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Characteristics of Karst Polje in Vietnam and Associated Geohazards

Le Canh Tuan

Hanoi University for Natural Resource and Enviroment, No. 41A, Phu Dien Str., North Tu Liem Distr., Hanoi, Vietnam

Abstract: ***Karst is widely distributed in Vietnam, over area of ~60.000km2, which approximately accounts for 20% of the Vietnamese territory. Although there have been many studies on karst in Vietnam and around the world, only few of them focus on formation and development of karst poljes and well as its linkage to the geological hazards. The karst poljes in Vietnam are very important for socio-economic development. Recent researches show that formation and development of the karst poljes have occurred in stages. Most of the poljes have been constrained within fractured, faulted and folded Permo-Carboniferous limestone formations. The karstification process has led to not only formation of the karst poljes but also causing geological hazards such as flooding, sinkholes, and pollution of groundwater.***

Keywords: karst polje, karstification, pollution, geohazard

1. Introduction

Karst region in Vietnam has been extensively developedover an area of ~60.000km^2. There have been many studies on karst in Vietnam [2, 4-12], and the obtained results demonstrate karst is mostly observed in northern and central Vietnam (Fig.1). According to Khien, X. N., Chu, S.K., (2005), karst in Vietnam was subdivided into of 4 groups based on their ages of formation: pre-Cambrian Limestome Group; Middle Cambrian - Middle Devonian Limestone Group; Devonian - Permo-Carboniferous Limestone Group, and Permo-Carboniferous - Middle Triassic Limestone Group. Due to such a diversified karstification in Vietnam, many karst poljes have been fom within the karst regions. The recent study results shows that karst poljes have been fomed in 5 stages, which have been strongly controlled by geological structures of the region.

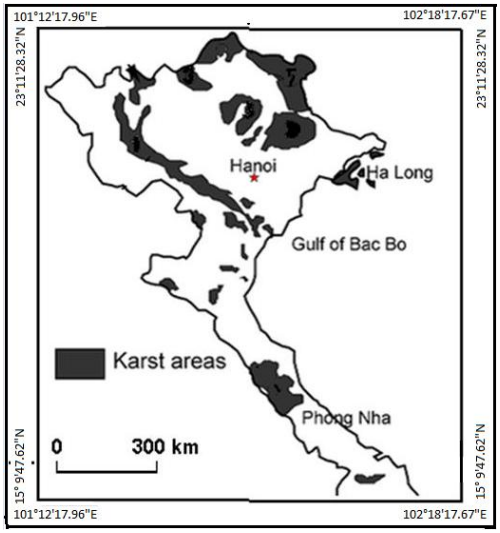

Figure 1: Distribution of karst areas in northern and central Vietnam

Through thousands of years of develoment, Karst poljes are very important for socio-economic development and livelihood of the Vietnamese people. Karstification has produced a numerous terrains such as blind valley, dolines, karst valleys, through valleys, ponor and polje. Among them, the most important is karst polje because a high population and many industrial areas are situated in karst poljes. In addition, goundwater extracted from karst aquifers becomes more important for human uasge and production due to the increased demand.

In this study, we aim to define the distribution, characteristics of karst poljes and its linkage to natural hazards in the karst areas to contribute to the peoper planning and management.

2. Methodology

In order to obtained the aforementioned objectives, we used the following study methods:
+ Rereviewing previous works focusing on the geology of karst in Vietnam in order to better understand their ages, distribution and identify major faulting and folding systems thay control kastification process.
Interpretation of satellite images together with analysis of topographic maps and field tests at Lang Son karst polje, Moc Chau karst polje, Tam Duong karst polje, Ban Hau karst polje, Yen Hoa karst polje,
+ Field investigation to collect and describe characteristics of karst products such as karst poljes, cave, blind valley, dolines, karst valleys, through valleys, ponor.

We futher measure and topographic parameters, gradient of the karst poljes, take samples, identify water sources, and construct geological section across the karst poljes.

3. Results

3.1. Vietnam has full karstification process

Geology of Vietnam is characterized by abundant carbonate rocks, whose ages varying from has a lot of limestone and dolomite in the diverse formations from the pre-Cambrian to the Quaternary but most of them have been deposited within the pre-Cambrian – Middle Triassic Time).

Due to strong tectonic activities, cracked limestone has produced a favorable environment for water and air circulation and hence intensified karstification process.

Situated in tropical zone North Vietnam receive high annual rainfall in many parts of the region as follow: 1.500 mm /yr in Son La and Moc Chau karst area; 1.846 mm/yr.in Nho Quan;1.862 mm/yr. in Hoa Binh; 2.085 mm/yr. in Lai Chau; 2.500 mm/yr. in Tam Duong;; 1.995 mm/yr. in Hon Gai and2.300 mm/yr. in Ke Bang, etc. Such a high precipitation is considered one of the important elements triggereing karstification process.

In addition, high humidity to gether with abundance of CO_2 derived from diversified terrestial and aquatic organisms is is another factor for intensifying karstification.

3.2 Karstification process

The most important for karstification process is a dissolution of calcite and dolomite. According to Derek Ford and Paul Williams (2007) [1] and Petar T.Milanpvic (2018) [6]: the pH of water in limestone and dolomite terrains usually falls between 6.5 and 8.9. In this range, $HCO3^-$ is the predominant ion while $CO2^-$ is negligibly below pH 8.3, It is more appropriate. The dissolution process of limestone and dolomite is summarized as follows (Figure 2) [1].

$Ca,Mg\ (CO3)_2 + 2CO_2 + 2H_2O \Leftrightarrow Ca^{2+} + Mg^{2+} + 4HCO_3^-$

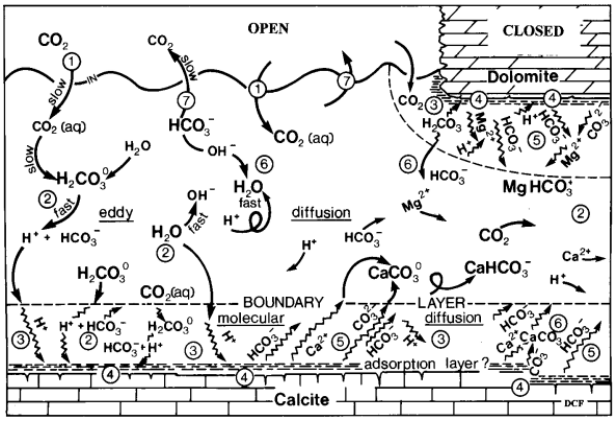

Figure 2: Cartoon depicting the dissolved species, reactions and comparative reaction rates that are involved in the dissolution of calcite and dolomite under open and closed conditions. Eddy diffusion dominates in the bulk liquid. There are very thin molecular diffusion boundary layers and adsorption sublayers in contact with the rock [1]

One of the key conditions that determine landforms in karst area is dissolution of calcite and dolomite. The rate of karstification depends on the amount of CO_2 contained in the water and the total amount of water for the karstification process. The amount of CO_2 for karstification depends not only on the availability of CO_2 in natural water but also on different sources of supply. For examples, microbial activity, vegetation cover, factories, plants, and even human activity. Besides, karstified intensity depends on reaction environment or geological environment. In fact, the karstification process is very complicated, it is difficult to specifically divide into steps as described above. It is a complex interplay between different agents, i.e. the lithosphere, hydrosphere, atmosphere, and biosphere. The karst landform is a product of a reciprocal reaction between agents for a long geological time. The complexity of the karst area is characterized by "karst environmental system" the product of the interaction of endogenous, exogenous processes in the karstified process. More precisely, it is the product of the interplay between the lithosphere, hydrosphere, biosphere, and atmosphere. Characteristics of the karst area have a double space structure. In which the space on the face is easily recognizable and accessible. The underground space is a system of caves and other pores in the rock, difficult to access, difficult to identify. Characteristics of a karst environment system are very sensitive, very vulnerable and when damaged, they cannot recover [13].

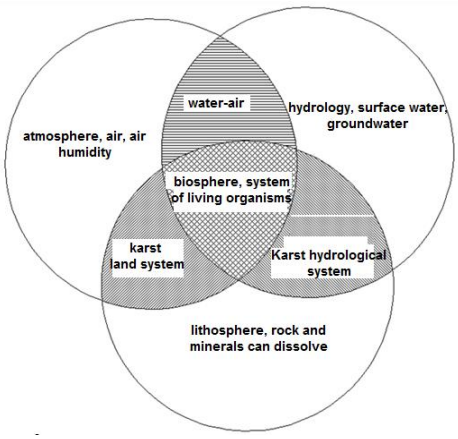

Figure 3: Structure diagram of karst environmental system [13]

4. Discussions

4.1 Characterisitis karst poljes in Vietnam

4.1.1 Karst poljes

Standards of karst polje have been shown by Derek Ford and Paul Williams [1, 3]. Poljes are large, flat-floored, enclosed depressions in karst terrains. They are landforms associated with the input and throughput of water and in many respects can be considered inlier of a normal fluvial landscape. Many karst poljes in the karst area of Vietnam (Figs. 4-5). Many residences and industrial factories or agricultural production areas have been arranged in karst polies in Vietnam. 6 karst poljes of in northwestern Vietnam were described by Tuyet, D. (1988) [10], including Tam Duong karst polje, Chieng La karst polje, Mai Son karst polje, Moc Chau karst polje, Cao Phong karst polje and Sin Ho karst polje. When describing karst poljes he only concerned the geomorphologyand seemed to ignored geological features. In particular, he did not interpret the relationship between topography and geological structure. In this article, the author try toanalyze the connection between these two elements (see structural poljes).

Figure 4: In the coner of Tam duong karst polje.

Figure 5: Moc Chau karst polje in Son La province

Figure 6: Mai Son karst polje in Son La province

Figure 7: Lang Son karst polje

4.1.2 Structural poljes

Structural poljes were described by Derek, F., Paul, W., (2007) in Figure 8. Structural poljes are dominated by bedrock geological controls. They are often associated with graben or fault-angle depressions and with inliers of impervious rocks or even of relatively low permeable rocks such as dolomite. Their depression form is elongated with the structural grain, although their tectonic boundaries may be modified by extensive planation across karst rocks. Structural poljes are very important features, giving rise to the largest karst depressions in the world [1].

Common characteristics of karst poljes [6] are:

- Flat quaternary cover surrounded with a karstic carbonate rock mass which extends far above the level of the polje;

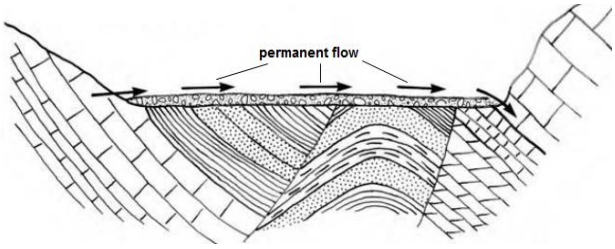

Figure 8: Structural polje [1]

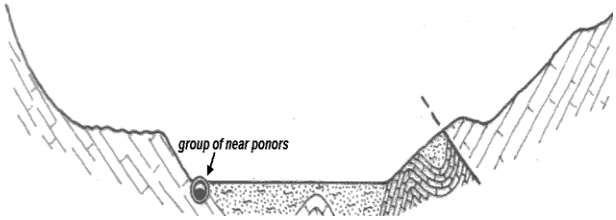

Figure 9: Structural polje [6]

- They are elongated in shape and their longer axis matches the stratigraphic and structural strike of the carbonate rock mass;
- Spring, estavelles, ponors mark their perimeters;
- Usually a temporary or permanent stream is formed between the most important spring and ponor, and this stream shows considerable variation in its flow;
- Alluvial ponors are often found in quaternary sediments;
- Ponors and zones of ponors with maximum recharge capacity are located at the lowest section of the polje; and
- The lowest parts of poljes are usually flooded during periods of heavy precipitation.

Thus, the concept of karst polje's structure (Derek, F., Paul, W., 2007) and (Petar T. Milanovíc., 2018) is consistent.

The results study in Viet Nam showed that karst poljes developed on the fold structural system (fig. 10 to fig. 15)

Tam Duong karst polje:

Tam Duong karst polje is distributed at an altitude of about 900m, extending in the NW-SE direction, with a length of about 20 km and a width of about 7 km. Tam Duong karst polje formed on Dong Giao limestone formation.

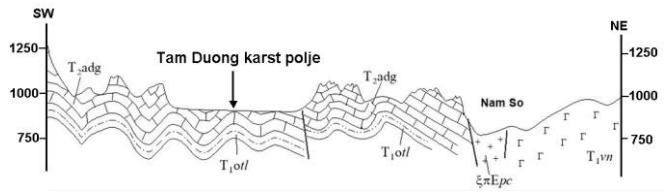

Figure 10: Section cross Tam Duong karst polje [12]

The geological activity created the fold system, promoting karstification. Southwest limb bedding measured 220-250 ∠ 30- 80, northeast limb bedding measured 60- 80 ∠ 25-55.

Moc Chau karst polje

Moc Chau karst polje is distributed at an altitude of over 1000m, developing in the Northwest - Southeast direction, an area of about 70 km2. The sections line cross to Moc Chau karst poljes show: Southwest limb bedding measured 240-260∠30-70, Northeast limb bedding measured 50- 80∠ 25-70. Karst polje formed on Dong Giao limestone formation. Tectonic activities have created the fold system.

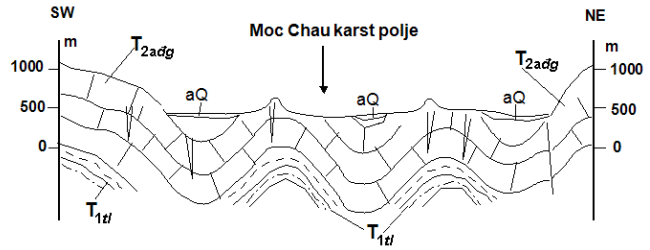

Figure 11: Section cross Moc Chau karst polje

Mai Son karst polje

Mai Son karst polje is distributed at an altitude of about 450m, developing in the northwest-southeast direction, with a length of about 40 km and a width of 7 to 10 km. Mai Son karst polje formed on the Dong Giao limestone formation. The sections line cross to Mai Son karst poljes show:Southwest limb bedding measured 220-240 ∠ 60- 75, Northeast limb bedding measured 60- 80 ∠ 50- 80.

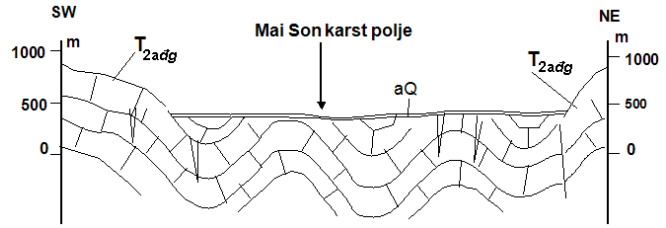

Figure 12: Section cross Mai Son karst polje

Lang Son karst polje

Lang Son karst polje has at rhombus shape, the long axis developed according to the meridians. The area of Lang Son karst polje is about 20 km2. Tectonic activity on formation of Bac Son limestone, forming a fold structural system. The sections line crosses to Lang Son karst poljes show: Northwest limb measured bedding: 300- 310∠25-50, Southeast limb bedding measured 120-14∠ 20-50.

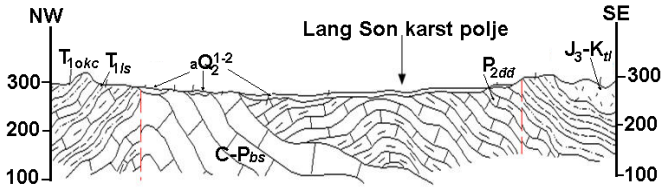

Figure 13: Section cross Lang Son karst polje [7]

In Viet Nam have many karst poljes, karst poljes are located on a fold structure too, but a small area, only about 1-2 kim2. They are Na Pai karst polje, Ban Hau karst polje (Lang Son province), Yen Hoa karst polje (Quang Binh province) (fig 15)

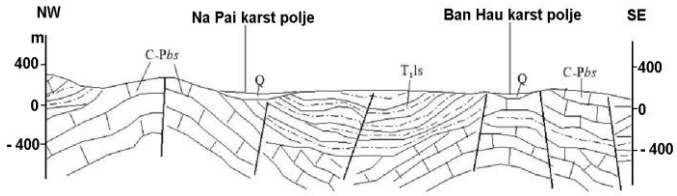

Figure 14: Section cross Na Pai and Ban Hau karst polje (Binh Gia, Lang Son province) [2]

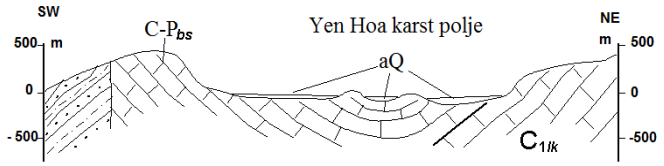

Figure 15: Section cross Yen Hoa karst polje (Minh Hoa, Quang Binh provice) [2]

4.2. The process of forming karst polje in Viet Nam

The research results on the karst area of Vietnam show that karst poljes have been developed on all types of folding structures. This study is well-matched with (Derek, F., Paul, W., (2007) and Petar T. Milanovíc., (2018). Analysis of geological structures and karstification allowed the author to subdivide the process of formation and development of karst poljes into 5 stages:

- The Carboniferous-Triassic period, the Tam Duong, Moc Chau, Mai Son, Lang Son, Ban Hau, Yen Hoa area was subsided in the sea. This is the time to produce limestone platform. Initially, these limestone formation have horizontal bedding (Fig.16A).
- Sine the Late Cretaceous, due to tectonic inversion, the Tam Duong, Moc Chau, Mai Chau, Lang Son, Ban Hau, Yen Hoa areas have been gradually uplifted and hence the pre-existing rocks have experience a strong ductile deformation to produce folding structures (Fig. 16B).
- The endogenous geological process continued affecting the rock layers, making them deform continuously and translated from ductile to brittle deformation. As results, fractures, cleavages and faults have been produced during this period (Fig. 16C).
- Over time, joints, fractures and broken zones have been enlarged by water infiltration corrosion, dissolusion, finally primary structure of carbonate have been destroyed by combination of endogenous and exhogenous processes. The process of chemical dissolution associated with invasion mechanism in the valleys, the basin is expanding.

The unconsolidated sediments have been deposited on the valley floor, along the surface flow system development. Finally, fold structural breakdowns and create reversed topographic forms like today (Fig.16D, Fig. 16E)

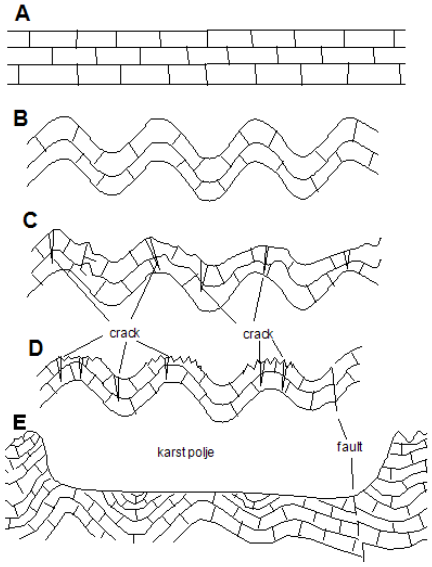

Figure 16: Illustration of karst poljes evolution in Vietnam

5. Geohazards associated with karst poljes

5.1 Pollution of ground water under karst poljes

This is the most outstanding threat in the karst poljes, In which many springs may appear in the surrounding high karst blocks. Those springs produce short-lived surface streamsflowing over a short distance before they are recyled into groundwater aquifers through sinkholes, dolines, and ponor. Drainage holes called ponor or swallow holes. The in-flow water may carry sufface contaminant to pollute the groundwater sources.

The thickness of sediment overlying karst poljes is very thin, it is <20m thick of unconsolidated quaternary formation at Lang Son karst and Tam Duong karst poljes. Because of thin onverlying sediment and high density of fractures, the underlying karst aquifers are sensitive to the pollusion (Figure 17).

Figure 17: Limestone and dolomit on surface, lots of cracks and holes, surface water flows straight down (Lang Son karst polje)

On karst poljes, there is no pretective structure, Surface water immediately follows into the cracks and caves without any filtering process, a direct circulation between surface and groundwater is established; contents and properties of the ground and surface water are very less different. Consequently, once the surface source is polluted by the living wastes, hospital rubbish, industrial sewage, pesticide, and fertilizers… the karst aquifers are immediately vulnerable and polluted (Fig. 17 to Fig.20).

Our survey results show that much of waste (Fig.17 to Fig.19) discharged on the poljes karst. Contaminants on the surface will be transported down to the underground aquifer. This is the main cause of contaminated groundwater.

Analysis of the cross-section through the karst poljes (Fig.7 to Fig 15). Karst poljes are located in subsided terrain, where water is concentrated. Water from other places flows with contaminants that flow straight into karst groundwater.

Figure 18: Garbage on the Ky River flowing into Lang Son karst polje.

Figure 9: Garbage at Nhi Thanh cave (Lang Son karst polje), black water is heavily polluted.

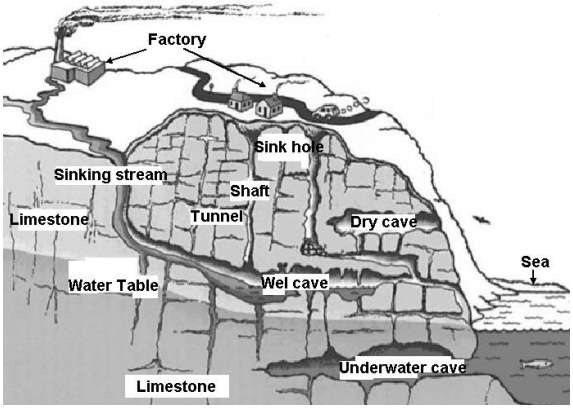

Figure 20: Schematic of a karst system.

5.2 Flood and sinkhole

Characteristics of karst poljes in Vietnam, they are developing on the folded structure of the Cambrian - Trassic limestone limstone, the most developement was during the Permian - Triassic period. Related geological hazards, including flood and sinkhole.

5.2.1. Flood

karst poljes is a convenient place to accumulate water when it rains, water flows very quickly, often causing flooding. Depending on the rainfall, flash floods may occur. On the karst regions, floods only occur on the karst with special positions, normally on the slope or foot of the denuded mountain ranges or plateaux that composed of the non-karst rocks. Then flood water is from the allogenic drainage networks collecting water from the denuded highlands and concentrates at the valleys of the karst areas. The place of flood is the bottom and the lower parts (including riverbed and flood plains) of the valleys. Floods often occur, on karst poljes in Lang Son, Tam Duong, Moc Chau, ... (Fig. 22 to Fig.25). Human activities in the region conducting more waterlog potentials are that the very forest cover has been razed; the slope surface has been ploughed for farming; besides the people still made many ponds and lakes for fishing and aquatic poultries. Structure of the karst poljes and economic activities are themselves the cause so that when it long and heavily rains since a tropical low pressure with a precipitation as high as 200-300mm per 1 or 2 days waterlog will be generated.

Figure 22: Flood on the Ky Cung river (Ky Cung river flows on Lang Son karst polje)

Figure 23: Flood on Lang Son karst polje (residential area)

In order to limit and mitigate the loss by the floods, it is first to be planned; building the houses and constructions avoid the flood path; organising the monitors and early alarm of possible floods to people, settling away from the floods to ensure a safety of life and properties of the civilians.

Figure 24: Flood on Tam Duong karst polje

Figure 25: Flood on Moc Chau karst polje

5.2.2. Sinkhole

On most of the karst areas of Vietnam is although observed the bare limestone, in some places in Viet Bac karst zone, West Quang Tri, Phu Nhung, Phieng Py of Tuan Giao, in Moc Chau Plateau, Mai Son of Son La, vicinities of Tam Duong, Lai Chau, etc. limestone is observed underlying a thin crust of unconsolidated reddish-brown sediments, which are the residual product of the karstification. In those places surface, subsidences have been commonly occured.

In karst regions, underground cave systems are very developed. The residential area on karst poljes are using from karst cave underground system. The sinkholes in Tam Duong (Lai Chau province- Fig. 27), Moc Chau (Son La province), Lang Son et cetera develop mainly on the karst poljes, corrosional plains. In the Tamduong town, both the sinkholes that are completely in the reddish brown clay and the one with the bare rock on slopes and bottom are present. The dolines are 10-15m deep and 15-20m in diameter. The Tamduong area develops on the karst polje. The results of speleological explorations in Lannhithang, Tamduong town and the vicinities show that the caves well develop there, many cave chambers of big size, many limestone blocs that are almost empty by a long and intensive karstification. Just in Tam Duong town, the karst aquifer is rather shallow; many segments of underground river-caves have been found; the river is below the limestone layers covered with the

reddish brown clay. The phenomenon of collapse of the underground spaces can happen at any time.

Collapses and subsidence of the karst underground spaces is a dangerous and disadvantageous phenomenon to the constructions and economy. The builders therefore must be learned of a nature and potential of collapses and subsidences and have the prevention ensuring a safety to the constructions.

Geological and geophysical research results show: On karst poljes in Vietnam, underground cave systems have developed. There is a water supply plant for constructions and people in the area.

Collapse happened on karst polje, causing damage to buildings such as houses, roads, etc. Typically such as Gia Thinh, Gia Vien, Ninh Binh provice (fig. 21), Tam Duong (fig 27 , fig 28), My Duc district, Ha Noi capital (fig 29).

Figure 21: Collapes on Gia Thinh, Gia Vien, Ninh Binh provice.

Figure 26: Collapes on Lang Son karst polje

Figure 27: Collapes on Tam Duong karst polje in 2001

Figure 28: Collapes on Km9+500, related underground karst in Nung Nang commune, Tam Duong district in 2019.

Figure 29: Collapes on My Duc district, Hanoi , Hanoi related underground karst in 2001

6. Conclusion

Based on geomorphological research, analysis of geological structure in karst areas of Vietnam, the author has some conclusions:

- The process of formation and development of karst poljes goes through 5 stages. The karst poljes are closely related to the fold structural system. Possible to identify karst poljes by satellite image analysis, topographic maps.
- The research results in karst areas in Vietnam show that all karst poljes are formed and developed on the fold structural system. This can be considered as a premise for geological structure analysis.
- The geohazard in karst poljes are floods, collapses, and water pollution. Warning and appropriate measures are needed to serve sustainable development.

References

[1] Derek, F., Paul, W., 2007, Karst Hydrogeology and Geomorphology. John Wiley & Sons Ltd, The Atrium, Southern Gate, Chichester,West Sussex PO19 8SQ, England. First Edition published in 1989 by Unwin Hyman Ltd.

[2] DGMVN (Department of Geology and Minerals of Vietnam). Results of geological mapping and mineral exploration in 1 / 50,000 scale.

[3] Gams, I., 1978, The polje: the problem of its definition. Zeitschrift fu¨r Geomorphologie, 22, 170–181.
[4] Jan, M., Rudy, S., Khien, X. N., 2003, Rural development in karst mountain area by sustainable water and land management and social learning: its conditions and facilitations. Storage Vietnam institute of Geosciences and Mineral resources.
[5] Khien, X. N., Chu, S.K., 2005, Sustainable Development of Limestone Areas in Vietnam. Research Institute of Geology and Mineral Resources.
[6] Petar T. Milanovíc., 2018, karst hydrogeology. Print by Centre Karst hydrogeology, Belgrade.
[7] Tuan, C.L., 2009, characteristics petrographic - Geomorphology of Ky Cung river valley (Lang Son town area) relation to geological hazards. Archive National Library, Ha Noi.
[8] Tuan, C.L., 2019, Tam Duong karst polje: Warning for environment and geohazard. Vietnam International water week vaci 2019. Publisher of National University of Hanoi.
[9] Tuan, C.L., 2019, Warning pollution of karst poljes in Vietnam. Vietnam International water week vaci 2019: Publisher of National University of Hanoi.
[10] Tuyet, D., Tuy, P. K., Ke, T. D., Tuan, C.Le., Quyet, D.X., Quynh, X. D., Thang, V. D., Xuyen, C. S., 1998, Karst geology research in the Northwest. Archives Institute of Geosciences and Mineral Resources, Hanoi.
[11] Tuyet, D., Quyet, D. X., Nam, N. X., Do ,V. T., 2002, Karst geomorphology of Thuan Chau area. Storage Vietnam institute of Geosciences and Mineral resources.
[12] Tuyet, D., et al., 2003, Rural development in karst mountain areas in NW Vietnam by subtainable water and land management and social learning: Its conditions and facilitations, Hanoi,
[13] Yuan, D. X., 1991, Karst of China. Geo. Pub. House; Beijing, China.

Author Profile

Tuan, C.L is the author of the paper. He is Geologist. From 1987 to 1992 studied at the University of Mining and Geology, Hanoi. From 1993 to 2010. He is working at the Institute of Geosciences and Mineral Resources. He is received a Ph.D. in geology in 2010. From 2010 up to now. Since 2010, he has taught at Hanoi University of Natural Resources and Environment. He has studied Geology, Geomorphology, Karst, Geohazard, Geological Heritage.