pha commune,Thuận Châu district , Son La province( taken by *Đào Văn Thịnh, 2001*).

## **2.5. Reasons of landslide hazards in North Western part of Vietnam**

According to the preliminary results the occurred landslide points are of one combination of reasons (at least 3 reasons).

### **a. Slope of relief**

The slope of relief can be divided into 5 level: < 15°; 16°-25°; 26°-35°; 36° - 45°; and > 45°. Landslides often occur at the slope of > 25° (most at the interval of 30° - 45°). At 16 - 25° slope interval landslide less occur and are with smaller size. At the slope interval of <15° landslide less occur or do not occur at all.

**b. Weathering process of rocks** is also important reason causing landslide. Landslide process may be divided in to 3 levels: strong, medium, and weak. Many occurred landslide points are on the area of ferosialite (Fesial) type of weathering crust (from sedimentary rocks and metamorphic rocks). Many landslides with sliding surface in the boundary of original rocks and uncompleted weathering zone.

**c. Modern present tectonic movement** (expressed by earthquakes and active faults) is one of the reasons causing landslides. Many landslide points are concerned with active tectonic faults (Dien Bien-Lai Chau, Tuan Giao-Tua Chua faults).

### **d. Hydro-system (surface streams, especially groundwater) is also one important reason**

All big landslide points are concerned with groundwater. The rain regime play one important role. In the study region there are 4 levels of raining: level I (<1500mm); level II (1500-2000mm); level III (2000-2500mm); level IV (>2500mm). Landslides often occur in the areas with high levels of raining and they increasing during in rainy season (from May to August every year).

### **e. Vegetation density**

In the areas with high vegetation coverage (> 50%), landslides almost do not occur. In the areas with medium vegetation coverage (30-50%), landslides area of small size and with rare occurrence. In the areas with low vegetation coverage (<30%), landslides occur strong and most often.

#### ***f. Striking and dipping of original rocks***

Many landslide points occur in the areas in which the relief slope direction is coinciding with dipping of rocks or with rock foliation.

#### ***g. Physical property and structure of original rocks***

In the weaken and strongly broken up rocks zones landslides occur strongly.

#### ***h. Human activity***

The human activities may directly or indirectly cause landslide, such as: forest destroying, agriculture, artificial lakes, road construction, mining,... For example, in 1968 one landslide with the volume of 300.000m<sup>3</sup> occurred in Am Ma D mine (in Cam Duong town, Lao Cai province).

Besides above mentioned reasons there are some other reasons: high, width of relief slopes, slope of streams, region of river flows, waves in lake (in Hoa Binh lake), earthquakes, mine explosions, transport,...

### **2.6. Proposing the methods of protection and avoiding from landslide hazard and reducing damages caused by it**

a. It is necessary to carry out one long term program of investigation and research of landslide from general level to detail level, establish the map of landslide at the medium and large scale, according to the developing plan of each province. The multi-time repeating observation of landslide must be paid more attention.

b. It is necessary to have close cooperation between various branches in research geohazard and landslides (Science-Technology; Resources-Environment; Industries; Agriculture and Rural development; Transport,...) to make useful prediction of geohazards in general and of landslides in particular of the NW part of Vietnam.

c. It is necessary to make close cooperation between various scientists from provinces and from Government, agencies in research of all types of geohazards in NW part of Vietnam, especially landslides and floods.

d. The protection and avoiding from geohazard including landslide should be gone ahead one step by the predictions made from concrete investigation research besides saving and rescuing activities when geohazards had occurred.

e. It is necessary to give to every people living in the areas with high danger of geohazard occur the basic knowledge about geohazard including landslide, so that the native people can save themselves when geohazards occur. It is necessary to socialize the geohazard protection work.

f. As for landslide hazard the best method of protection is avoiding it (no planning to construct habitant zones in the danger areas of landslide occur).

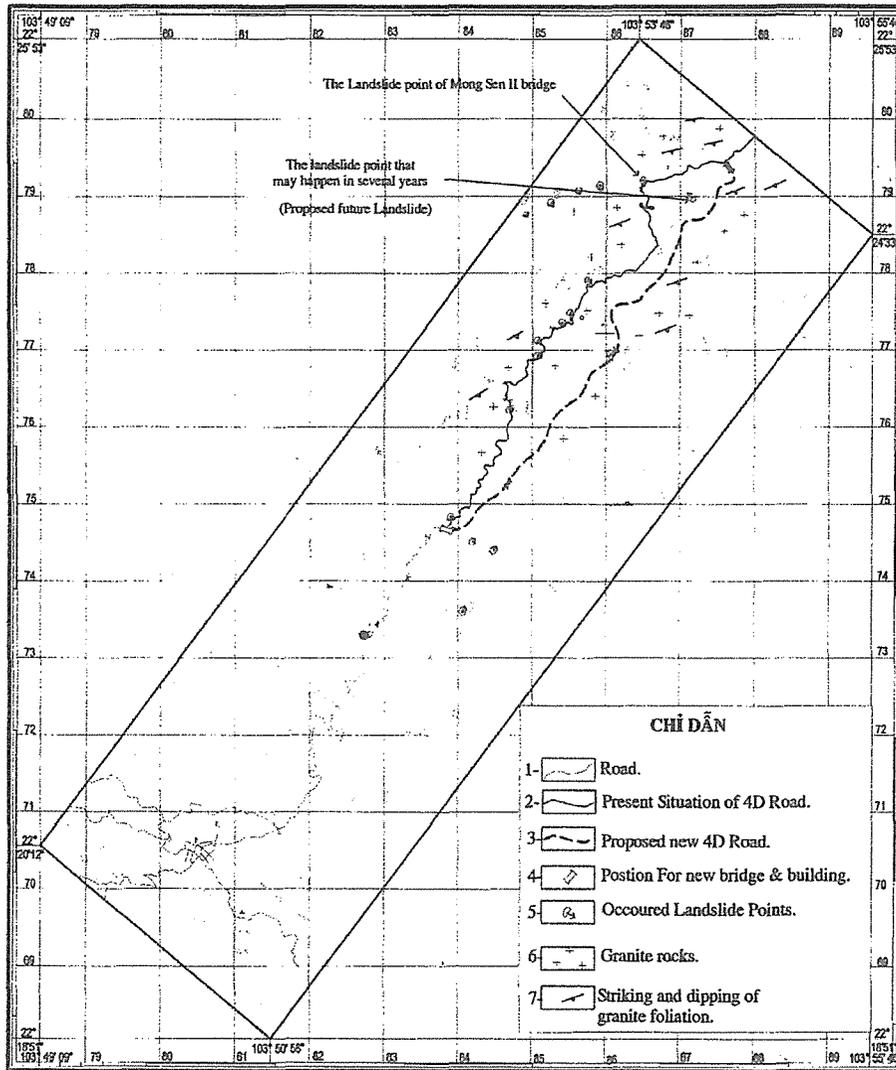
g. It is necessary to aware the local administrations the areas with high danger for landslides, no habitations along deep slopes, along the valleys surrounded by deep mountain slopes; in strongly weathered rock areas; vegetation planting in slopes; to do necessary engineering work to protect landslides. No house building by dipping holes in mountain slopes.

It is necessary to put aware signs in the places along road when landslides may suddenly occur.

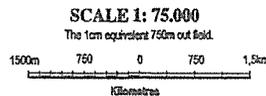
It is necessary to study at details all reasons causing landslide for making the method of protection and avoiding. For example, in Mong Sen II bridge landslide point the authors proposed to remove one part

of Road 4D to another side of the valley because all the protection methods done in recent years are not effective (see Fig. N° 3).

**Fig.No-3. Proposal of Removing position of one part of Road No 4D to a void landsliding (in Northern SaPa area)**



Compiled: by Dao Van Thinh and others.



### 3. Conclusions

On the basis of the preliminary results of investigation and research it can be defined that the NW part of Vietnam is in high danger for geohazards caused by landslide. Landslide is at the same time the result and the reason causing other geohazards such as: earthquakes, active faults, flash flood, tube flood,...It is necessary to do investigation and research of landslides at more detail level so that we can make some proposals of protection methods.

It is necessary to make concrete methods for damages reducing that caused by landslides for the sustainable development planning of the territory.

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