# Trans-KARST 2004

International Transdisciplinary Conference
on
Development and Conservation of Karst Regions

# Field Excursion Guidebook

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Hanoi, Vietnam

13 - 18 September 2004

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International Transdisciplinary Conference
on
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## Field Excursion Guidebook

# The Cat Ba and Cuc Phuong National Parks and The Ha Long Bay World Natural Heritage

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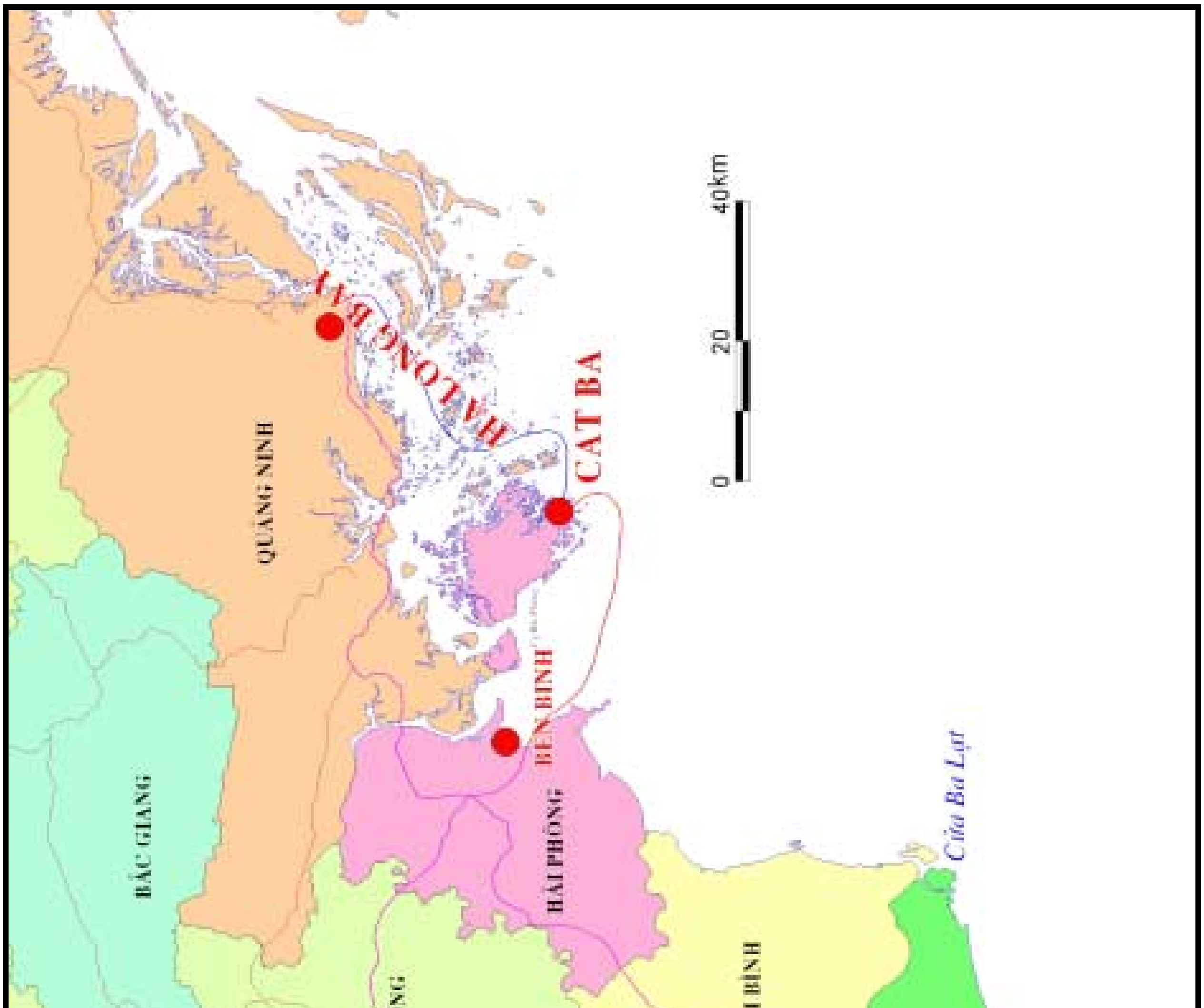


Location of Excursion Stops

# TransKARST-2004 Excursion Schedule

| Time | Content |
|---|---|
| September 15th, 2004 | |
| *Leave Hanoi for the Cat Ba Island and inland tour around the Island* | |
| 6.30 | Gathering at the Kim Lien Hotel in Ha Noi |
| 7.00 | Leave for Hai Phong City (by car) |
| 9.00 | Arrive at Ben Binh Harbour (Hai Phong City) |
| 9.30 | Leave for the Cat Ba Island (by high-speed ship) |
| 10.30 | Arrive at the Cat Ba Island |
| 10.30-11.30 | Check in the *Cat Ba Harbour Inn* hotel (in the southern part of the Cat Ba Island) |
| 11.30-12.30 | Lunch at the *Cat Ba Harbour Inn* hotel |
| 13.00 | Leave for the National Park of Cat Ba (by car) |
| 13.30 | Arrive at the National Park of Cat Ba |
| 13.40-14.00 | 15 minutes video show on the National Park of Cat Ba |
| 14.00-16.15 | Hill-walk tour around the National Park of Cat Ba. Visit Kim Giao forest and return to the Park headquarter. |
| | **Option 1:** Ecology- and biodiversity-interested participants will continue to explore Ao Ech (Frog Pond) until late afternoon. |
| 16.30 | **Option 2:** Geology- and landscape-interested participants will leave the Park headquarter for the Gia Luan Fish Harbour in the northern part of the Cat Ba Island (by car) |
| 16.45 | Arrive at the Gia Luan Fish Harbour |
| 16.45-17.45 | Show of a typical geological cross-section of the Cat Ba Island (along-road walk of approx. 1 km) |
| 18.00 | Return to the *Cat Ba Harbour Inn* hotel (by car) |
| 18.30 | Arrive at the *Cat Ba Harbour Inn* hotel |
| 20.00-21.30 | Dinner at the *Cat Ba Harbour Inn* hotel |
| After 21.30 | Free |
| September 16th, 2004 | |
| *Leave the Cat Ba Island for Ha Long City; the whole day tour around the Cat Ba & Ha Long Bay by touring boat; lunch on board* | |
| 7.00 | Breakfast at the *Cat Ba Harbour Inn* hotel |
| 8.00 | Shipping and departure (at the Cat Ba Harbour, about 10 minute walk far from the *Cat Ba Harbour Inn* hotel) |
| 9.00 | Arrive at the Cat Dua Island (another name: Monkey Island, 3 km east of the Cat Ba Island) |
| 10.00-10.45 | Show of wild monkeys residing in the Cat Dua Island |
| 11.00 | Return to the boat and continue the tour |

| | |
|---|---|
| 11.00-13.00 | Along the Bay: on boat shows of active caves (e.g. caves at the foot of on-shore rock wall, where the sea water flows in/out or both), stand-alone erosional karst peaks and towers in the Bay, wild coral clusters scattered in the Bay; lunch on board |
| 13.00-14.30 | Arrive and visit the Cua Van Island: show (presented by the Ha Long Bay Management Board) of a typical cultural marinary village in the Bay and an on-going community-based conservation and education project |
| 14.30 | Return to the boat and continue the tour |
| 14.30-15.30 | Along the Bay |
| 15.30-16.30 | Visit the Sung Sot (English meaning: Surprising) Tourist Cave, one of the most beautiful fossil cave in the Ha Long Bay |
| 16.30-18.00 | Continue the tour along the Ha Long Bay by boat |
| 18.00 | Arrive at the Ha Long City |
| 18.00-19.30 | Settle down in the Thien Long Hotel (located very close to the well-known Bai Chay seaside resort) |
| 19.30-21.30 | Dinner at the Thien Long Hotel |
| After 21.30 | Free |
| <u>September 17th, 2004</u> | |
| *Leave Ha Long city for the National Park of Cuc Phuong; half day on car; light lunch on car* | |
| 7.00 | Breakfast at the Thien Long Hotel |
| 8.30 | Leave the Ha Long City for the Ninh Binh Town |
| 8.30-13.30 | On road by car to the Ninh Binh Town; light lunch on car |
| 13.30 | Arrive at the Dinh-Le Temples (the two first feudal dynasties of Vietnam that resided in karst area) |
| 13.30-15.30 | Visit the Dinh-Le Temples (the Temples as well as the nearby community, located in a very beautiful karst valley, known as an ancient capital of Vietnam during the 12th Century) |
| 15.30 | Leave for the National Park of Cuc Phuong |
| 15.30-16.30 | On road by car to the National Park of Cuc Phuong |
| 16.30 | Arrive at the National Park of Cuc Phuong |
| 16.30-19.00 | Settle down in the Cuc Phuong Guesthouses (located inside the Park) |
| 19.00-21.00 | Barbecue dinner inside the Park |
| After 21.00 | Free |
| <u>September 18th, 2004</u> | |
| *Half day tour around the Park (in the morning); leave for Hanoi (in the afternoon)* | |
| 7.00 | Breakfast in the Cuc Phuong Park Restaurant |
| 8.00-12.30 | Walk tour around the park |
| 12.30-13.30 | Return to the Cuc Phuong Guesthouse, packing luggage |
| 13.30-15.00 | Lunch |
| 15.30 | Leave for Hanoi Capital |
| 15.30-19.00 | On road by car to Hanoi Capital |
| 19.00 | Arrive at the Kim Lien Hotel in Hanoi |
| After 19.00 | Free |

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# Introduction

The aim of this field excursion is to provide the TRANSKARST 2004 participants with authentic information on Vietnam's humid tropical karst system. The karst of Vietnam develops on an intra-continental structure, which since the Neoproterozoic to the Quaternary, has undergone several tectonic cycles under varied paleoclimatic and paleogeographic conditions. Hot, humid tropical conditions with monsoons may have already prevailed since Late Pliocene times to present. Limestones have been formed during Proterozoic, Middle-Late Cambrian, Middle Devonian, Carboniferous-Permian, and Middle Triassic times with nearly 10,000 m of cumulative thickness and nearly 60,000 $km^2$ in exposed area. Folding and faulting cycles along with persistent and strong climatic impacts have resulted in 3 typical karst landscapes in Vietnam: the peak cluster-depression, the residual, and the Ha Long-type (mainland karst invaded and sculptured by sea water) karst landscapes. A peculiarity of Vietnam's karst is its vegetation cover that once prevailed everywhere resulting in rain forests with high biodiversity and endemicity. Recent excessive economic activities, however, have changed many, once vivid karst regions into desert, with more and more risks and hazards. Reducing rock desertification, sustainable protection and development of the karst system are becoming urgent to both the government and all communes that live in karst regions of Vietnam.

During the 4 days of excursion, TRANSKARST 2004 participants will be acquainted with typical karst conditions and landscapes of Vietnam. They will also be offered a chance to compare the remaining primary tropical forest with the unexpected, heart-hurting scenes due to the excessive exploitation of karst. The participants will be encouraged to advise all concerned authorities, policy makers, managers, developers and even ordinary residents for a proper use and protection of these invaluable karst regions, including Ha Long Bay - the World's Natural Heritage, thus that they could really remain an eternal invaluable property of mankind.

Major excursion targets are briefly described hereafter.

# I. The Cuc Phuong National Park

## 1. Location

Recognising the significance and importance of the humid tropical karst since the early 1960's, the Government of Vietnam issued on July $07^{th}$ 1962 a Decision to acknowledge Cuc Phuong as the Vietnam's first national park with special protection regulations. The Park occupies an area of 22,000 ha at the coordinates: $22^{0}14'$ - $20^{0}24'$ N and $105^{0}29$ - $105^{0}44'$ E, belonging to the administrative territory of Ninh Binh, Hoa Binh and Thanh Hoa provinces. To the NW the Park is adjacent to the Pu Luong Nature Reserve. To the SE it is succeeded by the Dong Giao limestone range which is currently violently exploited. To the SW the Park borders the Thanh Hoa plain and to the NE it borders the Red River Delta via the Hoa Lu residual karst area. The area is very typical for Vietnam's peak cluster-depression landscape. It is also the remaining fragment of the primary limestone forest that once prevailed nearby the populous Red River and Thanh Hoa plains. In this setting, a famous cave culture - the "Hoa Binh culture" has been preserved.

## 2. Tectonic setting

The Cuc Phuong National Park and its vicinity therefore has a long and complicated history of geological development since Pre-Cambrian to Quaternary, of which the most important event was the Da river rifting acted during the Triassic period.

Collision between the Shanthai and Indochina mini plates occurred in Late Paleozoic-Early Mesozoic leading to the igneous intrusions of Ba Vi, Cao Bang, Dien Bien and Kim Boi etc. complexes. In the NW of Vietnam, intra-continental rifting resulted in the formation of the Da river rift zone. The rifting started since the end of Late Permian, climaxed in Triassic and closed at the end of Late Triassic (immediately prior to Norian). Consequently a deep, NW-SE sea was established in this region, inbetween the two denuded geoblocks of Ma river in the SW and Red river in the NE. A thick, up to 10,000 m, sequence of Triassic formations had formed, starting with the basic volcanic (Vien Nam, $T_1$vn) formation, changing upward into terrigeneous (Tan Lac, $T_1$tl), Co Noi, $T_1$cn), carbonate (Dong Giao, $T_2$adg), terrigeneous-carbonate (Nam Tham, $T_2$lmt), Muong Trai, $T_2$lmt) and ending with deep sea claystone (Nam Mu, $T_3$cnm) formations. The Cuc Phuong area has been under the continental regime since Late Triassic.

During the Mezozoic and Cenozoic, Displacement of the Pacific plate to the west created a subduction zone in the eastern margin of the European-Asian plate. At the same time, northward displacement of the Indian-Australian plate resulted in the Himalayan colliding zone and the Java subsidence zone. This is also the major causes of the occurrence of the exotic alkaline-calcareous pluton-volcanic arc along the E-SE side of the European-Asian continent where Vietnam locates. As a result, a series of mafic to acid extrusions occurred in Vietnam, most typical being the vast volcanism in Tu Le with the assemblage of terrigeneous clastics, terrigeneous and volcanic rocks, changing in the upper part into intermediate, alkaline or acid composition such as riolit pocphyr, anbitophyr quartz, fezite, comendite, dacite pocphyr, comendite, trachyte pocphyr, trachyte andezite of the intrusive complexes of Nam Chien, Pia Oac, Ban Chieng, Nam Xe-Tam Duong, Pu Sam Cap and Ye Yen Sun with the thickness of over 5,000 m. Of these, the Ye Yen Sun and Pu Sam Cap complexes are of typical batholite type.

During the Cenozoic, the Cuc Phuong National Park and its vicinity, as part of the "Da river rift zone, was affected by the successive uplift, denudation and subsidence of the Red River graben, and by the subsidence of the Tonkin Gulf. As a result, this area was tilted down toward southeast and gradually sunk under the Tonkin Gulf.

## 3. Geostructure

### *Stratigraphy*

With respect to geostructure, the Cuc Phuong National Park can be regarded as a southeastern part of the "Da river rift zone". It consists of a continuous series of terrigeneous, terrigeneous-carbonate and carbonate rocks, aged Early – Middle Triassic, of the formations of Co Noi ($T_1$cn), Tan Lac ($T_1$tl ), Dong Giao ($T_{2a}$ dg) and Muong Trai ($T_{2l}$ mt) (fig. 1).

The Tan Lac formation ($T_1$tl) is mainly composed of sandstone, tuffaceous sandstone, siltstone, shale, and marl with a maximum thickness of 850 m. It is thinly to averagely bedded containing such fossils as *Entolium discites microtis, E. discites, Costatoria costata, Neoschizodus laevigatus elongates* aged Early Triassic. The formation is distributed in two NW-SE marginal strips around the Cuc Phuong area.

The Dong Giao formation ($T_2$adg) is composed in the lower part of clayey limestone, thinly bedded limestone and in the upper part of pure, moderately bedded to massive limestone with a maximum thickness of 1,100 m, containing such fossils as *Pseudomonotis (?) michaeli, Mentzelia mentzenlii, Cuceoceras cuceonse, Paraceratites subtrinodus, Daonella elongata, D. sturi* etc. of Anisian age (230 mill. years.). This formation makes up the main part of the Cuc Phuong National Park

The Muong Trai formation ($T_2$lmt) has shale, siltstone, calcareous siltstone, lenses of limestone in the lower part; and limestone in the upper part, with the total thickness of up to 800 m. Conformably overlying the Dong Giao formation, the rocks contain such fossils as *Daobella bulogensis, D. pichleri, Posidonia wengensis, Protrachyceras costalatum, P. villanovae, Rimkinites tonkinensis* of Ladinian age (232 mill. years ago).

### *Folding and faulting.*

The above described rocks form a big NW-SE trending syncline with the two limbs consisting of the Early Triassic Co Noi formation and the core consisting of the younger Middle Triassic (Ladinian) Muong Trai formation. Both limbs dip 30-45$^0$.. This syncline is further complicated by anticlines of higher order while its central part is dissected by a normal fault of the same direction. The fault also results in the abnormal contact between the Dong Giao limestone and the Muong Trai terrigeneous rocks.

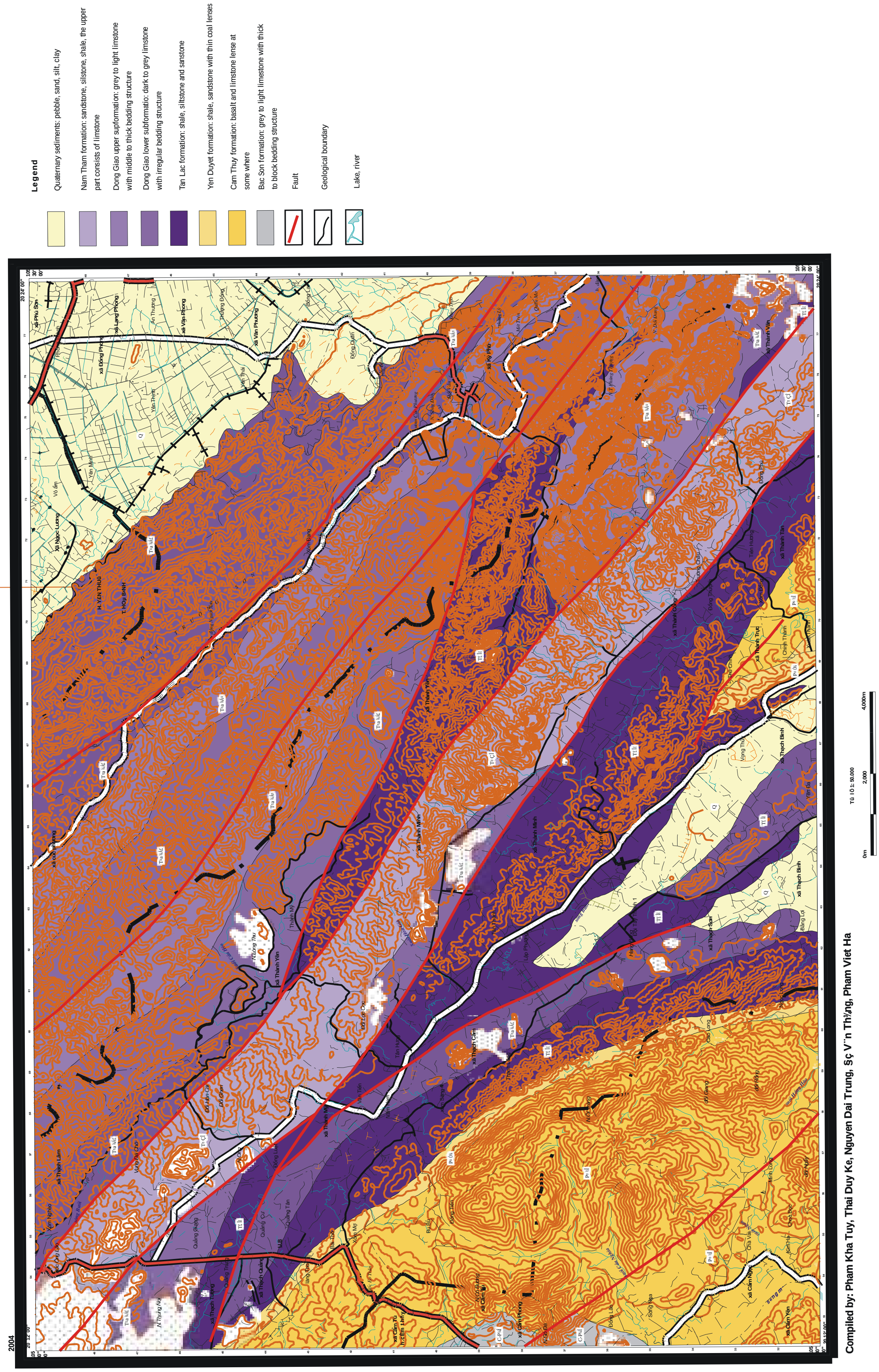



Fig 1: Geological map of cuc phuong area and it's vicinities

## 4. Hydrology

The Cuc Phuong-Pu Luong range has typical karst hydrological features. The main source of water for karstification is the precipitation (average rainfall intensity of 2,000 mm/year), as this range lies at the divide between the major river basins. The terrigeneous rocks of Tan Lac formation serve as the underlying aquitard while water is stored at the karstification depth within the Dong Giao limestone. Despite the high topography, the karst groundwater appears quite shallow in the central part of the area, sometimes exsurging directly on the ground surface. To the right of the main entrance road to the Park, one can observe some big resurgences that supply water for the locals. Some boreholes inside the Park reach water at the depth of only 30 m. The karstification depth is believed to be comparable to the Buoi river that crosses the Cuc Phuong range and serves as the local erosional base level. At this level, many karst springs can also be observed at the two NE and SW sides of the range.

## 5. Geomorphology

The Cuc Phuong area is the southeast extension of the NW Vietnam karst range that is regarded typical of the karst peak cluster-depression landscape. The karstified limestone belongs to the Dong Giao and Muong Trai formations. The peaks and closed depressions arrange themselves in the NW-SE direction in accordance with the regional geostructure. The bottom of valleys and depressions largely ranges from 20 m to 46 m while the Buoi river crossing the area is only 17 m asl. The peaks range from less than 100 m to over 500 m or 400 m on the average. The highest peaks attain 579 m, 589 m with the highest summit at 650 m (the so-called “Silver Cloud” Peak).Blind valleys are sized from less than 0.1 to several $km^2$. They tend to concentrate in topographically low NW-SE trending zones, indicating fault activity. In the area cavity collapse is not observed, implying that most depressions are formed by dissolution and corrosion. As a consequence, most dolines, closed depressions and blind valleys have slopes ranging from $30\text{-}50^0$. In some cases, steps and cliffs of outcropping limestone are observed over surfaces of 5-10 m height and some tens to 100 m length. The slopes are mostly covered with a thin veneer of clayey soil, tree roots and humus, nevertheless sufficiently fertile for the growth of vegetation. In large closed depressions and blind valleys the weathering crust can reach some tens of centimeters or more. On the bottom and slope of depressions there are numerous caves and fissures that drain water to the deeper karst aquifer.

The peaks are clustered either randomly or somewhat symmetrically in a NW-SE trend, reflecting the local geological structure. The peaks and higher parts of the slopes are often covered with micro landforms such as microkarren and karren of various types which are partly filled with reddish brown, clayey soil, humus, decayed tree leaves and branches.

## 6. Caves

There are both active and fossil caves in the Cuc Phuong National Park. Typical fossil caves include the Crescent Moon, the Con Moong, the Prince, the Spring Cheer, the Pagoda, the Ancient Man and the Water Fairy caves etc., all having their entrances lying higher than the bottom of dolines, depressions and valleys. Of these, the Water Fairy cave is located near a mountain summit indicating the corrosion work of autogenous water. . Inhabited by lots of bats, the cave has some small chambers adorned with stalactites, stalagmites and small columns. The Ancient Man cave is one of the sites that contain relics of the famous Hoa Binh culture of 12,000 year BP. Its entrances lie on steep slope at 30 m from the valley bottom. The cave has two entrances looking west and another one looking southeast. Several chambers are connected to form a nearly 200 m passage with many flowstones, stalagmites and draperies. On the bottom there are many allogenic accumulations of clay, guano and mollusc shells. At the right entrance there are 3 tombs with shells, tools, animal bones, and relics of firewood left by ancient people. The lower passage connects with another higher (about 15 m), though smaller one via an inclined way. The Con Moong cave has two entrances facing SW and SE. The SW one is at the altitude of 6 m above the valley bottom. It is about 5 m wide and 10 m high, with clay on the bottom. Four tombs of the ancient people with stone tools of the Son Vi (12,000 years BC) and Hoa Binh cultures have been found inside the cave.

## 7. Ecosystems

Although not very large, only about 22,000 ha, the Cuc Phuong National Park can be regarded as most typical of Vietnam’s humid tropical ecosystems. As stated by the New York Botanic Garden and World Wildlife Fund (WWF) Cuc Phuong and Pu Luong are one of the global biodiversity centers (Maxwell, 2000).

### *Flora*

Studies and surveys by many workers show that the Cormophytes only in Cuc Phuong already have 1944 species of 908 genera, 224 families, 80 orders, 15 classes and 7 phyla (Table 1). This corresponds to 24.6% of species, 43.6% of genera and 68.9% of families of the total number of flora species, genera and families in Vietnam (Vo Quy et al., 1996). Among these, angiosperms have the largest number of species and individuals. Some species e.g. *Pistachia cucphuongensis, Melastoma trugii, Heritiera Cucphuongensis, Brassalopsis Cucphuongensis, Scheffera globalifera, Costanopsis symtricapalata, Alysicaipus vaginalis* have been described in Cuc Phuong for the first time and remain endemic species of Vietnam.

**Table 1.** Number of Cormophyte species in Cuc Phuong-Pu Luong area (source: Le Vu Khoi, 1994; Vo Quy et al., 1996).

| Phyllum | Class | Order | Family | Genus | Species |
|---|---|---|---|---|---|
| Bryophyta | 3 | 9 | 31 | 75 | 127 |
| Psilophyta | 1 | 1 | 1 | 1 | 1 |
| Lycopodiophyta | 2 | 2 | 2 | 2 | 9 |
| Equisetophyta | 1 | 1 | 1 | 1 | 1 |
| Polypodiophyta | 3 | 7 | 7 | 55 | 129 |
| Pinophyta | 3 | 3 | 3 | 3 | 3 |
| Spermatophyta | 2 | 63 | 63 | 771 | 1674 |
| Total | 15 | 86 | 224 | 903 | 1944 |

Among the flora of the Cuc Phuong national park, some species were already present in the Neogene sediments of Dong Giao e.g. Cinnamomum balancae, Caryodaphnopsis tonkinensis, Celtis sinensis, Liquidamba formosana, Saraca dives, Amora giantea. They indicate the originality and indigenousness from Tertiary to present of the Cuc Phuong flora. In addition, the high biodiversity of the Cuc Phuong flora may also be interpreted by the convergence from the migrating currents. According to Vo Quy et al. (1996):

+ *The NW current:* is of temperate climatic characteristics from Himalayan foot and Yunnan, Guizhou with the winter-defoliated plants such as de family (Fagaceae), thich family (Aceraceae), jasmine family (Oleaceae), Du family (Ulmaceae), Ken family (Hippocastanaceae), Paris polyphylla - a species of *Carex genus*, Cyperaceae family and Platycarya strobilacea species.

+ *The SW current*: carries features from the Indian and Burmese regions with representatives of bang family (Combretaceae), cho xanh (*Terminalia myriocarpa*), cho nhai (*Anogeissus tonkinensis*), some species of the Combretum genus including bang lang family with *Lagerstroemia cornieulata* species, gao family (Bombaceae) with *Gossampinus bombax* species, bo hon family (Sapindaceae) with *Sapindus mukorossii* species, all defoliating in the dry season.

In the Cuc Phuong karst, the world of flora not only has high biodiversity but also great concentration of species with high density of biomass. Le Vu Khoi (1994) indicated that, at the bottom of some closed valleys of only some tens of ha in size there were as many as 200 species, resulting in a density of 1,000 $m^3$/ha. Flora with high diversity and density has produced in Cuc Phuong a thick tropical evergreen forest (Anh : Rung nhiet doi xanh quanh nam tren vung karst Cuc Phuong). Vu Quy et al. (1996) have distinguished 3 different types of forest in Cuc Phuong:

*Forest on bottom of closed depressions and valleys with a 5-layer canopy structure:*

*a. Over-canopy layer:* includes scatteredly growing trees 40-75 m in height, 3-4 m in circumference. Typical species are *Parashorea chinensis, Aglaia gigantea, Annetnocarva* *chinensis, Cinnamomum balancae, Thimilalia myriocarpa, Thirameles nudifora, Tetrameles nudifora*

.

*b. Ecological layer or principal canopy layer*: includes wooden trees 20-35 m in height, 1-2 m in circumference. Typical representatives are *Caryodaphnansis tonkinensis, Cinnamomum sp., Pomeria piñata*

.

*c. Under-canopy layer:* includes evergreen, irregularly growing trees 10-20 m in height. Typical representatives are *Gironniera sabaequalis, Acer decandrum, Saraca dives, Litsea amara, Horfildia prainii, Endosfernum chinensis*

.

*d. Shrub layer*: includes small trees less than 8 m in height. Some representatives are Euphorbiacae, trees of na family (Annonaceae), tea family (Theaceae) and gai family (Urticaceae).

*e. Fern and grass layer*: includes grasses and climbers covering the bottom of closed depressions and valleys with representatives from Bryophyta to Pinophyta and Magnoliophyta.

*Forest on mountain slopes with 3-layer canopy structure:*

*a. Over-canopy layer:* includes wooden trees 15-30 m high with such typical representatives as *Heritiera macrophylla, Pterospermum sp., Chukrasia tabularis, Paviesia annamensis.*

*b. Principal canopy layer*: includes wooden trees 10-15 m high, with such species as *Dimerocarpus brenieri, Teonongia tonkinensis, Arenga pinnata, Caryota bacsonensis* and some species of na family (Annonaceae) and thi familiy (Ebenaceae).

*c. Under-canopy layer:* includes small trees, srubs and herbal plants e.g. the oro family (Acanthaceae), gai family (Urticaceae), cafe family (Rubiaceae) and han family (Laportea sp.).

*Forest on top of mountains with 2-layer canopy structure*

*a. Upper canopy layer:* includes small wooden trees and bushes e.g. *Illicium griffithii, Quercus sp., Scheffera pes-avis, Dracaena cambodiana, Pleomete cochinchinensis*

.

*b. Lower canopy layer:* includes the Tre (bamboo) family (Bambusoideae), Lan (orchid) family (Orchidaceae), and Gai family (Urticaceae)

Typical ecological phenomena of the tropical rainforest can all be encountered in Cuc Phuong. Examples are the prevalence of wooden climbers with as much as 20 species from 10 families like the *Entada tonkinensis*; some as big as 20 cm in diameter and hundreds of meters in length, straddling from one tree to another. Symbioses rigorously develop with the orchid family (Orchidaceae), fern family (Fermaceae). Parasites are also abundant with the presence of tam gui (Loranthaceae). Squaring is also a very special phenomenon, e.g. the squares of the ancient sau (*Dracontomelum duperreanum*) that are 5-8 m high and 10-15 m outstretching from the trunk. After Vo Quy et al (1996), strungulation epiphytes are especially great in the Ficus and genera

***Fauna***

An adequate inventory of the fauna in the Cuc Phuong karst has not been made so far. Present studies have focused only on Chordata. Available publications show that as many as 541 species of Chordata have been booked in the Cuc Phuong-Pu Luong area (Table 2).

**Table 2.** Number of Chordata known in the Cuc Phuong-Pu Luong karst area (Vo Quy et al., 1996; Maxwell, 2000).

| Class | Number of species |
|---|---|
| Mammals | 88 |
| Birds | 319 |
| Reptiles | 39 |
| Amphibians | 60 |
| Fish | 60 |
| Total | 541 |

Of these, 88 mammal species account for 30% of the total mammal species in Vietnam. Over 50 species are of big and medium sizes. Primates predominate in the number of species and individuals. Typical primate species are *Hylobates concolor, H. leucogenys, Macaca mukata, M. artoides, M. assamensis, M, leonina, Nomascus leucogenys, N. concolor, Nycticebus pygmaeas, N, coucany, Trachypithecus phayrei, T. cristalus* etc. Some species are endemic to Vietnam e.g. *Trachypithecus francoisi delacouri, T. francoisi delacouri* is very beautiful and thus chosen as the icon of Cuc Phuong National Park.

Among the nocturnal mammals, there are two species of squirrel, one being the big flying squirrel (*Petaurista petaurista*) and the other is the furry-ear flying squirrel. The red-stomach squirrel (*Calloscirus cucphuongensis*) is endemic to Cuc Phuong. There are 38 species of bat, of which the species of Larut (*Rhinolphus rouxi*) and dotted bat (*Scotomanes ornatus*) are also endemic to Cuc Phuong.

Typical animals with claws are *Neofelis nebulosa, Felis temmincki, Panthera pardus, P. tigris, Ursus thibetunus*. The Asian tiger is considered extinctive in Cuc Phuong, but there are still some individuals in Pu Luong (Maxwell, 2000). The hoof animals are represented by *Cervus unicolor, C. nippon, Naemoiphedus sumatraensis, Mundacus mutjak* and wild pig.

Birds are plentiful with as many as 319 species, including aquatic birds in rivers, lakes and swamps in the Cuc Phuong National Park, accounting for 39.8% of the total 800 bird species currently known in Vietnam. Birds' color varies from white gray, gray, brown such as *Passer montanus, Lonch striata, L. punctulata* to gaudy such as

*Petieroconus flameus, Alcedo athis, Halcyon smymensis,* Barbet, Woodpecker. Some species are endowed with beautiful voice such as hoa mi (*Garrulax canorus*), khuou (*Garrulax chinensis*), bach thanh (*Lanius schach*) etc. Many precious bird species are in need of special protection e.g. cong (*Pavo muticus*), ga tien (*Polyplectron bicalcaratum*), ga loi trang (*Lophura nycthemera*), hong hoang (*Buceros bicornis*), cao cat (*Anthracoceras malabaricus*) etc.

Maxwell (2000) reported as many as 39 reptile species and 35 amphibian species from the Cuc Phuong-Pu Luong karst, but the real number could be more. Among these, there are some very poisonous snake species e.g. *Naja hannah, N. naja, Bunganus fasciatus, B. candidus, Thimeresurus macroaquanratus*. There are 13 species of lizards (including the flying lizard) and 3 species of mountain turtle, 60 fish species including cave species have been found. Typical cave fishes are *Lurus asotlis (L.) f. cavemicoles, Lurus cochichinensis, Silurus cucphuongensis, S. wynaadensis, Liobagrus nigricauda.* In particular, the species *Silurus cucphuongensis* is endemic to Cuc Phuong (Mai Dinh Yen, 1993).

The world of insects in Cuc Phuong is actually plentiful. As many as 1,800 species from 200 families, 30 orders have been recorded. Some species look like a twin stick, while others are as green as a tree leaf or as brown as soil etc., recognizable only when they move.In early summer, one can see countless of butterflies flying or landing like a colorful moving mattress.

***Dangers to the ecosystems***

The authorities have long been aware of the significance and importance of the Cuc Phuong karst by setting up the Cuc Phuong National Park in 1962 and issuing special protectional regulations. However, the high rate of population growth and a rapid economic development, on the background of a least developed country with the majority of population being farmers, have caused a strong pressure on the environment in general and on karst ecosystems in particular. The locals in the surrounding buffer zones continue to violate the forest for cultivation or stealing the land and forest specialties, hunting and trapping precious animals. In the last few decades, 5 species of precious animals such as the Asian tiger (*Panthera tigris*), the white-cheeked gibbon, sika deer, sambar deer, cong tien (*Pavo muticus)* have been extincted. Many other precious species in Cuc Phuong - Pu Luong such as *Trachypithecus delacouri, T. pollocephalus, T. cristalus, T. francoisi, T. phayrei, Ramopithecus avaculus, Pygaturix nemacus, Macaca assamensis, M. mulata, M. fascicularis, M. aretoides, Nyedcebus pymaceus, N. coucany, Nomascus leucogenys, N. concolor, Neofelis nebulosa, Catopuma temmincki, Yfus tibetamus, Muntiacus mutiak, Aquila heliaca, Arborophila charltonii, Picus rabiani, Jabouifleia danjoni, Chrotogale owstoni, Callosciusrus erythraeus Cucphuongensis,* wild pigs and black gibbons are in danger of extinction and listed in the Vietnam's red book.

# II. The Ha Long Bay World Natural Heritage

## 1. Position

Ha Long Bay, a meeting point of sea and land, is the karst area that once developed on land but was invaded then by sea. And the sculpturing action of sea water since Late Pleistocene times has made it a world's unique scenery. On December 2nd, 2002, in Cairns, Australia, the World's Heritage Commission (WHC) of the United Nations has recognised its global outstanding values in karst geology, geomorphology and history and entitled it to be the World Natural Heritage.

Located about 160 km NE of Ha Noi capital, the Ha Long Bay has an area of 1,553 sq. km with 1969 isles emerging above the sea surface, belonging to the administration of Ha Long city, Quang Ninh province. It can be accessed most conveniently either by the No. 5 and 18A highways or by the Ha Noi-Bac Giang-Ha Long railway..

## 2. Tectonic setting

Geologically Ha Long Bay is closely attached to the NE Bacbo and south China. Tran Van Tri et al (2003) considered it part of the Vietnam-China composite territory that has experienced a common evolution of rifting, drifting, collision and subsequent modification since the Late Pre-Cambrian throughout the whole Phanerozoic era.

Upper Pre-Cambrian formations are not present in Ha Long Bay but occur slightly further away, in Phu Tho, Viet Bac, Nam Dinh (of Vietnam), and Hainan island and Guang Dong (of China). They consist of metamorphic rocks as granulite, amphibolite and the lower greenschist facies. Movements and collisions during the Grenville orogeny united the Cathaysia craton, Yangtze-Hoang Lien Son and Indosinian blocks and made them part of the vast Rodinia continent. Subsequently the Pangaea continent broke down into Gondwanaland in the south and Laurasia in the north. The area of interest and the whole Vietnamese territory in general have a history closely related to Laurasia so that nowadays most researchers incorporate the Vietnamese territory in the SE Asia and European-Asian plates.

Major stages of crust accretion of Ha Long took place throughout the Phanerozoic. The oldest Ordovician-Silurian (approx. 455-420 ma) Tan Mai ($O_3$-S*tm*) formation consists, in the lower part, of sandstone, siltstone with interbeds of conglomerate, sericite schist, quartz schist, quartzitic sandstone, quartz-sericite schist, and quartz-sericite schist interbedded with phyllite, siltstone with phyllite, sandstone, siltstone, claystone with phyllite in the upper part, totaling 1960 m in thickness. The formation widely develops in Tan Mai area. The Co To formation ($O_3$-S*ct*) widely develops in the Co To island, Thanh Lan and many other areas of NE Vietnam. It consists of flysch sediments including tuffaceous rhyolite, turbidite, siltstone, banded siltstone, schist etc. The formation whose thickness attains as much as 2,000 m, contains fossils such as *Demirastrites triagulatus, Spirograptus turriculatus, Pristiograptus cf. regularis, Monograptus exgr. pandus* of

Early Silurian age. Since the lower boundary of these formations is not yet known, it is assumed that the age of these sediments could recede further in time.

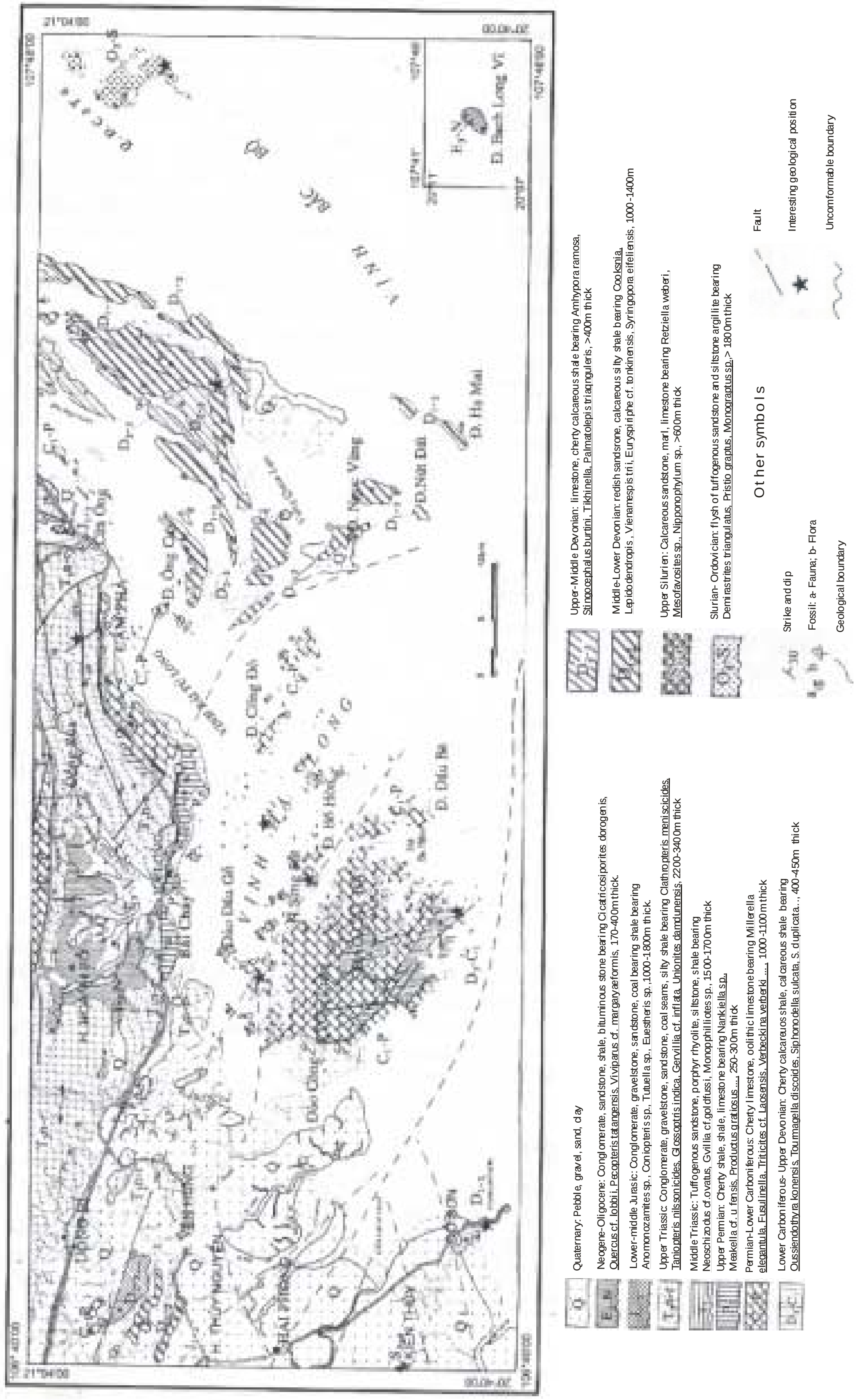


Fig. 2. Geological map of the Halong bay and it's vicinities (Tran Van Tri et al, 2003)

The Co To-Tan Mai sea appears to have been shallower to the south, hence longshore shallow marine formations can be observed in Kien An and Hai Phong areas including conglomerate, sandstone, siltstone, clayish limestone and limestone lenses. The rocks contain benthonic and coral fossils e.g. *Retziella weberi, Nikiforovaena Vietnamensis, Howellella bragensis, Schizodus kienanensis, Modiomorpha paracrypta, Mesofavosites sp., Xiphelasma sp., Nipponophyllum sp., Favosites admirabilis, F. gregalis* etc., giving Late Silurian age (425-410 ma).

Collision took place in Late Silurian, folding older sediments and giving birth to granite intrusions. Accordingly the Vietnam-China composite territory was enlarged southward.

Rifting activity together with transgression resulted in the formation of Devonian-Early Carboniferous sediments including continental and sub-continental molasse rocks, changing upward to terrigeneous-carbonate-siliceous rocks of the Song Cau ($D_1$sc), Duong Dong ($D_{1-2}$dd) series that unconformably overlying the Tan Mai ($O_3$-Stm), Co To ($O_3$-Sct) and Do Son (Dds) formations. The mentioned sediments are 1,000-1,400 m thick, forming hemicircular syncline plunging NW under Ha Long Bay, the coastal area of Quangninh, and NE in Thuy Nguyen, Hai Phong. The sediments contain abundant fossils of different types of flora and fauna such as *Lepidodendropsis sp. (flora), Eurypterid arthopods (large-fin scorpion), Zhanfilepsis vietnamaspis trii, Bothriolepsis (primary fish), Lingula aff. yunanensis, Eurispirifer cf. tonkinensis, Desquamatia desquamata, Acrospirifer sp. (brachiopod), Syringopora eifeliensis, Amphipora vatustia, Caliapora battersbyi, Amphipora ramosa, A. rudis, Stachyodes costalata (coral), Palmatolepis triangularis, P. perlobata, P. subrecta, Nothognathella abnormis, Apatognathus sp. (conodonta), Tikhinella, Eotournayella* (foraminifera) etc. Particularly in Ha Long Bay a conformable boundary between Upper Devonian-Lower Carboniferous rocks has been found with an assemblage of Famennian (Late Devonian) fossils e.g. Palmatolepis gracilis, sigmoidalis, Quasiendothyra konensis, changing upward to the set of Tournaisian (Early Carboniferous) fossils e.g. Siphonodella sulcata, S. duplicata, Parathurammina suleimanovi, Syringopora distans. These are the outstanding scientific arguments for regional and global value of Ha Long Bay.

The Late Paleozoic or Carboniferous - Permian (340-260 ma) was a time that Ngo Thuong San (1965) considered relatively quiet. A shallow sea covered vast areas in Indochina and South China bringing favorable conditions for the formation of a series of terrigeneous, terrigeneous-carbonate and carbonate rocks with a thickness of 1,500 m. Classified as the Bac Son (C-$P_1$bs), Da Mai (C-$P_1$dm) and Cat Ba ($C_1$cb) formations, these are the limestone series that created the present topography of Ha Long Bay and Cat Ba island.

The Bac Son formation is made of the following strata, from the bottom to the top: (1) siliceous and clayey limestone, 20-25 m; (2) recrystallised limestone, 50-100 m; (3) oolithic limestone, 40-70 m; (4) coarse grained limestone, 200 m; (5) oolithic limestone, 250-400 m; (6) massive limestone, 100 m; (7) bituminous limestone, 70-90 m; (8) massive limestone, 150-200 m; (9) massive limestone containing organic matter, 50 m. In

Halong Bay one can see the inclined, horizontal or ripple layers of limestone. Research by many authors have divided these into 13 foram biozones including: (1) Uralodiscus - Glomodiscus; (2) Endothyranopsis - Pseu-doendothyra; (3) Millerella - Eostaffella; (4) Profusulinella; (5) Fusulinella-Fusulina; (6) Obsoletes-Protriticites; (7) Triticites-Daixana; (8) Schwagerina; (9) Robusto-schwagerina; (10) Misellina; (11) Cancellina; (12) Neoschwagerina; (13) Lepidolina-Yabeina.

Rifting and displacement again took place in Late Permian, creating in NE Bac Bo the so-called An Chau-Song Hien (Hien river) intra-continental rift. The rift is filled with assemblages of acid volcanic formations, tuffaceous conglomerate, agglomerate, gravelstone, sandstone, siltstone, claystone with thickness of 1,685 m, containing Early Triassic fossils e.g. *Lyptophiceras cf. multiformis, Dieneroceras sp., Anokashmirites sp., Claraia wangi, C. stachei, C. clarai, C. vietnamica, Liptophiceras sp., Koninkites cf. vidarbha, Eumorphotis inaequicostata* etc. They change upwards into 1,200 m of siltstone, sandstone, shale, black limestone of Na Khuat formation ($T_2$nk), containing Middle Triassic fossils e.g. *Kellnerites samneuaensis*, *Neoschizodus orbitacularis, Langsonella elongata, Mysidioptera gigantea, Vellopecten albertii, Costatoria proharpa, C. pahangensis, Trigonodus sandbergeri, T. trapezoidalis, T. zamoidai* etc. Further up are the terrigeneous rocks of Mau Son formation ($T_3$cms), 1680 m in thickness, consisting of conglomerate, sandstone, gravelstone, red siltstone, calcareous sandstone, marl, black shale, containing Late Triassic fossils e.g. *Utschamiella perlonga, U. elliptica, Tutuella nuculiformis, Genvilla aff. G. praecursor, Euestheria minuta, Sphaenestheria sp. exgr. S. kawazakii, Balleiichthys (?) sp*

.

In Late Triassic i.e. immediately prior to Norian, Dovjikov et al (1965) indicated that strong collisions and compressions led to granite intruding orogeny, folding and faulting, with sea receding at the same time from most of Vietnam territory. Along Highway No. 18, on the western side of Ha Long Bay, faulting activity led to the formation of a great graben, the so-called “Hon Gai graben”. The graben stretches in between the Trung Son fault in the north and the Highway No. 18 fault in the south, with subsidence reaching 3,430 m, compensated by deposition in continental-lagoonal-coastal marsh environment of alternating strata of conglomerate, gravelstone, coal seams, shale, coaly shale (Hon Gai formation, $T_3$n-rhg). In total, 39 coal seams of industrial value and 19 others of less value, with mining reserve of 1 billion tons have been defined, making it the most important coal district of Vietnam. The fossil flora is renowned for its diversity, with 192 types, including 62 local types. Typical types are *Clathropteris menisciodes, Podozamites lanceolatus, Taeniopteris nilssonioides, T. spathulata, T. jourdyi, Didymophyllum nathorstii, Thaumatopteris remauryi, Cycadites saladini, Glossopteris indica, Asterotheca cottoni, Pecopteris tonquinensis, Pterophyllum portali, P. inconstans, Eoblattina obscura*, *Otozamites obtusus*, *Anomozamites gracilis* etc. Fauna fossils are represented by e.g. *Gervillia cf. inflata, Thracia sp* etc.

After the coal-forming stage in Hon Gai, red continental sediments of Ha Coi ($J_{1-2}$hc) formation were deposited in the adjacent area to the north of Ha Long, including a 1,186-1,850 m complex of red conglomerate, gravelstone, sandstone, siltstone and claystone, containing Early-Middle Jurassic fossils e.g. Anomozamites sp., Coniopteris sp., Podozamites sp., Czekanowiskia cf. rigida, Cladophlebis haibwenensis, Sagenopteris sp., Phoenicopsis sp etc. The above formation is observed in Van Hoa island, Cai Bau, Tien Yen, Dam Ha, Ha Coi and Mong Cai.

During the Late Jurassic-Cretaceous, strong subduction took place at the contact between the Pacific and European-Asian plates. It gave rise to the formation of the East Asian active marginal continental zone characterised by mountainous topography and the occurrence of an exotic calcalkaline plutonic arc. Accordingly along the Tonkin Gulf shoreline, the coastal zone of China, and the West Pacific shoreline in general, one can observe plenty of intrusive rocks and the contrasting mountainous topography.

In the Cenozoic, Fromaget (1941) saw a clear role of Himalayan orogenic movements that strongly influenced the Indochinese structural framework. Due to that collision, shear faults accompanied by subsidence occurred further to the east, of which the Red River fault and the Tonkin Gulf subsidence are typical examples. This fault was active during the whole Cenozoic, resulting in a compensating basin with fluvial-deltaic-lagoonal sequences as thick as 5,000 m in the Red River delta and 18,000 m in the center of Tonkin Gulf. Gas of industrial value was found in Thai Binh, Tonkin Gulf while petrolith and asphaltite were found in Hoanh Bo and Bach Long Vi (tail of a white dragon) island.

Finally, about 40,000 years ago, the sea invaded the mainland, forming the Ha Long Bay.

**3. Geostructure**

Ha Long Bay is part of the “Quang Ninh anticlinorium” (Tran Van Tri et al, 1977). This structure occupies most of Quang Ninh province and the southern margin of Hai Phong city. It borders with the An Chau intra-continental rift-type superimposed depression in the north and the Red River- Tonkin Gulf young subsidence region in the south. It is composed of the following Paleozoic formations: Tan Mai ($O_3$-Stm), Co To ($O_3$-Sct), Kien An ($S_3$ka), Do Son (Dds), Cat Ba ($C_1$cb), Bac Son (C-$P_1$bs), Bai Chay ($P_3$bc), and Mesozoic formations as the Binh Lieu shield ($T_2$bl) and Hon Gai ($T_3$n-rhg). Main anticlines of the anticlinorium are composed of the Tan Mai and Co To formations with an E-NE trending axis. Main synclines are made of the younger Bac Son formation. A more detailed division of the Ha Long area was made by Tran Van Tri et al (2003) with the Van Don monoclinal uplifted block, the Ha Long subsided synclinal block and the Cat Ba anticlinal uplifted block. Boundaries between these blocks are NW-SE, NE-SW and sub-parallel faults

**4. Geomorphology**

Ha Long Bay - a wonder of the Creator and worldwide famous beauty spot - is at the same time a typical humid tropical karst landscape invaded and sculptured by sea, yielding numerous magnificent islands seen as floating on the sea surface. The geomorphologist Le Duc An (1972) has proposed the term “Ha Long karst type” to name this distinctive karst type.

Waltham (1998) indicated that karstification has started in Ha Long Bay in the Miocene (20 ma), with 5 stages of evolution: (1) formation of ancient plains; (2) formation of doline-depressions; (3) formation of conical hill clusters; (4) formation of high isolated pyramids with vertical scarps; and (5) formation of new plains.

However, the above mentioned tectonic analysis shows that karstification in Ha Long Bay could have started much earlier. After the Bac Son (C-$P_1$bs) and Cat Ba ($C_1$cb) limestones had formed, places under sea cover could become the mainland. Especially in Late Triassic, after the Hon Gai coal-forming stage (Hon Gai formation - $T_3$n-rhg), the sea withdrew completely from Vietnam territory in general and the Ha Long area in particular. Under these conditions, limestone emerged from sea surface and was further subject to continental denudation including karstification. Perhaps pulsating uplift during the whole Mesozoic and Cenozoic has governed the Ha Long karst development. In particular, the presence of the uplifted and subsided blocks directly influenced the formation of Ha Long-type landscapes. The Ha Long syncline subsided block has been the main cause of the formation of Ha Long-type karst with scarped islands dotting the sea surface; the Cat Ba uplifted block resulted in the peak cluster-depression landscape in the island; and the Van Don uplifted block resulted in the formation of the peak cluster-depression landscape in Quang Hanh.

So, before the sea invaded in Late Pleistocene-Holocene different karst types including peak cluster-depressions ("Fengcong", Yuan Daoxian, 1991) had existed in Cat Ba, Quang Hanh, in Ha Long Bay and its vicinity. There were dolines, closed depressions, valleys, and sinkholes at their bottom. These low landforms vary in form, shape and size, with round, distorted or elongated projections, height from less than 10 m to less than 100 m; bottom covered with a thin layer of reddish brown clay and humus. The peaks are often conical, pyramidal; sometimes forming clusters or ranges. Their top surfaces often have karren and microkarren. In most cases the peaks are seen with slopes from less than $20^0$ to $40\text{-}50^0$, outcropping or covered with a thin veneer of brown clay and humus. The vegetation cover on the bottom and top of hills is the tropical evergreen rain forest. At the same time, karst residual hills or pyramids that emerged on the plain surface also exist in Ha Long area ("Fenglin", Yan Daoxian, 1991). This type of karst is popular in South China and very common in Vietnam e.g. in Hoa Lu, Ninh Binh, Thanh Hoa, Quynh Luu, Trang Kenh, Hai Phong etc. In forming this type, in addition to erosion and resolution of limestone by rain water, mechanic erosion of river water and erosion-corrosion of karst aquifers in residual limestone massifs also play important role. Due to these actions, the limestone massifs decrease in size, while their slope increases, leading to the formation of vertical cliffs on the more and more developed plains. The karst residual hill-plain landscape is established.

Thus, before the sea invaded Ha Long, the karst residual hill-plain landscape already existed. Research by Tran Van Tri et al (2003), Tran Duc Thanh (1998), Le Duc An (1996) indicated that the formation of Ha Long Bay has undergone 6 stages: (1) Starting in Late Pleistocene-Early Holocene, sea began crawling to Tonkin Gulf, bobbing into the southern Ha Long Bay at 8,000-7,000 years BP; (2) Maximal transgression took place approx. 7,000-4,000 years BP, forming the entire Ha Long Bay; (3) Sea regression 4,000-3,000 years BP, with the arising relief and sporadic lateritisation; (4) Ingression again 3,000-2,000 years BP, reopening Ha Long Bay; (5) Ha Long Bay narrowed down, with development of mangrove marshes, sedimentation in many places by the Red and Bach Dang rivers; and (6) Ha Long Bay tends to enlarge in the last 1,000 years due to the rise of ocean water and daily tidal currents.

Evidence of transgressions and regressions is recorded also by notches and sea levels on the limestone island cliffs, with traces of shells, mussels and sea worms. Some $C^{14}$ isotopic analyses show different ages of organisms at different sea levels (table 3).

Tran Van Tri et al (2003) interpreted that position of the sea level was not only due to the fluctuation of water but also caused by local tectonic movements.

When invaded by sea, karstification in Ha Long Bay became more complicated. In addition to the erosion by rain water, limestone is also mechanically and chemically

**Table 3.** Data on the times of lowering sea levels in Ha Long Bay (source: Doan Dinh Lam & Boyd, 2002).

| Location | Level | Isotopic dating |
|---|---|---|
| Hon Cau Ngu | 3.50 m | 2,280 ± 60 a and 3,820 ± 50 a |
| | 4.25 m | 3,280 ± 60 a |
| | 4.55 m | 4,100 ± 50 a |
| | 4.85 m | 4,990 ± 90 a |
| | 4.90 m | 4,050 ±140 a |
| Hon Dau - Gieng Cut | 7.05 m | > 40,000 a |
| | 7.80 m | 32.960 a |
| Quang Hanh | 5.30-5.50 m | 4,420 ± 70 a |
| | 9.10-10.10 m | > 40,000 a |

corroded by sea. This process is strongest in zones under tidal influence. Accordingly, residual limestone massifs are corroded and quickly sculptured, forming porches, or as Tran Van Tri called, “sea vaults”. The shelter-like water marks surrounding the limestone residual massifs make them look like mushrooms with a small stalk below supporting a large head above. Hon Ga Choi (the fighting-cock island) gives a very typical look of this phenomenon

Another action of sea is the tide erosion. Ha Long has a daily tidal regime, with the range between high and low tides being as much as 4 m. Tidal recession results in underground flows cutting the sea bottom to make narrow but prolonged channels. These channels often develop at the base of karst valleys that already existed before the sea invaded. One more visible action of sea is the leveling seabed by sedimentation. The karst dolines, depression and valleys before the sea invasion had their bottom at different heights. When the sea invaded, deep depressions were filled up with marine sediments.

The sea bottom has therefore become comparatively flatter and their depth decreased from less than 5 m in the near shore to 10-15 m in the isles offshore.

*Morphology of island and depressions:*

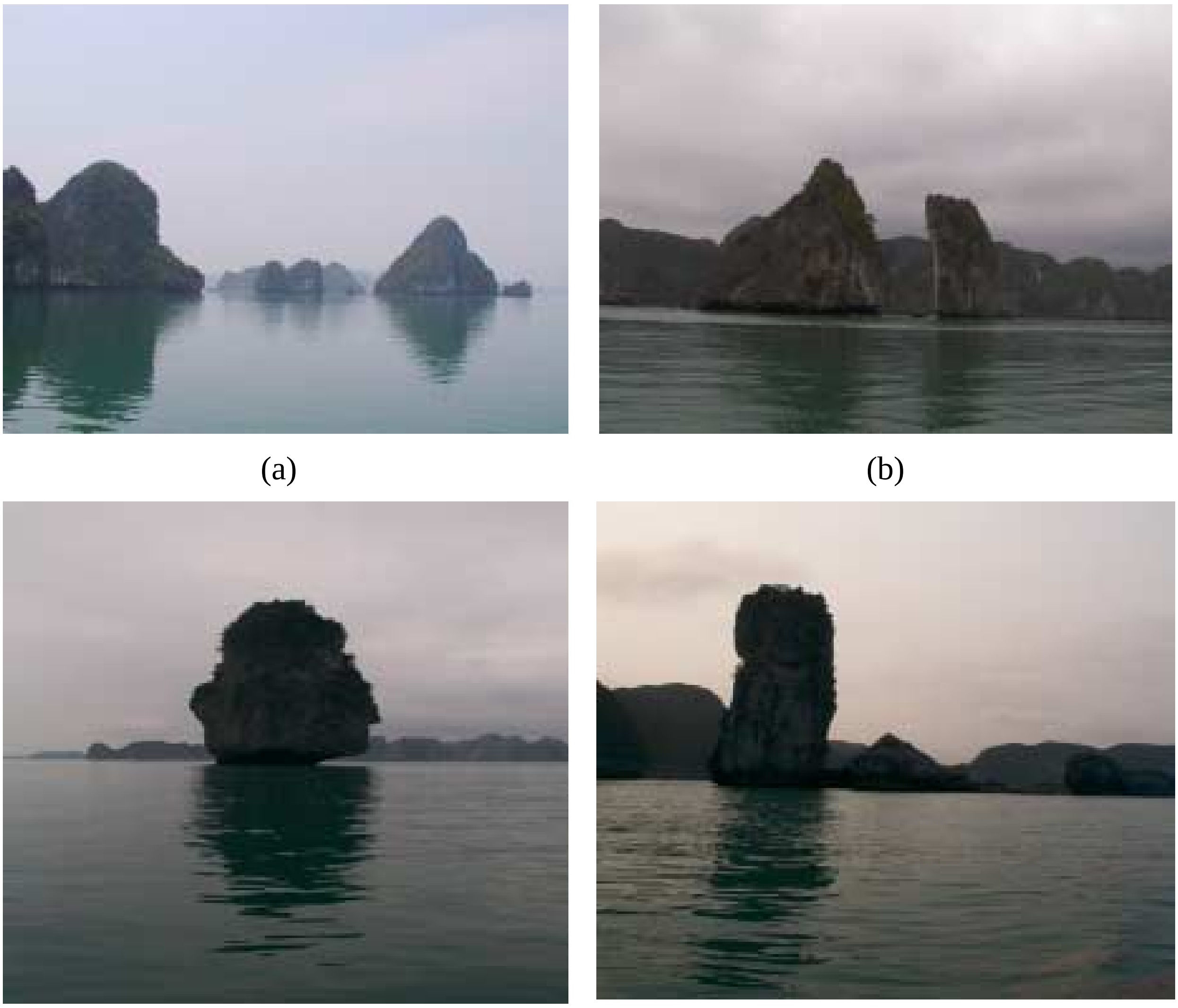
In the area of 1,550 $km^2$ of Ha Long Bay, 1969 large and small islands have been counted with a density of 1.27 island per sq. km. Among these islands, the extremely small (0.0001 to 0.01 sq. km) and very small (0.01 to 0.1 sq. km) make up 91.8% of the total numbers but only 25.79% of total island area. There are only 7 islands larger than 1 $km^2$ in area, and the largest is the Hang Trai Island (4.613 $km^2$). The areal ratio of island/water is 1/9. Tran Van Tri et al (2003) used the K coefficient (proportion of the island heights over their bottom radii) and I coefficient (the ratio between number of the isolate and connecting islands) to calculate the occurrence frequency of the conical, pyramidal, and domal islands. He commented that the further from shore, the more the conical islands are separated from one another. He further showed that the value of I is ranging from 0.12 to 2.40. The island height largely ranges, from less than 10 m to over 200 m. The height tends to stand at 3 levels: 140-220 m, 50-130 m, and 10-14m.

A ratio between number of the isolated and connected islands (K) of Ha Long Bay averages 0.7, i.e there are as much as 70% of isolated islands. The isolated islands are dominated by pyramids with a height greater than bottom diameter; the conical and domal islands have a height smaller than bottom diameter. And the connected islands often concentrate in clusters reflecting the peak cluster-depression landscape and peak forest plain had once originated on the mainland, only later invaded by sea

The islands have a rugged karren topography; their slopes are mostly vertical. The notches near sea water level are mostly concave to make the porches or vaults of as deep as 5-7m. The researches have discovered the ancient sea levels at 2.0-2.5 m, 3-5 m, 7-8 m, and 9-12 m on the Ha Long's islands. The islands are isolated as the mushrooms, the pyramids emerging from sea surface with thousands of shapes and sculptures that make Ha Long a stunning beauty. Dolines and closed depressions occur in areas where there are connected islands. Most of them are symmetric, elliptical or semicircular and of less than 5m deep. Those submerged by water and encircled by pyramidal and conical islands are called "ang". In Ha Long there are 62 ang. Typical are the Tremoi (pouting) ang of 0.7ha, 1-3m deep, the Rem tung of 28.8ha with blue water. Karstic valleys inundated by sea water are called "tung". In Ha Long, Catba there are 57 tung; typical are the Gau (bear) tung of 220ha, Mayden (dark cloud) tung of 1.5ha.

**5. Caves**

Investigation and exploration of caves in Ha Long has not been promoted, but so far as many as 24 caves have been checked out. On the whole they are the old (or fossil) caves that had been formed before the sea invasion. It can be imagined that there could be many caves on various limestone islands but submerged under water, or their entrance filled up with young sediments. Tran Van Tri et al (2003) relied upon the sea levels to classify the caves in Ha Long: level 1 includes the caves of 3-5m high directly related to the present sea level; level 2 includes the caves of 5-15m high; level 3 includes the caves of 25-30 m (fig.3).



(a) (b) (c) (d)

**Photo 1:** Some different limestone islands of Ha Long Bay: (a) Dispersally distributed in further the shore, (b) Concetrated distributed in near the shre, (c) Notches corroded by the sea, and (d) in the form of "pilar".

*The caves of level 1*: lie slightly higher than the present tidal fluctuation. There, the role of the sea clearly stands out in forming new caves and modifying existing ones. There have not been experiments testifying of the erosion rate of limestone by sea water, but field observations can show that close to the current sea level, almost all island slopes are corroded by sea water strongly deepening the notches to make them as Tran Van Tri et al (2003) explained "the sea vault". Average penetration of water into the vaults is 38m deep, and 3-4m high surrounding the islands. It is assumed that the present sea level has existed during the last 1,000 year i.e. the erosion rate of sea water can reach as much as 3-5mm/ year, and 8-10 mm/ year somewhere. If the porches and sea levels are solely the products of the sea, then "sea vaults" are an indication of the enforcement by sea water of pre-transgression caves. Sea water enlarges the chambers, lengthens them, and bites the flowstones in the caves. Typical of this type are Ho Ba Ham (lake of three vaults) that is a complex of 3 caves linking 3 saline lakes with one another and getting through to the sea, in which the outmost one is 150 m long and 10 m wide; the Bo Hon cave of 50 m long standing only 2m above the high tide.

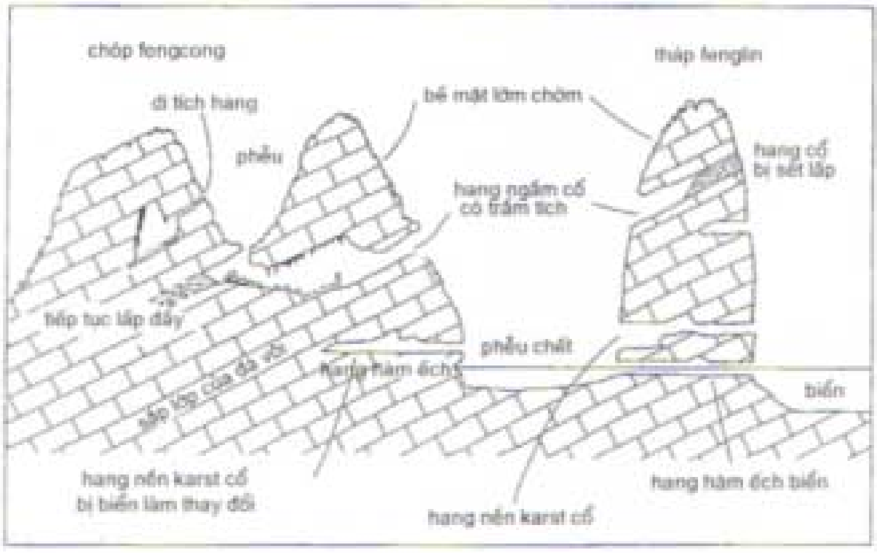



**Fig. 3.** Cave types in Ha Long (Tran Van Tri et al., 2003).

*The caves of level 2:* In this level the porch-like caves include only fossil caves that had occurred before the sea invasion and were subsequently enlarged by sea corrosion. Different from level 1, the caves of level 2, the sea could not have destroyed and corroded all flowstones in the caves probably because sea water had not stayed long. As a result, there are many flowstones in the caves. Typical are the Trinh Nu with the ceiling as high as 12m (compared to the present sea level), 80 m long, many stalactites, draperies in the caves; or the Bo Nau cave of 70 m long, where remained many flowstones.

*The caves of level 3*: include fossil caves beyond reach of the sea water. Accordingly, all the pre-transgression cave formations are preserved intact like stalactites, stalagmites, draperies, clay, guano… These caves have not been the dated so far but it is assumed that those are the caves formed before the Holocene, may be even in the Pliocene. Giant flowstones witness wet periods in the past; accelerated karstification has also increase the growth rate of flowstones. Most typical of these old caves is the system of Thiencung (Paradise palace) – Daugo (Wooden head). It can be considered as the biggest in Ha Long. The Thiencung cave is composed of one big chamber of over 100 m long, 20-60 m wide, its bottom not being very flat. A highlight of Thiencung is that speleothem formations are much developed including mainly calcite, aragonite in big and clean crystals, the microcrystal or cryptocrystals mixed with clay. These speleothems display odd looks and irregular dimensions; stalactites and stalagmites meet each other becoming columns. The shape of flowstones is really fantastic and of numerous appearance upon which one can imagine a series of mystical legends. Moreover, the speleothems in Thiencung are very big, reflecting abundant precipitations in the past.

(a)

(b)

(c)

(d)

**Photo 2.** (a, b) Caves of level 1, (c) Cave of level 2, and (d) Cave of level 3.

The Daugo (wooden head) cave (or Giaugo – concealing wood) connects to Thiencung by a small passage; but the Daugo itself is a single-room cave with an area of nearly 100,000 $m^2$. The bottom is slightly depressed compared to the entrance which is 12 m high by 10 m wide lying midway of the slope. From the cave looking out to the gulf one can see the wading islands, sometimes dotted with the brown sails somehow like the islands. How poetic and charming it then looks speleothem formations are much developed including mainly calcite, aragonite in big and clean crystals, the microcrystal or cryptocrystals mixed with clay. These speleothems display odd looks and irregular dimensions; stalactites and stalagmites meet each other becoming columns. The shape of flowstones is really fantastic and of numerous appearance upon which one can imagine a series of mystical legends. Moreover, the speleothems in Thiencung are very big, reflecting abundant precipitations in the past.

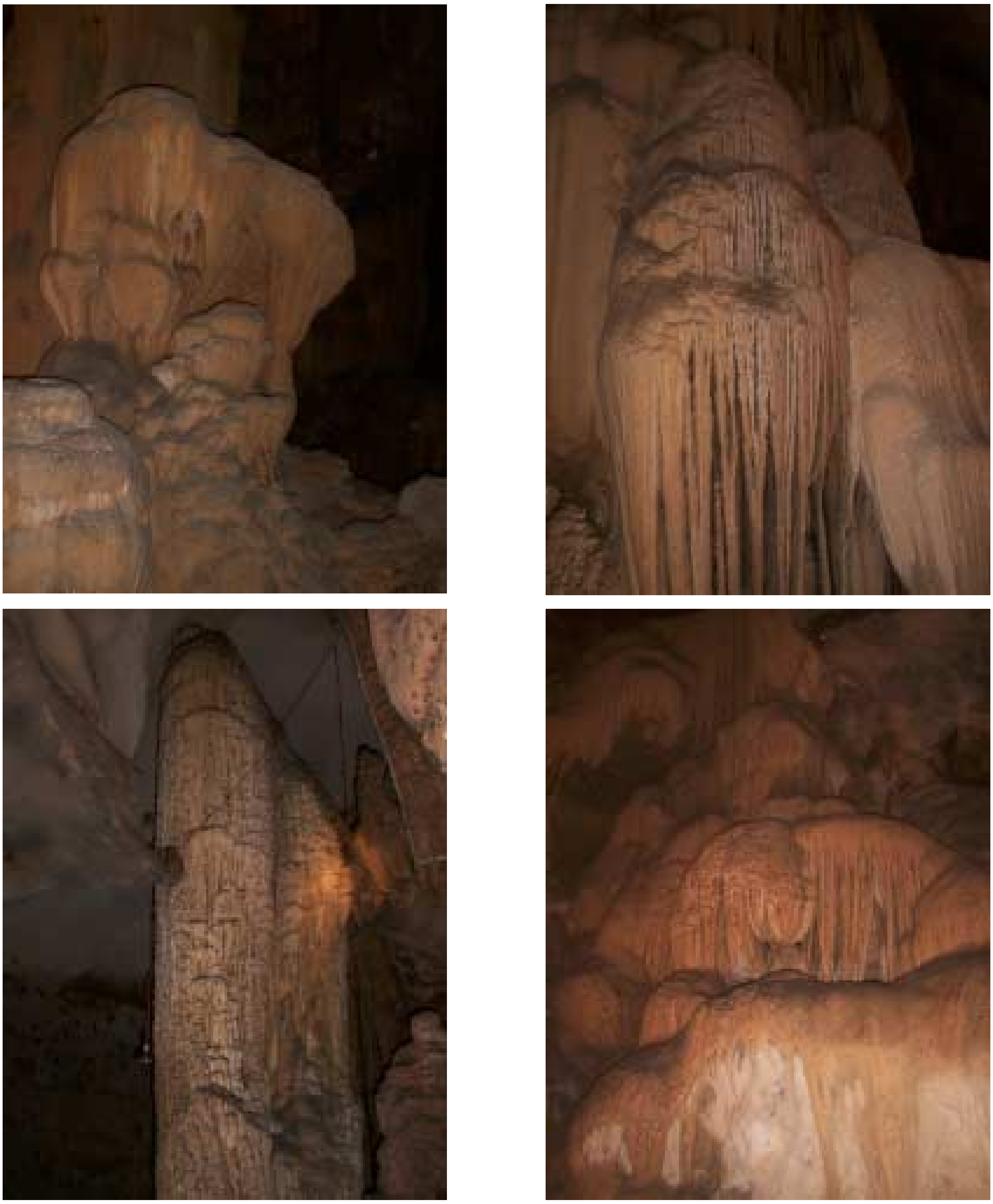


**Photo 3.** Big stalactites and Stalagmites in The Thiencung cave

The Daugo (wooden head) cave (or Giaugo – concealing wood) connects to Thiencung by a small passage; but the Daugo itself is a single-room cave with an area of nearly 100,000 $m^2$. The bottom is slightly depressed compared to the entrance which is 12 m high by 10 m wide lying midway of the slope. From the cave looking out to the gulf one can see the wading islands, sometimes dotted with the brown sails somehow like the islands. How poetic and charming it then looks

**6. Ecosystem**

Ha Long Bay has been twice recognised by UNESCO as the World's Natural Heritage not only because of its appealingly majestic landscape with thousands of eccentric islands on a sea blue surface, but also because of its distinctive value of culture, history, geomorphology, and the specific ecosystem. According to many people Ha Long Bay carries a great potential of biodiversity. It is an important resource needed to be preserved and protected for sustaining the ecological balance for the whole region. It is composed of two major ecosystems which are the tropical evergreen forest and the marine – coastal systems.

*a. Ecosystems of tropical evergreen forest*

*a. 1. Mainland flora :* There has not been an adequate inventory of flora species so far in the Ha Long Bay area. By overall observation there are more than 1,000 flora species. According to the World Natural Heritage Management Board of Ha Long Bay (2002) the Ha Long and Baitulong tropical evergreen forest have 477 orchid species, 12 fern species, and 20 mangrove species. In fauna there are 4 amphibian species, 8 reptile species, 4 bird species, and 14 mammal species. The flora speices unevenly distribute on the islands. Some plant communities according to Nguyen The Hiep & Kiew (2000) include:

Mangrove forest in the muddy beaches around some islands and in the muddy tidal beaches. When tide rises most of the forests are inundated; when tide lowers, the roots are bare. The root system shaggily comes down as the bell supporting the trees from falling down. Most typical of this community is the mam tree (Avicennica marina), su tree (Aegiceras corniculatum), and the dang tree (Rhizophora stylosa). Dang and su have the bivalve grain shot on the trees, when falling to the mud it quickly grows to a new individual

**Photo 4.** The mangro forest in Ha Long Bay.

*Seashore plants:* according to Nguyen The Hiep & Kiew (2000) this is an onshore flora community without evidence of the mangrove community species. Plants grow on the sand beach around some isles and not inundated by tide. Typical species are tra lam chieu (*Hibiscus taliaceus*), hep cay (*Scaevola taccada*), ho da thit (*Hoya balancea, H. canosa*), xuong rong (*Euphorbia antiquorum*), tiet canh (*Sarcostemma brevistigma*). These are the herbal climbing, and scattered bushy species on the sandy beaches.

*Slope flora community:* On the slope of the rocky islands there is usually the plantation cover including the evergreen trees with a height of 1-2m such as mang kien (*Pterospermum truncatolobatum*), ngoc nu (*Clerodenron tonkinense*), rau ong lao (*Clematis cadmia*), mong bo thom (*Bauhinia ornata*), cay sang (*Sterculia lanceolata*). Beside the wooden trees are also seen the climbers such as thu hai duong (*Begonia bosiana*), gieng nui (*Alpina calcicola*), khoai nua hoa chuong (*Amorphophallus paleoniipolius*), nhai Ha Long (*Jasminum alongse*), sung Ha Long (*Ficus alongensis*), mong tai Ha Long (*Impatiens Ha Longensis*)

(a)

(b)

**Photo 5**. (a) Flora on the limestoe slope, and (b) Smoetime big tree has been seen

*The cliff flora community:* Thos are the species hanging over limestone cliffs. Their roots are firmly penetrated in the cracks to support the trees from falling down and take nutrition. Only some species can survive on such severe conditions. They include the endemic species of Ha Long. Typical species are hai ve nu hoa vang (*Paphiopedilum concolor*), kho cu dai tim (*Chirita drakei*), thien tue Ha Long (*Cycas tropophylla*), phat du nui (*Dracaena cambodiana*), xuong rong (*Euphorbia antiquorum*), aand tiet can (*Sarcostemma brevistigma)*

The peak mountain flora community: includes the small, bushy, thorny and climbing species scattering on the mountain peaks. Some typical species are kho cu dai nhung (*Christa hiepii*), kho cu dai Ha Long (*Christa alongensis*), and Ha Long palm (*Livistona alongensis*) as high as 10 m

*The cave entrance and fissure flora community:* Since there is some soil sifted by the cliffs into the entrances of caves and fissures, plants grow. There are trees as high as

10 m with broad canopy such as bong moc (*Boniodendron parviflorum*), quao nuoc (*Dolichandrone spathecea*). Besides, there are herbal species growing in half-dark places such as kho cu dai moc (*Christa hamosa*), la han (*Stinging tree*) that are very poisonous.

The outstanding values of Ha Long plants: When observing Ha Long's plants, Nguyen The Hiep & Kiew (2000) assumed that the richness in genera, species as well as number of individuals itself produces a biodiversity here. In which, there are the extremely rare species. There are species which have just been discovered such as *Alpinia cacicola, Cycas tropophylla, Livistoma halongensis, Christa hiepii, C. halongensis, C. drakei, Impatiens halongensis*. These are endemic to Ha Long i.e. they can only accommodate with the natural conditions of the limestone isles in Ha Long that are not seen elsewhere in the world.


**Photo 6.** Forest on the islands of Ha Long

Some species have a canopy structure and nice-looking trunks and branches to make bonsai such as hue nu hoa vang (*Paphiopedilum concolor)*, thien tue Ha Long *(Cycas tropophylla),* phat du nui (*Dracaena cambodiana*), sung Ha Long (*Ficus halongensis*).

Some species of high economic value such as tra lam chieu (*Hibiscus tiliaceus)* with fibres to make mattress, leaves of bau dat tai tree (*Gynura auriculata*) and fruit of vang lo tree (*Maclura cochinchinensis*) which can be eaten, climbing tea (*Secamone elliptica*) which produces refreshing tea. Some species can serve as treatment or nutrient medicine such as ngu gia bi Ha Long (*Scheffera alongensis*)

*a.2. Fauna:*

*Mainland fauna includes:*

*Invertebrates:* An observation by Tung (2003) assumed that in Ha Long Bay, invertebrate animals had a global importance with the diversity in genera, species and a high rarity and endemicity. Research is still in progress. Cave invertebrates of Ha Long are considered as one of the richest spots of the world. There are more than 20 known species  Crustaceans are abundant and there are many endemic species.

Terrestrial and freshwater molluscs show a special diversity and a high endemicity. 130 shell species have been found. In Sungsot cave only, 14 species have been found, which can therefore be considered as the richest spot in cave shells. There are as many as 60 endemic mollusc species. Some typical species are *Diplomatinidae sp., Sonoennae sp., Haloptychius diespter, Diplomatina sp., D. fulva*

Amphibians and reptiles have not yet been studied.

Mammals have not been adequately checked out. After Michelle Tung's information, in a 4 day survey, IEBR has recently recorded the presence of 4 bat species, 8 rodent species, 2 carnivorous species, 2 primate species, 2 hoof species. Species in danger listed in the world's redbook are *Macaca aretoides, Capricornis simatraensis, Lutra lutra.*

*Birds:* Ha Long Bay is home to many big black kites (Milvus migrans) and the biggest white-abdomen osprey (*Haliacetus leucoaster)*. The eastern horny-beak black feather (*Anthracoceras albirostis*) is the showcase of the big fruit-eaten birds such as blue pigeon, king's blue pigeon, pale-head pigeon. Sparrows are presently recorded.

*b. Marine and longshore ecosystems*

*The wetland and marine ecosystems:*

*b. 1. Wetland ecosystem:*

The Ha Long Bay management board (2002) has divided the wetland ecosystem in Ha Long and vicinities into 6 ecological types such as:
Ecosystem of tidal zone: Mangrove develops well in Ha Long and is a favourable habitat to many animals. There are 169 hairy worm species, 90 fish species, 20 bird species, 5 reptile species, and 6 species of other animals.

Ecosystem of the hard bottom, corals: Presently 170 coral species of the 9 orders have been inventoried in Ha Long. Hard coral has 122 species, constituting the main reefs in the bay. Reefs are the habitats to 130 bivalve species, 55 hairy worm species, and 57 crab species. Reefs are also the filter of the marine environment.

Ecosystem of tung and ang: Ang is a closed water area between the islands, tung is a channel having a mouth to the sea where it is usually not turbulent, suitable for the dwelling and growth of organisms. Only in the Ngon tung, for instance 65 coral species, 40 benthonic species, 18 seaweed species have been found.

Ecosystem of soft bottoms: This is the community of sea grass with 55 species and home to many other species in which there are 17 species of seaweed (of the 91 seaweed species in Ha Long Bay), 41 species of benthonic animals, 3 hairy worm species, 29 mollusc species, 9 crustacean species.

Ecosystem of tidal beaches without mangroves: includes the organisms in the low tide zone among which there are bivalve molluscs and sea worms.
Man made ecosystems for the economic objectives: Man has invaded the sea by dyking, pooling for breeding fish, crab, culturing weed, or making the cages culturing fish, lobster, pearl shells, oysters…

*b. 2. Marine ecosystems:* including many plant and animal species:

*Plant plankton:* These are the small plants floating in water that can photosynthesize. Presently 185 species have been known, especially in Cua Luc there are 64 species.
Animal plankton: These are the small animals floating in water playing the second role after plant plankton in the food series yielding the primary productivities in the Ha Long sea. 104 species have presently been inventoried.

*Benthos:* These are the animals attached to sea bottom. 980 benthonic species are currently known in the Ha Long – Catba sea. There are 300 mollusc species, 200 hairy worm species, 170 coral species and 13 echinoderm species.
Free swimming animals: These are the animals who can freely move in water. Presently there are 326 species inventoried of self-migrating animals among which are 313 fish species, 10 reptile species, and 3 marine mammal species (Ong Ngu fish – Neophocaenoids, Ca Heo (delphin) – Orcaella brevirostris, and humpback delphin – *Sousa chinensis*).

# III. Catba Island

## 1. Position

The Catba area lies north of Haiphong, and is 150 km from Ha Noi. It is an island district of the Haiphong city.The Catba island is located in the west side of the Tonkin Gulf bordering on Ha Long Bay in the north-northeast. To the west is the sea and Bachdang estuary with river mouths of funnel-like shape such as the Hot, the Lemon, the Lachhuyen, the Namtrieu river mouths. To the south-southwest is the open sea of Tonkin Gulf. Total area is about 15,200 ha of which the mountain takes 9,800ha, sea area is 5,400ha. Catba has been acknowledged as National park with large humid tropical wetland ecosystems with a high biodiversity. Catba can be accessed by railway, motorway, and airway. The first gathering is in Haiphong, then one can travel to the island by boat or canoe.

## 2. Geostructure

Catba island is part of the Quangninh anticlinorium; to the north, it contacts with the depression block of Ha Long syncline; to the south it contacts with the young subsiding zone of Red river. The island itself has the structure of a complicated anticlinorium.

***Stratigraphy***

Phohan formation ($D_3$-$C_1$ph): One of outstanding geological values of Ha Long is the discovery of conformable boundary between Late Devonian and Early Carboniferous in this formation. Phohan formation is divided into 3 parts. The lowest part is averagely to thickly, or massively structured limestone with small to average grain texture, black or dark gray color, 100-150 m thick, containing the Late Devonian fossils such as Amphipora laxefenforata, *A. patokensis, var.micro, Uralinella bicamerata, Shuguria flabelliformis, Pihelli tubiformis…*

The middle part is limestone, siliceous limestone, silicites, clayey limestone and calcareous schist. The rock is thinly bedded with black to dark gray color, 150-200 m thick. In the formation, have been found the Late Devonian fossils such as *Camarotoechia cf. batalensis, Cyrtospirifer sp., Septaglomospiranella compressa.*

The upper part is siliceous rocks interbedded with schist, lenses of limestone, siliceous limestone; the rock is black to dark gray, thinly bedded, 150-250 m thick. In which, the Famennian to Early Carboniferous fossils such as *Lingula aff. yunnanensis, Cyrtospirifer aff. subparallella, C. chaoi, C. aff. whitneyi, C. aff. triplisisosus, Camaratoechia cf. batalensis* have been found.

The base of the Phohan formation is undefined, the top is overlain by the Catba formation. Because of the discovery of Famennian and Tournaisian fossils and the

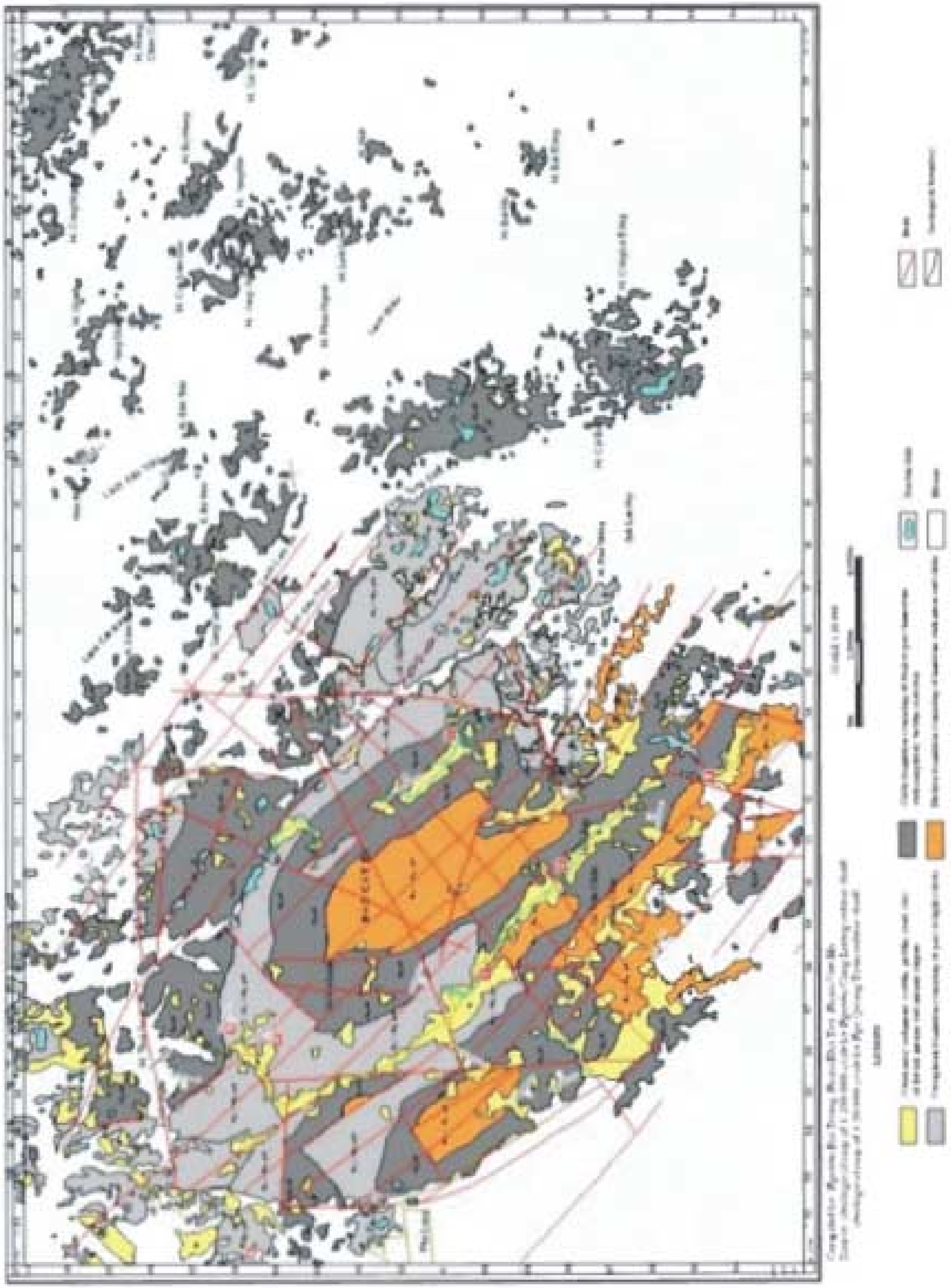


Fig 4. Geological map of the Catba island

relation with the Catba formation, its age has been determined as Late Devonian – Early Carboniferous ($D_3$-$C_1$). Rock of this formation most largely outcrops in the island center in an elliptical shape with the great axis in NW-SE direction of over 5km long, the small axis in SW-NE direction of about 2km wide. Additionally the formation is also observed outcropping in two NE and SW margins of the island embedding the island central dome. The SW strip is in Minhchau – Phohan, Lienhoa, Chantrau. The NE strip is in Viethai. Besides, the formation also distributes in strips of NW-SE direction in the south-southeast part of the island.

Catba formation ($C_1$*cb*): This is the major component forming the island. Rocks belonging to this formation are observed in many places forming strips that embed the central core of the Phohan formation ($D_3$-$C_1$ph). The Catba formation includes two parts.

The lower part consists of cryptocrystalline limestone of gray to dark gray color. Layering varies from below 10cm to 1m, interbedded with lenses or intercalations of siliceous rocks or marl. Many fossils have been found such as *Syringopora geniculata, Schizophoria cf. resupinata, Cyclocyclicus aff. tieni, Parathurammina procushmani, Septaglomospira-ella grozdilovae, Chernyshinella disputabilis, Septatournayella questida, Dainella nucula, D. uralica, Spinoendothyra ukrainica, Corforchina moelleri (Mol.)*.

The upper consists of pseudo-oolithic limestone with black to dark gray color, averagely to thickly bedded or massive, with frequent calcite veins. Locally dolomitized. Containing many fossils such as *Endothyranopsis crassa sphaerica, Archaediscus sp., Midiocris breviscula, M. mediocris, Eostaffela mosquensis, Globoendothyra insigra, Spinoendothyra cf. spinosa, Coendothyranopsis sp., Asteroanchaediscus rugosus, Costaffella (Costaffela) sp., C. prisca.*

Specified thickness is 450 m. Since the Catba formation unconformably overlies the Banpap ($D_1$e-$D_2$gbp) and Phohan ($D_3$-$C_1$ph) formations and confirmed by the presence of the above mentioned fossils, its age is defined to be Early Carboniferous ($C_1$).

Quanghanh formation ($C_2$qh): This formation is most widespread in the SE of Catba island. In the Tungau and Lanha straits, and in Gialuan area in the north island, it encircles the core of the Catba fold. The Quanghanh formation consists of limestone also including two parts:

The lower part consists of gray and pale to bright-gray limestone, thickly bedded to massive, cryptocrystalline. This limestone is rather pure. Some samples exhibit 100% of calcite. Many fossils have been found such as *Mediocris ovalis cupelaeformis, Millenella cf. uralica, Pseudostaffela cf. antiqua, Pseudoendothyra struvei, P. angulata, Asteroarchaediscus bashkiricus, Neoarchaediscus greorii, Profusulinella parva, P. rhomboides, P. regia, Schubertella toriyamai, Sch. obscusa, Costaffella postmasquensis acutiformis, Ozawainella pararhomboides, Fusulinella cf. pseudobecki.*

The upper part consists of pseudo-oolithic limestone of pale-bright gray color, cryptocrystalline, thickly bedded to massive. Many fossils have been found such as

*Pseudostaffella cf. quadrata, Fusulinella cf. tupica, Schubertella pseudoglobosa, Sch. lata, Pseudoendothyra arcuata, Neofusulinella sp., Rugosofusulina sp., Fomichvella cf. linguriensis.*

Total thickness is 550 m. The Quanghanh formation conformably overlies the Catba formation and is unconformably overlain by the Hongai formation ($T_3$n-rhg). The above-mentioned fossils give a Middle Carboniferous – Permian age ($C_2$-Pqh).

***Fold characteristics***

As presented above, the Catba island is a component of the Quangninh anticlinorium. Tran Van Tri et al. (2003) named it the Catba uplift block . On the whole, rocks on Catba island form an anticlinorium consisting of alternating anticlines and synclines with a constant axis direction of NW-SE. The first subordinate anticline in the SW part of the island contains in its core rocks of Phohan formation ($D_3$-$C_1$ph) which outcrops in two locations of Hienhao and Catdon, Xuandan. The flanks are composed of the Catba ($C_1$cb) and Quanghanh ($C_2$-Pqh) formations. In the SW at ang Coi, Phulong its end rather beautifully exhibits the limestone strata of Catba and Quanghanh formations bending toward the northwest holding the core of the Phohan formation. Due to the presence of a fault, this end is complicatedly broken.

A second subordinate anticline lies in NE Catba island. This anticline does not expose the core of Phohan formation but only the Lower Catba sub-formation ($C_1$cb1). Surrounding the core are the rocks of Upper Catba sub-formation ($C_1$cb2) and the Quanghanh formation ($C_2$qh). Unlike the subordinate anticline in the SW, perhaps because of faults the plunging end of the anticline is not observed here.

The major anticline of Catba island has a core of the Phohan formation ($D_3$-$C_1$ph) outcropping in a rather large area, approx. 1,000 ha. Surrounding the core are the rocks of Catba ($C_1$cb) and Quanghanh ($C_2$-Pqh) formations that make an oval with great axis in NW-SE direction and small axis in SW-NE direction. The convex end of the anticline with parallel beds plunging NW is rather well preserved.

Between the major anticline in the island center and the two subordinate ones in the SW and NE parts of the island are two synclines, whose cores are all composed of Quanghanh formation ($C_2$-Pqh), and the flanks are the rocks of Catba ($C_1$cb) and Phohan ($D_3$-$C_1$ph) formations. Axes of synclines all develop in NW-SE direction.

Catba has an anticlinorium structure with short fold axis. This clearly differs from the linear narrow folds, as observed in the Da river rift zone. Since having a shortened structure, dip of strata on the island is generally gentle, often ranging from below $10^0$ to $20$-$30^0$. At some places along the fault zones inclination can rapidly increase but this is only local and does not reflect the general characteristics of the fault.

***Fault characteristics***

Together with folds, faulting activity is rather clear, obviously complicating the fold structure as well as influencing in the island topographical development. The main fault systems are NW-SE, NE-SW, sub-meridian and sub-parallel. The principal fault system displays a NW-SE trend. It includes an assemblage of 16 parallel faults. These faults displace the strata and deform the fold. Morphologically they control topographical development, create the elongated valleys such as the one from the NW via the center to the SE part of the island, from Gialuan to north Caba town. That fault valley looks like a big cut through the island. At the same time, they form the elongated straits submerged under water that the locals named "tung" such as Angke, Dauxuoi…The NE-SW system is less well displayed than the NW-SE system and at the same time less continuous. Especially in the core of the Catba anticline, the NW-SE and the NE-SW faults meet each other producing there a lattice network.

The sub-meridian fault system is even less developed. In the island there was observed only one fault through Gialuan – Hienhao, and another one through Giaida isle – Catba town – Namhong isle. The relationship of this fault system with the NW-SE one is not clear but it appears that they are dextral strike-slip faults with nearly vertical fault plane. The sub-parallel fault system is dimly exposed. Currently only one fault has been discovered in the north side of island. It does not displace the strata but it seems to control the formation of Ngan channel and a channel in north Gialuan. Certainly the activity of the above-mentioned faults is an important reason of the occurrence of the fractures on limestone of the island, facilitating the karstification.

**3. Geomorphology**

Catba area with the big island of Catba and surrounding small isles is a typical peak cluster-depression landscape invaded by the sea. Average elevation is 150 m asl, in which the highest peaks are Caovong peak of 320 m, an unnamed peak in south Gialuan of 305. There are many peaks of approx. 300 m which gradually lower from NW to SE. The surrounding sea is not more than 1-3 m deep in the west, northwest, and north; in the southeast and east depth of seabed increases from 1-2 m to 10-15 m at 1-2 km from shore. In the mouth of Lanha strait, the depth reaches 16-19 m; depth of seabed reaches more than 200 m when 5 km from shore.

With the exception of some narrow zones in Catba national park with the denudation topography on calcareous claystone, siliceous limestone belonging to the middle part of Phohan formation, all the big island of Catba and the surrounding isles consist of karstified limestone of the Phohan, Catba and Quanghanh formations.
On the Catba Island the two main negative landforms that are commonly seen are the closed depressions and elongated valleys.

On the closed depressions, their plan is normally symmetric, oval, or distorted with surfaces from some ha to some tens of ha; no case of depression over 50 ha has been seen. The depth to the bottom of the closed depressions is from some tens to over 200 m. Depressions due to cavity collapse are mostly absent, gradual corrosion appearing as the main karstification process. As a result, the depressions often have variable slopes. The bottom may display outcrops of limestone bedrock or may be covered with clay, humus, sometimes forming crusts. Of course there are sinkholes draining rain water.

**Photo 7.** Peak cluster-depression karst of mainland origin of Catba

The most prominent elongated valley is the one cutting through the island from the NW in Gialuan via Chantrau to Catba town of nearly 20 km long; its width changes from 100 to over 500 m. The depth to the bottom decreases from 40 m to less than 10 m in Chantrau. The valley bottom is rather flat; it is covered with a thin reddish brown clay. In the rainy season there are the temporal streams. Both sides of the valley are marked by limestone cliffs. Besides this main island-through, on Catba there are many other valleys in Hienhao, many valley segments in Xuandan, Lienminh, Minhchau, Tailai, Viethai, Trabau, ang Ke…. Furthermore in Catba many short valleys of NE-SW direction are observed at Doi 2 of Hienhao commune, NW Dinh hamlet of the Xuandan commune, Ngoai hamlet of Gialuan commune, ang Vong of Viethai commune.

For all the elongated valleys in Catba, a sound relation with the NW-SE and NE-SW fault systems is observed. Faults created the breaking zones in limestone favoring a quick karstification leading to those valleys. And the more or less symmetric closed depressions also exhibit a genetic relation with both limestone stratigraphy, extending NW-SE, and tectonic structure, with nodal points of NW-SE and NE-SW trending faults.

The peaks in Catba include the common types of scattered peak clusters and associated peaks in the prolonged ranges.

The scattered peak clusters are common and typical. In morphology, they are normally pyramidal, conical and raised domes. Their plan is somewhat symmetric. Between the peaks and peak clusters are closed depressions. Height difference between the peak and valley bottom varies from some tens to over 100 m. The peaks expose limestone bedrock with rugged karren and microkarren. Walking on this karst exposures is actually difficult.

The type of prolonged associated peaks often closely relates to the valleys; they distribute on the two sides of valleys. Despite this arrangement, the peaks do not produce continuous prolonged strips as the on the denuded non-karstified mountains, but appear as rugged indentations. The 'sawteeth' are irregular with scarps sometimes widely exposed, then giving way to slopes down to the valley bottom.

The isles around Catba big island possess a similar topography. The closed valleys that are submerged under sea water are fringed by the isles named "¸ng" by the locals. Dimension of these depressions is not large from a few ha to some tens of ha; depth is from nearly 1 m to 3-4 m. The valleys invaded by sea to form straits or channels are named "tïng" by the locals. Typical channels are as Gialuan, Angke, Angle, Tunggau, Langha, Lanha, Lachtau… Their depth is often fairly great, among which the Lanha – Lachtrau is deeper than 10 m.

Like in Ha Long, Baitulong bays, the isles arround Catba become smaller in size and decrease in number when getting away from the central big island. Their height is from some tens of meters to over 200 m; they have the odd look, almost vertical slopes, with deep corrosion levels reflecting that a mainland karst has been invaded and modified by sea

**Photo 8.** Central valley of Cat Ba

## 4. Caves

A general observation on caves in the Catba karst is that it is an area of well-developed caves which mostly are old (fossil) with horizontal or slightly inclined floor. The caves are produced by dissolution, corrosion of autogenous rain water during the karstification. Some caves only have one room while others have several chambers connected to each other to form passages of conduits.

In a short survey in Catba carried out by the project: "An assessment of the status of karst environment in some key region of Northern Vietnam", the research team has explored and mapped 8 caves (Table 4).

All the caves do not lie higher than bottom of depressions and valleys; and they are almost horizontal. Among the surveyed caves, the Trung Trang is longest (271.40 m) and unfinished. This is a horizontal fossil cave with entrance of 3.8m wide, 2.3m high. Getting inside is a series of continuous rooms; the widest place can be 8m; average is 3-5m; the narrowest place is only 1.1-1.5m. Ceiling is 3.5m of average height. Some chambers have ceiling of over 8m high. Ceiling has stalactites; there is some mud and clay on floor.

**Table 4:** The caves in Catba explored and mapped in 2003.

| No. | Cave | Length (m) |
|---|---|---|
| 1 | Trung Trang | 271,40 |
| 2 | Quan Y (Army health) | 100,35 |
| 3 | Gieng Ngoe (Frog's Well) | 120,20 |
| 4 | Thien Long (God's Dragon) | 148,10 |
| 5 | Cau Cang (Quay) | 93,00 |
| 6 | Dia Dao (Tunnel) | 43,00 |
| 7 | Da Hoa (Marble) | 111,80 |
| 8 | Bo Doi (Solders') | 64,60 |

The Da Hoa (marble cave) has a total length of 111.80 m including two big rooms and a connecting passage. The floor is rather flat; ceiling is 10-11.5m high. Feature of this cave is that the flowstones are well developed forming systems from ceiling (stalactites), from bottom (stalagmites), or columns connecting bottom with ceiling. Many flowstones with giant size reflect the mature karstification stages in the past. Flowstones are pure calcite. The sparkle under light and their odd looks are the inspiration for magic tales.

## 5. Ecology

Catba is also one of the typical addresses for the humid tropical karst ecosystems, and of a vennue between land and sea.

*Plant systems on mainland limestone:* According to initial inspection, 620 species from 123 families of Cormophyte have been found. Among these, there are species of precious woods and specialities of high value. The precious woods to be protected and developed are cho dai (Annomocarya chinensis), trai li (Garcinia fagracides), lat hoa (Chukrasia tabularis), dinh (Markhamia sp.), kim giao (Podocarpus fleurgi), and nuoc (Salix tetrasperma), lim xet (Peltophorum tonkinensis), and Bacson palm (Caryota bacsonensis).

Forest mattress: The Catba forest is of “the low zone tropical evergreen seasonal rainforest”. It can be divided into 3 main types which are forest on limestone, mangrove, and forest of inundated limestone.

Forest on limestone can further be subdivided into forest on bottom of closed depressions with multi-layer canopy, high biomass, many big trees of 1-2m in diameter and 20-30 m high or more. The forest on slopes of mountains has a 3-layer canopy with many big trees of 10-20 m high.

The forest on peaks includes the small and bushy trees. In Catba, on some closed valleys grow precious plants such as kim giao (Podocarpus fleuryi).

Mangrove: includes the su, vet, duoc, and other saline plants on the muddy tidal beaches in the north island of Phulong commune and west Gialuan. Su and vet trees usually grow in thick forests. The trees have a root system as bells passing through the mud for steady support of the trees.

**Photo 9.** Forest in Cat Ba

Forest on inundated limestone mountains: these are the trees rooted to rocks but inundated by tide. This type grows in the straits such as the Frog's, the Inner Flood's, the Outer Flood's, the Rededa, the Caycau… Typical of this type is the va nuoc tree (*Salix tetrasperma).*

*The Mainland fauna system:* Catba possesses a rich diversity of animal species. There have been 20 mammal species, 69 bird species, 20 species of reptiles and amphibians inventoried. Among these, the white-headed gibbon or so-called Catba gibbon (*Trachypithecus policcephalus*) is endemic to Catba and IUCN has enumerated it as one of the most endangered primate species in the world. According to Roswitha Stenke and Chu Xuan Canh (2003) in an article presented in a seminar on biodiversity of the World's Ha Long Natural Heritage on 23-24 December 2003 of the Ha Long Management Board, there are nowadays 59 individuals of Catba gibbons (additionally 4 more individuals); there are 9-13 mature male individuals, they are inhabiting the hanging cliffs near the shore. They are split in flocks averaging 3.7 individuals. There are also flocks composed solely of females which do not give birth nor grow in numbers. The conservation of Catba gibbon is getting promising results. In 2003, 7 individuals were born.

Together with the white-headed gibbons, many other mammal species need protection such as wild goats (Capricornis sumatraenis), yellow monkeys (Macaca mulata), duoi lon monkey (Macaca nemestrina), red-face monkey (Macaca arctoides), deer (Cervus unicolor), black squirrel (Rafufa bicolor), and hedgehog (Hystric hegdsoni). Birds, though not so diverse as in Cuc Phuong and Ha Long, include many beautiful species such as cao cat (Anthracoceras malabaricus), kingfisher (Ceryle rudis insignis), red-face hut (Aethopyga siparaja), and khuou (Garrulax sp.)…

*Marine animals:* In the sea area of Catba, a large number of sea animals have currently been recorded including 900 fish species, 500 mollusc species and 400 crustacean species. There are species of high economic value. Endemic species include lobster (Palinurus sp.), bao ngu (Haliotis ovina), vem (Mytilus sp.), oyster (Arca granulosa), pearl shell (Prinetada margarifera), tu hai (Lutrarina philipinarum), turtoise (Eretmochelys imbricata)… There are also dolphins (Delphinus sp.) in the straits or channels around the island.

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