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Morpho- structure characteristics of some karst caves in Yen Mo- Tam Diep area, Ninh Binh province

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Abstract. Ninh Binh province is well known as an area with famous karst landscape that likes inland HaLong Bay. An attractive and charming cave system is developed in Triasic limestones of the Dong Giao formation, created a wonderful sites for tourism. The exciting features of karst landforms in the Ninh Binh province are mogots. It is mogots make Ninh Binh province became inland HaLong Bay. In the study area most wide spread karst forms are: mogots, karst slope and peaks, karst remnant relief, karst relict relief, karst polje, karst dry valley and karst ponor and sinkholes. Because of tropical climate, limestones in the study area undergone a strong chemical weathering process, created many wonderful and diverse landscapes on the surface and cave system underground. Many caves of different size and forms were developed underground of limestone mountains at different altitudes. Caves of Yen Mo-Tam Diep area were investigated and mapped for tourism developing. Many caves have a culture-historical significant such as: Hang Mat, Tam Giao, Tra Tu, Ong Mich, Ma Tien, Chua Hang, Hang Doi and Hang But. A study results is contribution to planning, exploration a tourism potential of Ninh Binh province as well as to kart investigation in the region.

Keywords: karst, mogot, caves, karst relief, speleothern.

1. Introduction

Located to the south of the Red River Delta, Ninh Binh is well known as an area with famous karst landscape that likes inland HaLong Bay [1]. Beside famous sites such as Hoa Lu ancient capital, Bai Dinh pagoda, Dinh-Le temps, Phat Diem cathedral,…there is a very attractive and wonderful karst landscape in Ninh Binh province that makes Ninh Binh became a famous area for tourism. A karst landscape and its sights in Tam Diep-Yen Mo area have been investigated and described in some works [1-4]. Some caves of the Trang An (Hoa Lu ancient capital), Tam Coc-Bich Dong were investigated and study results are effectively used for tourism development in this area. However, with increasing tourism demand in Ninh Binh and many caves were discovered in Yen Mo-Tam Diep area, it is necessary to conduct investigation in the YenMo-TamDiep karst area. Geological, historical and religious worth of cave systems in this area were still not enough evaluated. They also are not explored

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for tourism purpose. In order to evaluate tourism potential of Ninh Binh's caves system for tourism planning and development in the next future, during 2005-2007 Ninh Binh Tourism Department and Institute of Geological Sciences (VAST) had implemented a project: "*Research science basics and solutions of karst cave potential exploration for tourism development in Ninh Binh province*". Morpho-structure features of 36 caves, including 8 famous caves in Yen Mo-Tam Diep area were studied and described here.

2. Some geological - geomorphological characteristics of the Yen Mo-Tam Diep area

2.1. Geological features

Located at the end of the southeast part of the carbonate range, which is extended from Lai Châu, Sơn La, Hòa Bình to Ninh Bình, the Yên Mô-Tam Điệp area is composed mainly of Middle Triasic carbonate, Đồng Giao Formation ($T_2a\text{đ}g$). Besides, there are Early Triasic terrigenous-effusive deposits, Cò Nòi Formation (T_1 *cn*) and the Middle Triasic terrigenous-carbonate sediments, Nậm Thắm Formation (T_2l *nt*). A karst process is strongly developed in the Đồng Giao Formation, and as its result a diverse and fantastic cave systems were formed in this area.

The Đồng Giao Formation included 2 subformations. Lower Dong Giao subformation ($T_2a\text{đ}g_1$) consists of a gray, blackish grey, thin- to medium bedded limestone, interbeded with yellowish grey, light brownish yellow clayish limestone and limestone clay and sandstone which had been undergone a silicification and dolomitization process. Its total thickness is 320-400 m. They are distributed in Hoa Lư, in Northern and Northeastern margin of Tam Điệp, Yên Mô district Their chemical composition: CaO: 48.52-55.26%; SiO_2: 0.10-0.52%; Al_2O_3: 0.02-0.32%; Fe_2O_3: 0.04-0.83%; MgO: 0.10-1.02%. Upper Dong Giao subformation ($T_2a\ \text{đ}g_2$): consists of dark grey, bright grey, thick-bedded dolomite with some lens of limestone and dolomitic limestone. In areas, where tectonic activities were strong, breccias bands and ash-grey milonited zones were formed. The chemical composition of limestone of lower part: CaO: 30.7-32.1%; MgO: 19.26-20.24%. Upper part is composed of brightly grey, thick to massive-bedded limestones, which are breakable. In this part, limestones are pure and lithologicaly consists of calcite (100%), their chemical composition: CaO: 55.56%; MgO: <0.53%. A thickness of this subformation reaches 600-900 m [5, 6].

On the Vietnamese Tectonic map, most of Yên Mô-Tam Điệp area is located in Northwest Vietnam region and the rest in Trường Sơn region. Limestones, dolomitic limestones of the Đồng Giao Formation were controlled by Northwest-Southeast faults, which caused their original dip changes and leading to form folders and limestones ranges with a cuesta and discontinuous landforms.

2.2. Geomorphological features

A karst process depends on geomorphological features of limestones and CO_2 content in water. In study area, the karst process has developed strongly [7, 8] and as its result many giant mountain ranges were developed continuously and separated into many unconnected blocks. This process leads to form underground halls, ponors, karst polje and other negative forms like famous karst forms with a deep incised valleys and positive forms like a columns, pyramids….creating a carving relief with many fantastic karst forms.

-Karst mogots are popular relief form in the area. The word *mogot* comes from Polish that implies an alone separated limestone block which has a circle form (Fig.1).

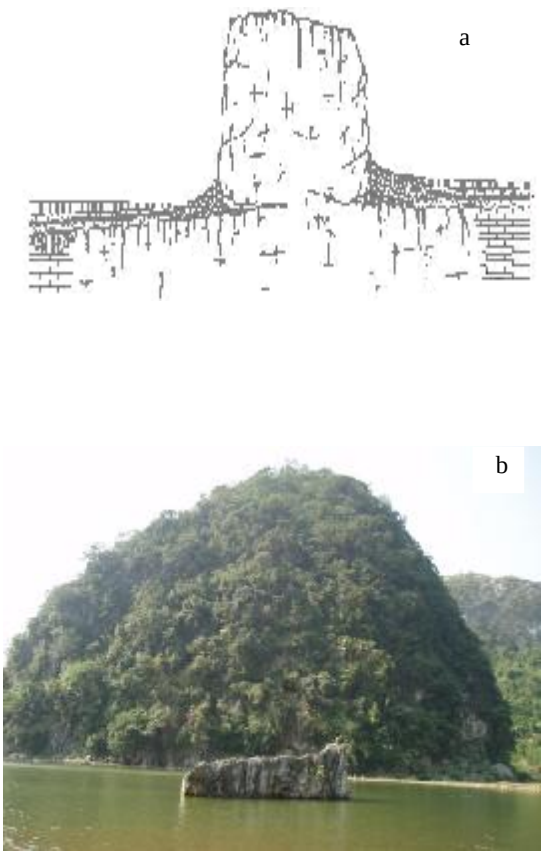

Fig.1. Mogot form in section (a) and in a field (b)(Photo Doan Dinh Lam, 2006).

It is this relief form makes study area becomes an attractive, fantastic tourist area. Limestone mountains are long range or relict. Because of tropical climate, limestone undergone a strong chemical weathering, crated many wonderful and diverse landscapes on the surface and underground. On the surface there are slopes and peaks, karst valleys, ponors and sinkholes of different forms. Many caves of different sizes and forms were developed underground of limestone mountains at different altitudes. Besides mogots, in study area most wide spread karst landscape forms are (Fig.2):

- Karst slopes and peaks

A peak of these karst massive have a sharp, pointed form with a typical karen relief [3,4]. These limestones have a massive structure, thick bedded with a various slope. Mountains with a veridical slope, carved by karen in a form of gutters or furrows that make a very beautiful natural scenes. There are many collapsed boulders like an amazing figures on the foot of these mountains. Because limestone of the Dong Giao formation are pure so a chemical weathering had developed deeply and widely. On the surface there is only a thin layer of soil in gutter or furrows. That's why here a flora is scare and small. Because of its wild, many tourists rush there to observe its fantastic scene.

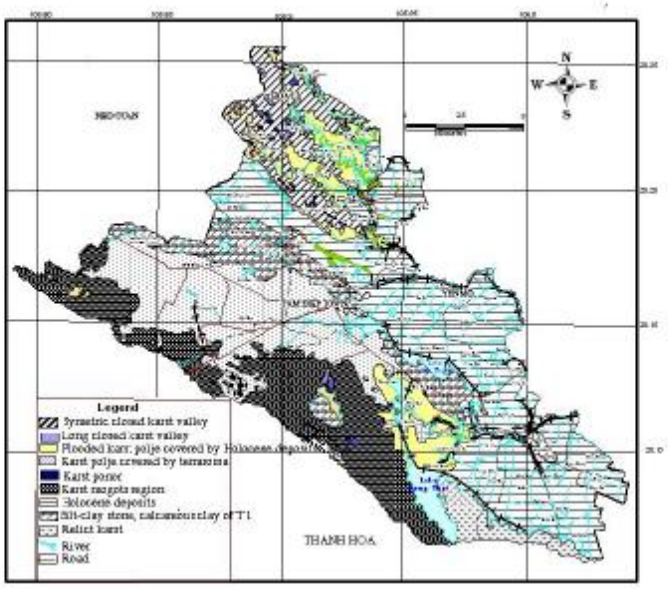

Fig 2. Geomorphologic map of Tam Điệp-Yên Mô area, Ninh Bình province.

- Karst remnant relief

This kind of relief can be observed in area where karst process almost stopped. Limestone massive were strongly eroded, left separated limestone on a surface, covered by dark yellow terraossa.

- Karst relict relief

This relief developed on the flat, lowland. They are massive of limestone that sparely located on the lowland. Their height is not too high, varies from 20-30 to 50-60m and their forms are different from semicircle to circle.

Fig.3. Karst polje in Dong Son, Tam Diep area (Photo Doan Dinh Lam, 2006).

- Karst poljes

Karst poljes are a closed valley that has a flat floor in karst area. One of its features is its flat floor on rigid fundament or covered by non-cemented sediments. It has a slopes around and drain water system (Fig.3). This kind relief is not spread well in study area, it presents only in Ninh Hai, Dong Son Village and in ward Nam Son, TamDiep.

- Karst dry valley

In study area, erosion activity of water (ground and surface) play an important role in forming karst valleys [8,9]. Tectonic characters also have an influence in forming this relief, especially for line valleys. Two kinds of valleys are most spread in study area: a symmetric closed valley and line karst valley. Their length varies from 600m to 700m. A closed symmetric valleys are most spread in study area such as in village Ninh Hai (Fig. 4), with a length from 100-200 to 300m. It is surrounded by limestone mogots or mountain range.

Fig.4. Karst dry valley in Tam Diep area (Photo Doan Dinh Lam, 2006).

- Karst ponors and sinkholes

On the surface, ponors and sinkholes are negative karst forms, having various forms, from circle to symmetric…Most of sinkholes are symmetric. Their distribution is very complicated. Their diameter is from 10-20m to hundreds meters. There are positive relief like mogot between ponors or sinkholes.

3. Morpho-structure characteristics of some famous caves in TamDiep-YenMo area

Morpho-structural features of 36 caves in a study area have been described, of which 8 famous caves are described in more detail here (Fig.5).

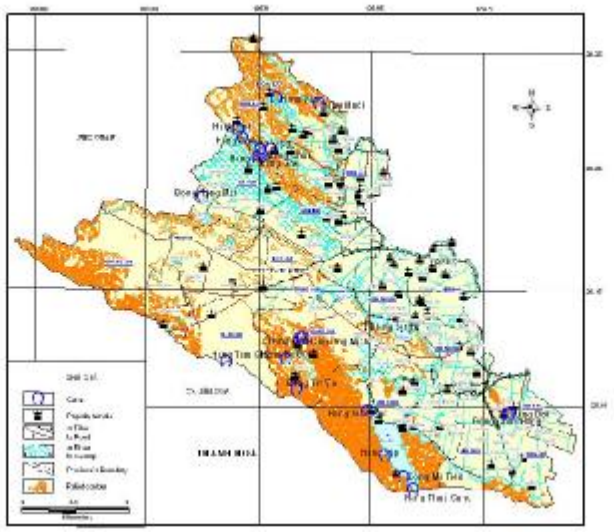

Fig 5. Cave distribution in Yên Mô-Tam Điệp area, Ninh Bình province.

3.1.Chua Mat cave (Fig.6)

Location: Vĩnh Khương, Yên Sơn, Tam Điệp Town ($20^0$11, 322'; $105^0$52, 557')

A cave locates in the relict karst field. Mountains around are relatively low-lying. The altitude of mountain with a cave is 87m. To cave one can assess easily. Limestones here are thick bedded. The name Chua Mat came from history that a King Quang Trung had overnight here on the way to the Thang Long city to wipe out 200 thousand of the Ch'ing dynasty troop. Inside of cave people constructed a temple-temple Chua Mat. The entrance to the cave is small (2,45m) and it looks to 70^0. Its relative altitude is 5m. From 5m from an entrance, a cave became wider. Its ceiling is flat, low (height is 1,5-1,7m). Most of speleotherns in this cave were destroyed for building pagoda. There are 10 very old stone statues on 5 altars in the cave. Some travertine remain on the floor with a thickness of 0,3m (Fig.7). On the left corridor one can observe a layer (0,5m) of cave deposit that consists of dark yellow silts, cemented by carbonate. Beside an altar there is a wave cut-off (Fig 8). This wave cut off has 0,7m height and a depth of cut-off is 0,8-1,0m. This water cut-off level is the same as a height of cave sediment on the wall. Further 22-25m from the entrance the cave is opened to the southeast. Its width became wider (5,5m). From here water begin running. After 22-25m, the cave changed its direction into other passage that open to 130^0 with a width of 4,m. Inside further, its width became wider, to 5,5m. From here, water start running. The width of passage varies from 6-7,5m to 9,86m. Total length of this passage is 35m. On the wall of this passage there are 5 water's wave cut (Fig.9). These wave cuts are an evidence of 5 stages development of this cave in the past. The height of these wave cuts are from 30cm to 87cm. These 5 wave cuts are observed only on right wall, on the left wall observed only 3 levels. The ceiling's height is about 2,0-2,20m with some small stalactites. In this passage water is running and goes to a ponor. Total length of this passage (1/1) is about 250-300m. Its width varies from 2-3m to 20-25m. Its ceiling is circle and there are some small stalactites on it.

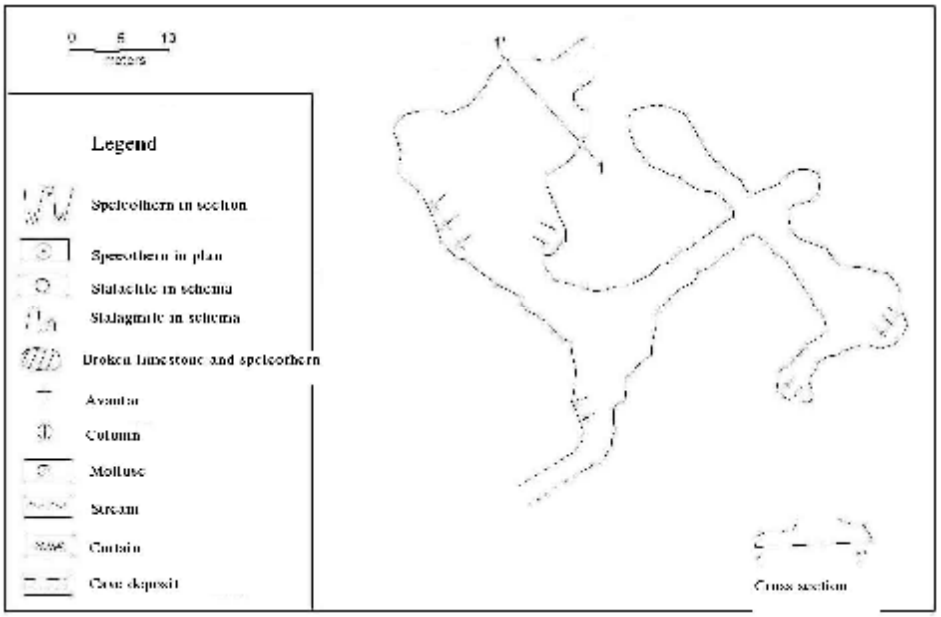

Fig.6. Schema of ChuaMat cave.

Fig.7. Travertine in Chúa Mát cave (Photo Doan Dinh Lam, 2006).

Fig.8. Water wave cut-off in Chúa Mát cave. (Photo Doan Dinh Lam, 2006).

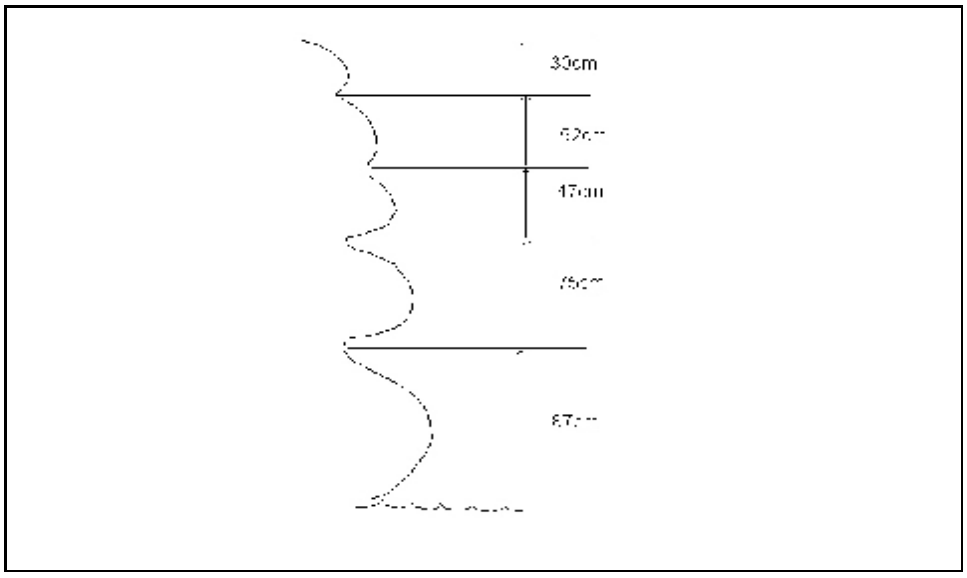

Fig.9. Wave cut off in the cave Chua Mat.

3.2. Cave Tam Giao

Location: ward 16, village Nam Son, town Tam Diep, Ninh Binh. 20^0.07'.03/105^0.53'.18

The way to the cave is bendy with many karen that is typical form of limestone due to tropical weathering process. The cave has a many entrances at different altitudes (Fig-10). The main entrance looks to the south. This cave locates on the boundary between the Thanh Hoa and Ninh Binh Province. The main cave's entrance (Fig.11) locates at relative altitude about 100 m above the rice field. This karst field is in ruin stage. The entrance has a circle form with many grayish curtains of 0,5-1,0m. It was collapsed and filled up by many big stone boulders of 1-2m in size. There are some curtains, stalagmites and broken columns lying on the cave floor. The size of these speleotherns is about 0,5 to 1,5m (Fig.11). It is an erosive karst dried cave. Its ceiling's height is of 10-12m, flat floor. There is a big hall between the entrance 1 and 2 with a size of 4 x 13,80 x 12m. The cave has a two floors. 5m from the main entrance, the floor became higher (2,5m).

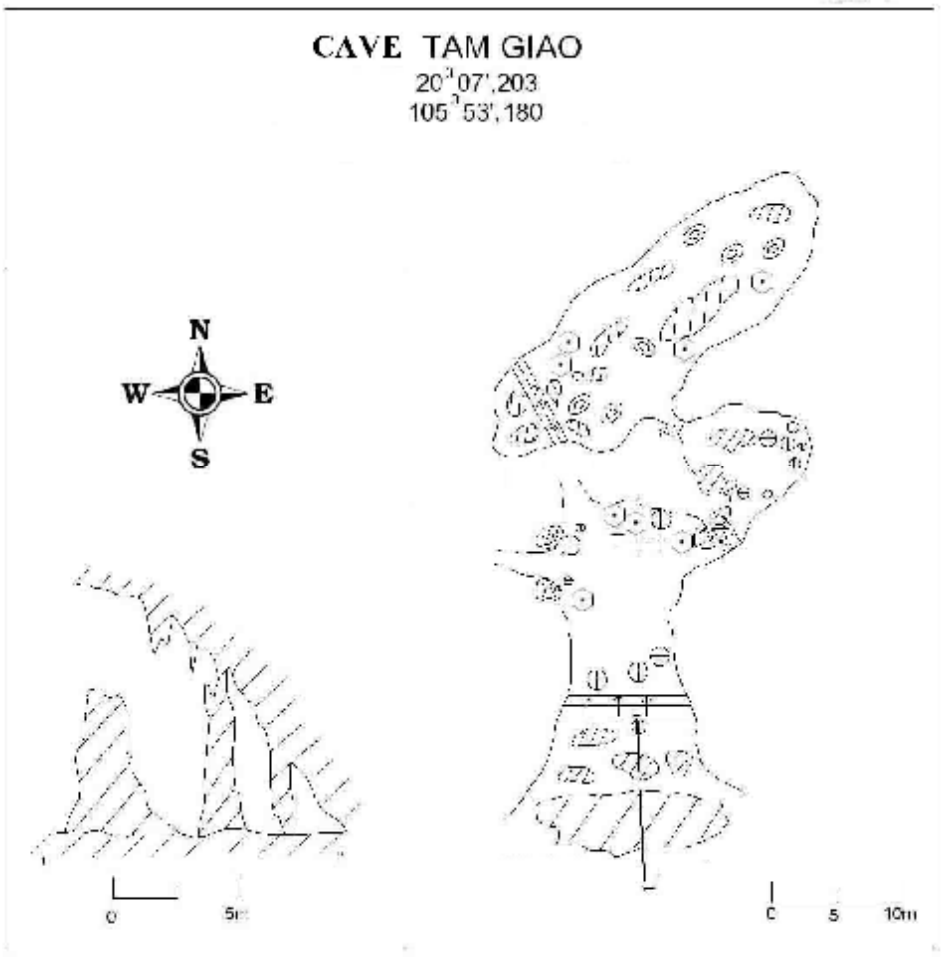

Fig.10. Schema of TamGiao cave.

There is a big hall on this floor of a size: 15,40 x 10,0 x 8,5m (Fig.10). This hall has two passages with many beautiful stone columns with perimeter of 20-30cm, height of 0,5-0,8m (Fig.12). A right passage became a narrow corridor that goes to the lower floor. There is a huge boulder lying in front of the entrance of this corridor. Its size is 3,5m, likes a huge mammoth lying on the curtain. There are many dried curtains on the walls. Hall number 2 is 1,5m lower than number 1 and there are many speleotherns, stone columns with diameter 10-15cm and height of 1,1-1,2m. There is a huge boulder in centre of the hall with a size: 2,2 x 2,0m. There are many grayish curtains on the wall of the hall. This second hall has a width of 9,5m and length of 7,7m. Its floor and ceiling are not flat. The height of ceiling varies from 5-6m to 8-9m. There are many speleotherns on the ceiling. From the second hall, through a narrow passage, one can pass to the third hall, that follows 308^0. There is a small ponor at the end of this hall. The depth of this ponor is more than 3,5m. There are many broken stalagmites and stalactites around ponor and on the floor as well as many carbonate oolites on the wall like mushrooms lying side by side.

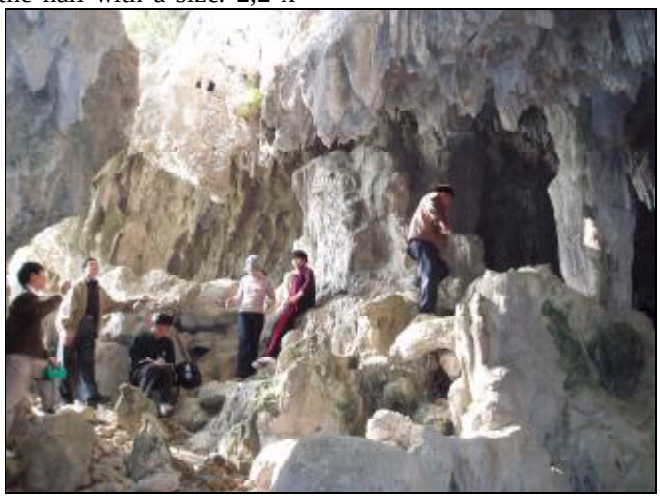

Fig.11. Entrance to Tam Giao cave (Photo Doan Dinh Lam, 2006).

Fig.12. Speleotherns in Tam Giao cave (Photo Doan Dinh Lam, 2006).

3.3. Cave Tra Tu. This cave locates in village 12, Dong Son, town Tam Diep, Ninh Binh.

This cave has 2 entrances. A coordinate of first is: 20^0.06'.495/105^0.55',044. Relative altitude of this entrance is about 200m above rice field (Fig.14). The entrance looks to the east (Fig.13). There are 2 floors. There are many stalactites on the ceiling. The floor is flat, its width is of 4,0m and length of 19,20m. There are many curtains and columns on the wall at the end of hall. Stone columns have a perimeter from 0,55m to 1,16m, stalagmite's size is from 0,8m to 3,15m and height is about 1,5m to 3,03m (Fig.15).

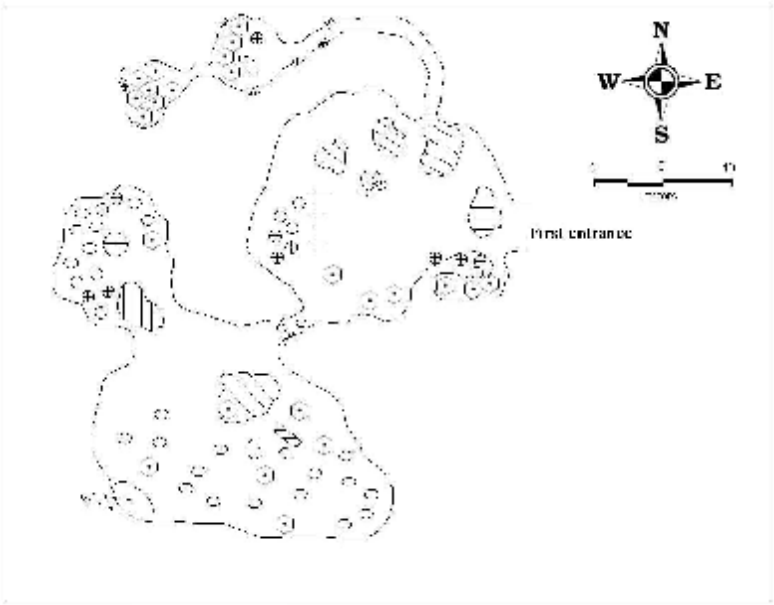

Fig.13. Schema of Tra Tu cave (Entrance $N^0$1).

There is a small (5,20 x 2,0 x 2,5m) passage at the left, about 2m from the entrance. In fact, this passage is connected with a mail hall but separated by system of stalagmites, stalactites and curtains. The height of these speleotherns is about 2-2,5m and perimeter from 1,0m to 2,50m. There is a narrow (0,5-0,6m) corridor on the right wall. This corridor open to195^0. Its length is 9,10m. There is a medium hall (4,18 x1,50m) at the end of this corridor with many beautiful stalagmites, stalactites and curtains (Fig.14, 15) that if one hits them they sound very well like organ in a church. This hall is connected with other small hall at the and there are also many white, beautiful stalagmites, stalactites and columns in this hall. There is a small passage at the end of this hall that leads to a huge room (width: 23-24m) with many big and beautiful speleotherns. There are many broken stalagmites and stalactites available on the floor (may be of paleo-earthquake). Some stalagmites have a diameter of 0,80-1,2m and a height of 2,0-2,20m. Many beautiful curtains are also available on the wall, some curtains like a king's umbrellas.

Fig.14. First entrance to Tra Tu cave (Photo Doan Dinh Lam, 2006).

Fig.15. Speleotherns in Tra Tu cave (Photo Doan Dinh Lam, 2006).

The second entrance (Fig.16,17) located at 20^0.06',498/105^0.55'.059, looks to the southeast (144^0) and far from the first about 100m. Its width is 10m, height of 5-6m. There are some big boulders on the floor and some stalactites on the ceiling. The length of this room is 15 m. There is a small passage at the end of the room leads to a medium hall (8,20m x 4,30m x 1,4-1,6m). In this hall many stalagmites and stalactites available of medium size (0,2-0,3m length). Some water running from a ceiling. This hall leads to other very huge hall (19,0 x 28,4 x 15,0m)-the last hall. In the last hall there are many big, beautiful stalagmites, stalactites and curtains that make this hall so charming and attractive (Fig.18).

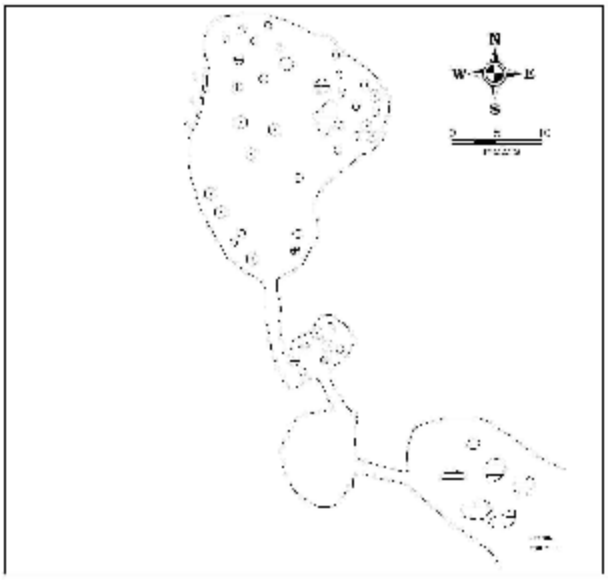

Fig.16. Schema of Tra Tu cave-second entrance.

Fig.17. Second entrance of Tra Tu cave (Photo Doan Dinh Lam, 2006).

Fig.18. Stalagmite and stalactite in Tra Tu cave (Photo Doan Dinh Lam, 2006).

3.4. Cave Ong Mich

Location: ward 12, Dong Son, Tam Diep Town, Ninh Binh. (20^0.07', 277/105^0.55',270.)

On the way to the cave one can observe a wide karst ruin field with some relict of limestone that demonstrated a strong denudation had occurred in the past. Thickness of a surface sediment only 0,5-1,0m. The entrance looked to 276^0, was semi closed by collapsed boulders (Fig.19, 20). Its width is 3,0m. This cave developed following the fault by 125^0. Total length of whole cave is 32,40m; its height is 12-13m. There are many big boulders (5 x 6 x2,5m) available on the floor (maybe they are evidence of historic paleo-earthquake?) (Fig.20). There is a few speleothern in this cave, only some white curtains available (Fig.21). This cave is not so much attractive for tourism.

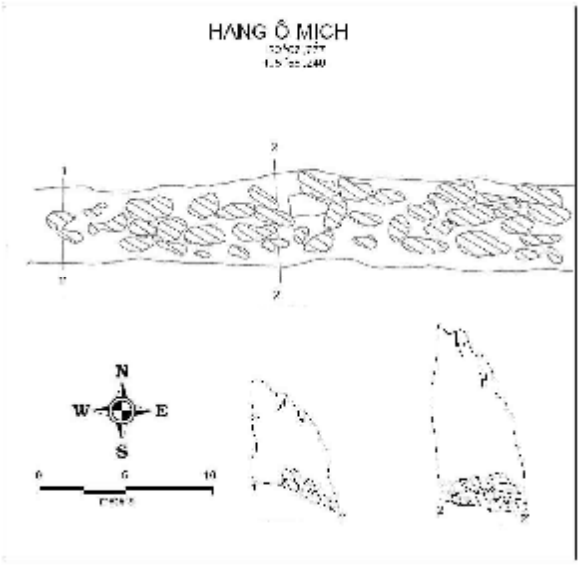

Fig.19. Schema of Ong Mich cave.

Fig.20. Entrance of Ong Mich cave (Photo Doan Dinh Lam, 2006).

Fig.21. Curtains in OngMich cave (Photo Doan Dinh Lam, 2006).

3.5. Cave Ma Tien

Location: Dong Thai, Yen Dong, District Yen Mo, Ninh Binh. 20^0.04', $32/105^0$.57', 928.

The relative altitude of entrance is 35-40m above the rice field. The way to a cave consist of 114 steps. The entrance has a circle form with a height of 10-12m, width of 21m (Fig.24). It looks to 170^0 (Fig.22). There are some yellowish brown cave deposits on the left wall. The cave has two floors. In front of the entrance many collapsed boulders available. On some of these boulders one can see a thick (o,4-0,5m) cemented cave deposits, consist of silt, silty clay, contain many mountain snails. It is an evidence of ancient man's life in this cave during Early Holocene.

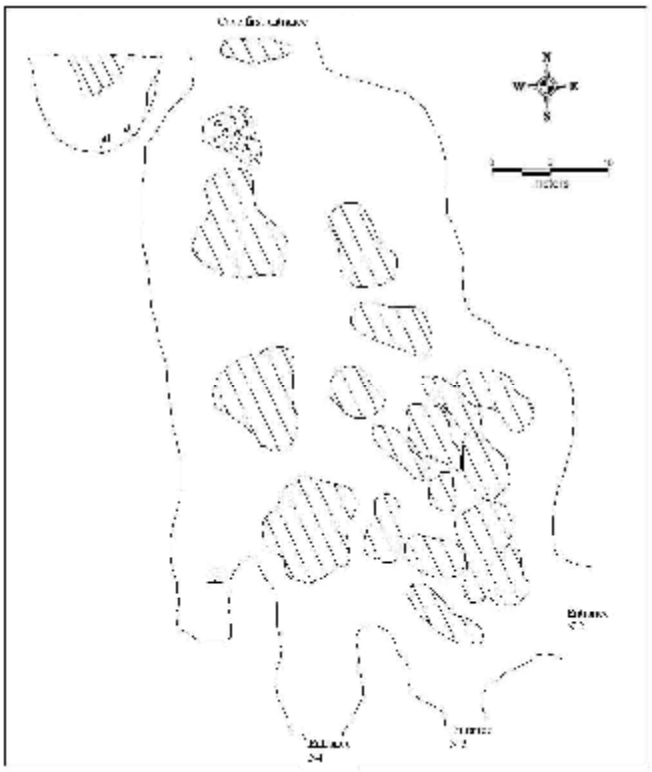

Fig.22. Schema of MaTien Cave.

Fig.23. Mountain snails in MaTien cave (Photo Doan Dinh Lam, 2006).

The cave's floor is relatively flat and cave deposits (2,0m thick) remain on the wall of this floor. These deposits are coarsening-upward, consist of silty clay with gravels in the lower part and coarse sand, gravels in the upper part. Coarse sediments are cemented by carbonate material and contain a lot of mountain snails (Fig.23). A thick cave deposits on the wall, located 15m above the floor can be observed. The cave has 4 entrances. These entrances have a big size, the width from 7m to14m and a height from 5 to 12. There are 3 huge halls in this cave (width from 6-8m to 25-30m, length from 35 to 55,8m and height is from 5-6m to 10-12m). There are many big, colorful and attractive speleotherns in these halls that it is worth to visit (Fig.25). Some water's level still remained on the wall and these water levels proved 3 developing stages of this cave. The water level is located above cave's floor about 1-1,2m. Many huge white, grayish white curtains (20-30m^2) and columns available in this cave, which make it very attractive and charming.

Fig. 24. Entrance to cave MaTien (Photo Doan Dinh Lam, 2006).

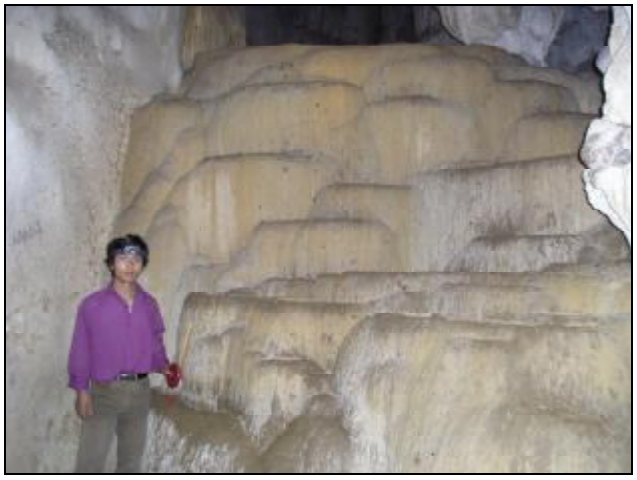

Fig 25. Speleotherns in MaTien cave. (Photo Doan Dinh Lam, 2006).

3.6. Chua Hang Cave

Location: Phuong Tri, Yen Mac, District Yen Mo, Ninh Binh. 20^0.05', 871/106^0.00', 695.

Chua Hang cave and some small caves locate around mountain Nui Voi. Most entrances are at periphery of mountain and at the same old-water level (1,90m above present water level). There are many erosive hallows available below this water level. These hallows have a circle form with a size of 1-2cm. The size of a cave is: 16,3m x 13,0m x 5,0m. The cave's entrance looks to 160^0 (Fig.26). Its floor is flat. There is no speleothern in this cave (may be they were destroyed before for establishment an altar) only some cave deposits available on the ceiling with some fauna remains (Fig.28). These deposits are composed of coarse grains sediments such sand, graves, breccias, cemented by carbonate. There is some white curtains at the end of cave. In this cave there is a pagoda with the name Tien Linh Son Dong. In this pagoda there are 10 very old stone statues (Fig.27), the age of which is still not been determined. These statues are 30cm height, 20cm width.

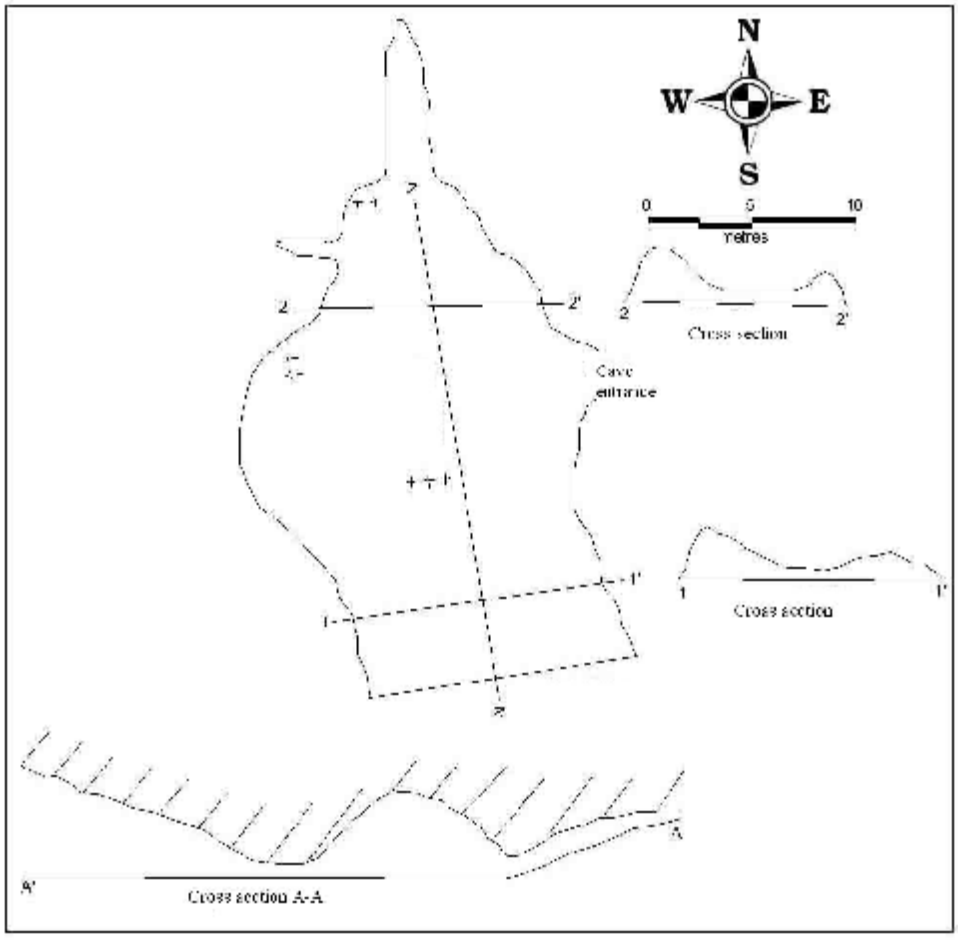

Fig.26. Schema of Chua Hang cave.

Fig 27. Ten old stone statues in Chua Hang cave (Photo Doan Dinh Lam, 2006).

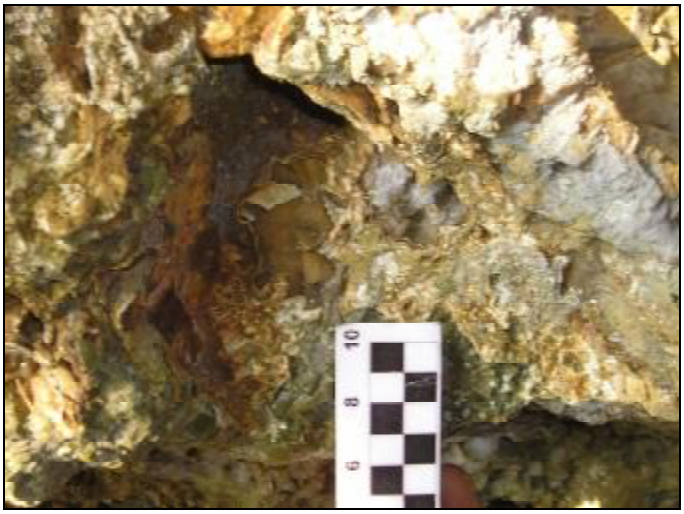

Fig.28. Fauna remains at wave cut off (Photo Doan Dinh Lam, 2006).

3.7. Hang Doi cave

Location: Phuong Tri, Yen Mac, District Yen Mo, Ninh Binh. 20^0.05', 895/106^0.00', 781.

The entrance locates at the same level of rice field. The height of cave entrance is 2,5-3,0m, width: 12,0m, likes a shelter (Fig.30). Total length of this cave is about 35-40m, its width is 6-12m. The height of ceiling is 4-5m. There is a few of speleothern in this cave (Fig.31), some cave deposits remain on the ceiling, consist of gravel and breccias, cemented by carbonate. There are small halls and passages on the left side (Fig.29). These passage are low (1-2m) without speleothern. Hall and rooms are medium size (5,2 x 3,7 x 2,5-6,0m). There is some cave deposits on the ceiling, consist of breccias, gravels weakly cemented by carbonate.

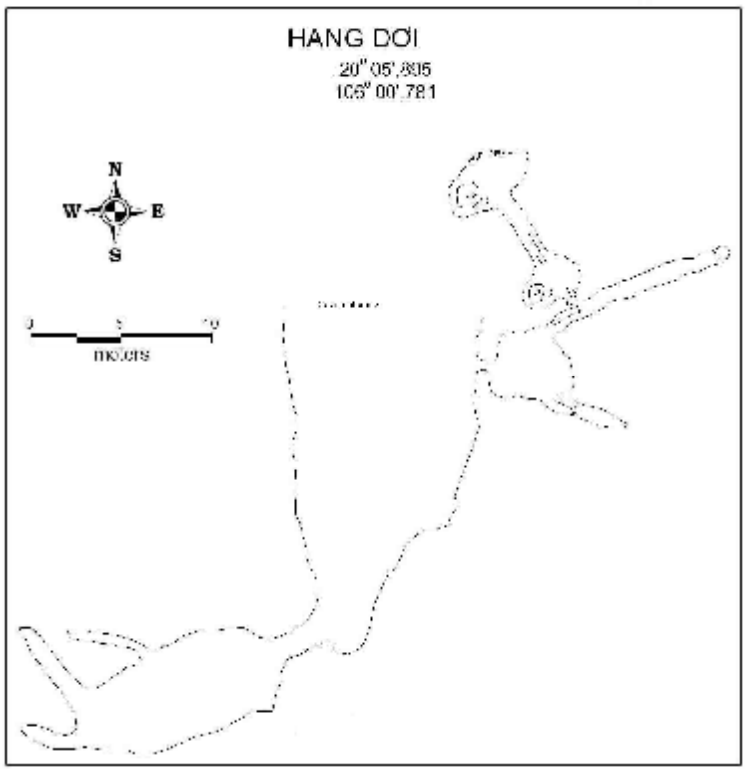

Fig.29. Schema of Hang Doi cave.

Fig.30.Entrance to Hang Doi cave (Photo Doan Dinh Lam, 2006).

Fig.31. Curtains in HangDoi cave (Photo Doan Dinh Lam, 2006).

3.8. Hang But cave

Location: Hai Nham, Ninh Hai, District Hoa Lu, Ninh Binh. 20^0.13', 076/105^0.53', 498.

To go to the cave Hang But, one has to pass Tam Coc-Bich Dong and go far by boat through two small water cave: Hang Chua, Hang Ghe.

Hang But cave (Fig.32) is water cave. From water level to ceiling is about 1,20-1,80m. The entrance looks to 250^0 (Fig.33). Its ceiling if quite flat with some stalactites. During rainy season water rising up to ceiling so going through the cave is impossible. This cave was developed following fissures by 220^0/10^0. A water depth is about 60-70cm. At the survey time (dry season) the height from ceiling to water level varies from 1,5-1,6 m to 2,0-2,5m. Width of cave is from 5 to 8m. Cave deposits in this cave are clays, silty clays of brown color. Their observed thickness is about 1,0-1,3m and they are attached to wall of the cave. This cave likes a long corridor filled up by water. Total length of the cave is about 500m. At second entrance that looks to west, in the evening the sunlight creates a charming sight (Fig.34).

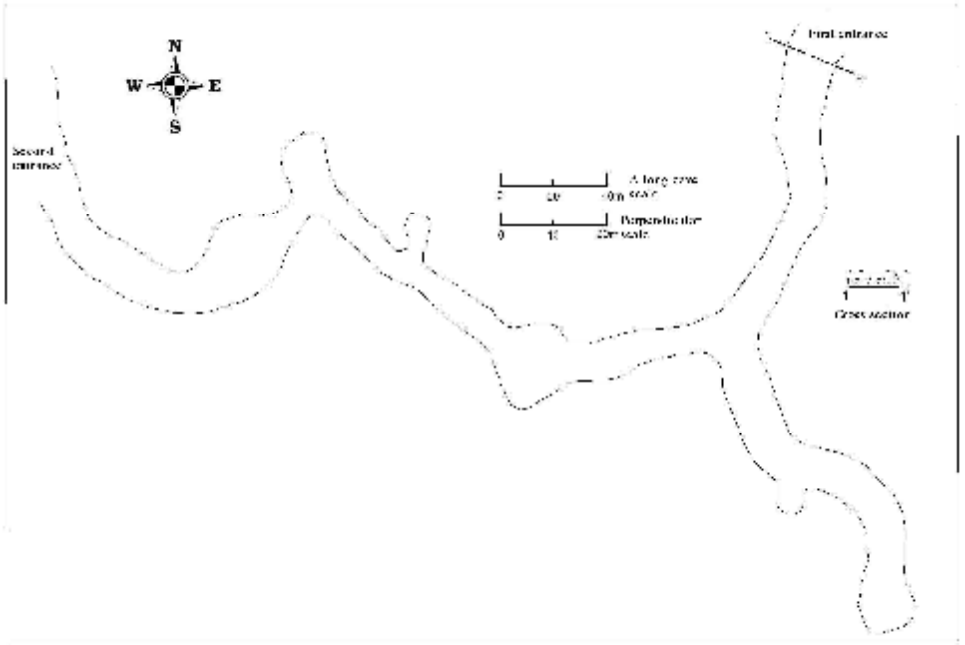

Fig.32. Schema of Hang But cave.

Fig.33. First entrance to Hang But cave (Photo Doan Dinh Lam, 2006).

Fig.34. Second entrance to Hang But cave (Photo Doan Dinh Lam, 2006).

4. Conclusion

Among 8 caves the Hang But is a longest one with a length of about 500m and this cave is unique water cave. Attractive of this cave is much like Tam Coc-Bich Dong system. Ma Tien cave has a high value from archeology point of view. Although in this cave there are not to much beautiful speleotherns but its archeological significant is worth to visit. The Tra Tu is very beautiful and attractive cave from tourism point of view because of many charming speleotherns available there. This cave can compare with most famous cave in HaLong Bay. Other caves in the study area have a cultural and life significant and can be used for tourism purpose.

Cave system in Tam Diep-Yen Mo, Ninh Binh province has a high tourism potential. There are many other very beautiful and attractive caves in this area that still not founded and studied. In the future these caves should be protected for developing a green industry-tourism in the region./.

References

[1] J. Glazek, On the karst phenomena in North VietNam, *Bulletin de l'Academie Polonaise des sciences,* Volume XIV, N 1. Varsovie, 1966.

[2] Luyen Nguyen Ngoc, Doan Dinh Lam et all., *Study a scientific aspects and measures for exploration karst cave potential in Tam Diep-Yen Mo, Ninh Binh, Kenh Ga-Van Trinh, Van Long,* Ninh Binh for tourism development. Project report.120p., 2006.

[3] Mong Dinh Minh (Editor), *Geology of the Ninh Binh sheet, 1:200.000,* Geological survey of Viet Nam, 1978.

[4] My Nguyen Quang, *About karst of Viet Nam,* Hanoi University, 1997.

[5] Nang Dao Trong, *Karst relief in Viet Nam,* Science and Technology Publ. 158p., 1979.

[6] Tuyet Do, *Geomorphology of the Ninh Binh sheet, 1:200.000,* Geological survey of Viet Nam, 1975.

[7] Truong Nguyen Ngoc, *Investigation physical characteristics, human features of Hoa Lu and Tam Co-Bich Dong for planning and development,* Hanoi University, 1994.

[8] M.A. Zubashenko, *Problem of karst development in Northern VietNam,* In "Hydrogeology and karst" Vol 2. Perm, 1964.

[9] Thao Le Ba, *Nature of VietNam,* Science and technology Publ., 1977.