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# Chrono-ecological vegetative assemblage and historical development of Neogene and Neogene-Quaternary floras of Vietnam

Trinh Dzanh

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Nine chrono-ecological vegetative assemblages are recognized in the Neogene and Neogene-Quaternary of Vietnam based on the evidence of megafossil plants. The assemblages may be referred to four developmental epochs : Middle-Late Miocene, Late Miocene, Pliocene and Pliocene- Early Pleistocene. The detailed composition and the spatial and geographical distribution of each plant assemblage are discussed.

**Key-words**—Chrono-ecology, Megafossils, Neogene, Quaternary (Vietnam).

Trinh Dzanh, National Geological Museum of Vietnam, 6 Pham NguLao Str., Hanoi, Vietnam.

सारांश

वियतनाम के पश्चनूतन एवं पश्चनूतन-चतुर्थक युगीन वनस्पतिजातों का ऐतिहासिक विकास एवं कालानुक्रमिक-पारिस्थितिक शाकीय समुच्चय

त्रिन दान्ह

गुरुपादपाश्र्मों के प्रमाणों पर आधारित वियतनाम के पश्चनूतन एवं पश्चनूतन-चतुर्थक कल्प में 9 कालानुक्रमिक पारिस्थितिक समुच्चय अभिनिर्धारित की गई हैं। ये समुच्चय 4 विकासीय चरणों से सम्बन्धित हैं जो मध्य-अनंतिम मध्यनूतन, अनंतिम मध्यनूतन, अतिनूतन एवं अतिनूतन-प्रारम्भिक आदिनूतन के नाम से विदित हैं। इस शोध-पत्र में संरचना तथा प्रत्येक पादप समुच्चय के भौगोलिक वितरण आदि की विवेचना की गई है।

IN Vietnam, the Neogene continental sedimentary strata are widely distributed, well developed and exposed with abundant fossil plants preserved therein. During the Neogene, marine sediments and lagoonal, deltaic ones were restricted in the large coastal basins and in the shelf. In Neogene sediments, coals, bituminous rocks, oil and gas, kaolin, etc., frequently occur. In southern Trungbo (southern of Central Vietnam) there were frequently volcanic activities. This is why Vietnam serve as a good place for studying floral succession and climatic change.

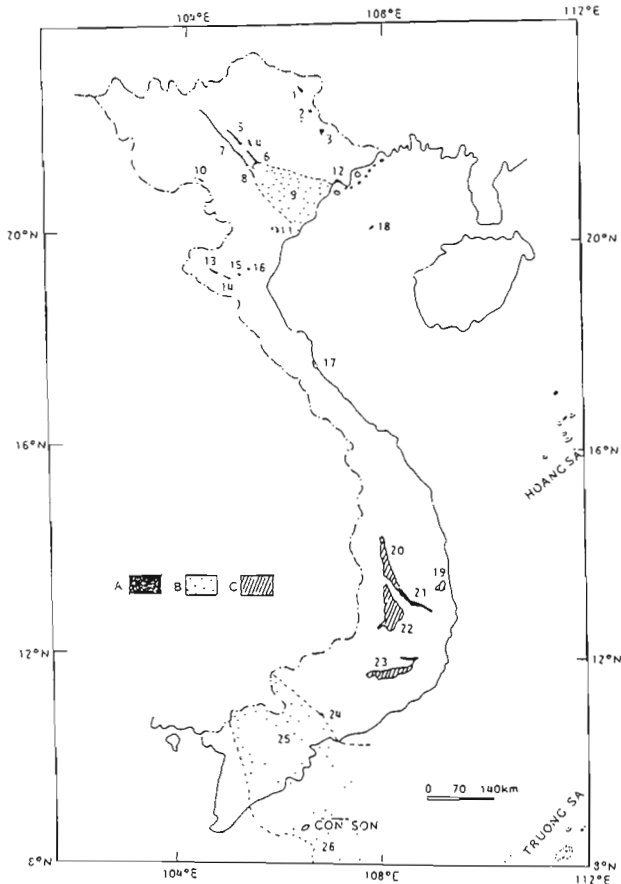
The present paper is based on the megafossil plants to follow the chrono-ecological vegetative assemblages and historical development of Neogene and Neogene-Quaternary floras of Vietnam.

## CHRONO-ECOLOGICAL VEGETATIVE ASSEMBLAGES

In Neogene and Neogene-Quaternary of Vietnam there are following nine chrono-ecological vegetative assemblages :

### 1. The Middle-Late Miocene assemblage of humid subtropical forest vegetation

This assemblage is known from the Phuoc Formation of Hanoi depression and named as *Ficus beauveriei-Ulmus longifolia* assemblage. It consists of 36 species belonging to 18 families; among them, 33 species (17 families) belong to Magnoliopsida and 3 species (1 family) to Liliopsida.



**Text-figure 1**—Distribution of Neogene Basins in Vietnam: A- Neogene deposits cropping out in the areas. B- Neogene deposits covered by Quaternary sediments. C- Neogene deposits covered by Pliocene-Pleistocene basalt.

1. Caobang, 2. Thatkhe, 3. Naduong in Northern Bacbo; 4. Tuyen-quang, 5. Lucyen, 6. Phanluong, 7. Yenbai, 8. Phutho in Songlo-Songchay-Songhong; 9. Hanoi depression in Bacbo Plain region; 10. Hangmon, 11. Donggioa in Southwest Bacbo; 12. Hoanhbo on the northern edge of the Bacbo plain; 13. Curarao, 14. Khebo, 15. Donphuc, 16. Vietthai in North Trungbo; 17. Donghoi in Central Trungbo; 18. Bachlongvi Island in Bacbo Gulf; 19. Vanhoa, 20. Gialai-Kontum, 21. Ba River Valley, 22. Buonmathuot, 23. Djilinh-Baoloc in South Trugbo; 24. Bamieu in East Nambo; 25. Cuulong depression in West Nambo, 26. Namconson Depression in South Vietnam continental shelf.

This assemblage contains Lauraceae (23%), Moraceae (15%), Ulmaceae (8%), Juglandaceae (5%) and Poaceae (8%). Among them, *Ficus beauveriei* Zeill., *Ulmus longifolia* Ung., *Acer hilgendorffii* Nath., etc. are much predominant.

The assemblage is composed of two ecological groups as follows :

The group of humid subtropical evergreen plants covers more than 90 per cent of the assemblage composition. The main representatives are *Ficus*

*beauveriei* Zeill., *F. lanceolata* (O. Web.) Heer, *Ficus* sp. (Moraceae), *Ulmus carpinoides* Goepf. (Ulmaceae), *Acer hilgendorffii* Nath. *A. tricuspidatum* (Sternb.) Heer (Aceraceae), *Artocarpus* sp. (Artocarpaceae), *Rhus triphylla* Ung. (Anacardiaceae), *Populus balsamoides* Goepf. (Salicaceae), *Juglans* sp., *Carya* sp. (Juglandaceae), *Diospyros brachysepala* A. Br. (Ebenaceae), *Quercus* cf. *lobbii* Ett. (Fagaceae), *Laurophyllum* sp. 1, *Neolitsea magnifica* (Sap.) Takht., *Cinnamomum* cf. *lanceolatum* Heer (Lauraceae), etc. Generally, these plants are the indicators of humid and warm climatic conditions.

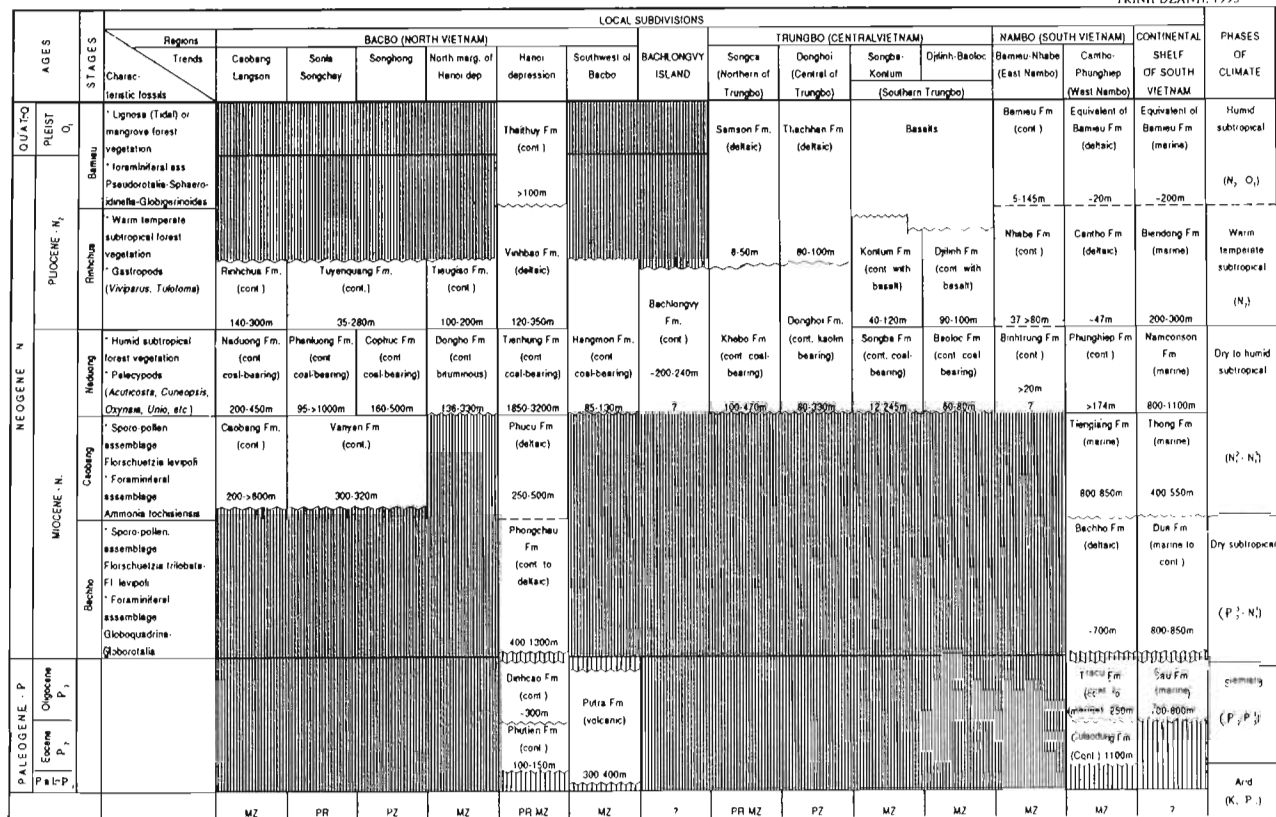
The group of swampy and coastal plants consists of less than 10 per cent of the assemblage. It is composed of representatives of Poaceae, Salicaceae, Clusiaceae, remains of which were conserved in the form of phytolite.

## 2. The Late Miocene assemblage of the dry subtropical forest vegetation

The assemblage is identified at first at Naduong region and named *Quercus* aff. *parceserrata-Laurophyllum* assemblage with 14 forms belonging to 8 families. The fossil plants are usually imprints of leaves, sometimes carbonized trunks. Rarely these imprints are associated with the small fresh-water molluscs such as *Unio* sp., *Viviparus* sp. In this assemblage dicotyledons played a dominant role. The representatives of Fagaceae (37.5%) and Lauraceae (29%) predominated. Amongst them the most abundant species are *Quercus* aff. *parceserrata* Sap. et Mar. (12%) and *Laurophyllum* sp. 1 (12.5%). The assemblage also consists of three ecological groups :

The group of dry subtropical plants from the promontane forests reaches more than 80 per cent of the assemblage composition. This group is composed of Lauraceae, Ulmaceae, Cercidiphyllaceae and Rosaceae. The main species of which are *Quercus* aff. *parceserrata* Sap. et Mar., *Q.* aff. *lantenosii* Col., *Laurophyllum* sp. 1, *Cercidiphyllum* sp., *Ulmus longifolia* Ung. and *Pecopteris totangensis* Col.

The group of swampy and coastal plants is monotonous and occupies only 16 per cent of the assemblage composition. The plants of this group belong to Poaceae and Potamogetonaceae. They are usually *Arundo goeppertii* (Muenst.) Heer, *Phragmites oeningensis* A. Br., *Graminiphyllum* sp., and *Potamogeton* sp. Besides, *Ulmus longifolia* Ung., some remains of musci and *Selaginella* sp. (4%) are



Text-figure 2—Stratigraphic correlation of Neogene deposits of Vietnam.

also present. These forms are rare and conserved badly.

The plants of two ecological groups are also known from Caobang (assemblage *Quercus-Castanea*), Thatkhe (assemblage *Apocynophyllum-Castanea*), Nagiao-Hopthanh (assemblage *Asplenium-Quercus*), Khebo (assemblage-*Rhamnus*). However, these assemblages are usually monotonous.

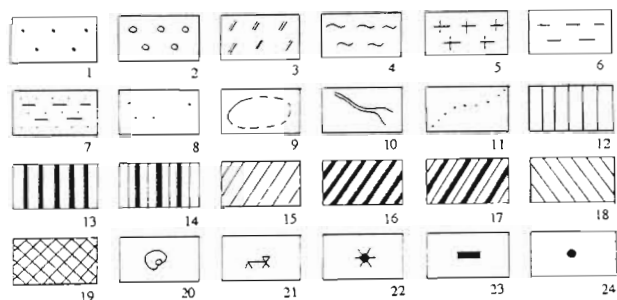
The group of mangrove and coastal plants are present only in the coastal regions. They are grouped in an assemblage named *Trapa-Acrostichum-Oleandra* assemblage.

**3. The Late Miocene assemblage of the swampy-forest, swampy or mangrove vegetation**

The assemblage is known from Bacbo (at Hopthanh, Naduong, Phanluong, Yenbai, Xuanhoa and Hanoi areas). In some regions, this is the assemblage of the feeble flooded continental swamps. The composition of this assemblage is usually monotonous. The main representatives of this assemblage are *Arundo goepperti* (Muenst.) Heer, *Phragmites oenin-*

*gensis* A. Br., *Phragmites* sp., and *Graminiphyllum* sp. In different regions this assemblage is named differently: *Arundo-Phragmites oeningensis* (at Hopthanh), *Graminiphyllum-Phragmites oeningensis* (at Naduong), *Graminiphyllum-Phragmites* (at Yenbai). Aquatic plants (hydrophytes) occur in a very small percentage and consist of *Nelumbo protospeciosa* Sap., *Nymphaeites* sp. The hygrophilous plants developing in the banks of lakes occurred also in a small percentage. They are *Juglans* cf. *zaisanica* Iljinsk., *Eugenia* sp., etc. They possibly formed the swampy-forests at Naduong, Yenbai and Phanluong. In Hanoi depression (Kienxuong, Tienhai areas) the mangrove vegetation with *Acrostichum* sp., *Oleandra nerifolia* A. Br., etc. are found. The remains of these plants are collected usually together with remains of fresh-water swampy plants such as *Trapa* sp., *Typha latissima* A. Br., etc. alongwith hygrophilous plants—*Juglans* cf. *zaisanica* Iljinsk., *Eugenia* sp., etc.





**Text-figure 3**—1. Sea; 2. Low coastal zone; 3. Low plateau and highland; 4. High plateau and mountain (about 1,200 m); 5. High plateau and mountain (about 1,500 m); 6. Swampy-lacustrine area; 7. Deltaic area; 8. Depositional accumulation area; 9. Proposed boundary of the depositional accumulation area; 10. Proposed river-bed; 11. Proposed boundary between sea and land; 12. Area of the humid subtropical forests (with the dominance of *Quercus* cf. *lobbii* and *Diospyros brachysepala*) that is replaced periodically by swamps; 13. Area of the humid subtropical forests (with the dominance of *Ficus beauveriei*, *Artocarpus*, *Salix varians*, *D. brachysepala*) that is replaced periodically by swamps; 14. Area of the humid subtropical forests with the dominance of *F. beauveriei*, *Dipterocarpus*, *Anacolosia*; 15. Area of the warm temperate subtropical forests (with the dominance of *Q. lantenoisi*, *Q. bonnieri*, *Fagus* cf. *stuxbergii*, *Phoebe pseudolanceolata*) that is replaced periodically by swampy forests; 16. Area of warm temperate subtropical forests (with the dominance of *Q.* cf. *gilva*, *Q.* cf. *saravanensis*, *Machilus* cf. *nothorstii*, *Persea* cf. *pliocenica*, *Libocedrus*, *Glyptostrobus*) that is replaced periodically by the swampy forests or swamps; 17. Area of warm temperate subtropical forests with the dominance of *Q.* cf. *glauca*, *Q. lantenoisi*, *Ocotea heeri*, *Arbutus elegans*; 18. Area of coastal (tidal) forests; 19. Mangrove forests; 20. Foraminifers; 21. Mammals; 22. Volcanism on land; 23. Area of peat accumulation; 24. Area of bituminous rock accumulation.

#### 4. The Late Miocene assemblage of the humid subtropical forest vegetation

This assemblage is distributed over the whole regions of Vietnam. In Caobang-Langson trend this assemblage is named as *Quercus* cf. *lobbii*-*Diospyros brachysepala*, in Songlo-Songchay—*Ficus beauveriei*-*Diospyros brachysepala*, in Songhong—*Ficus beauveriei*-*Artocarpus*, in north margin of Hanoi depression—*Quercus* cf. *lobbii*-*Diospyros brachysepala*, in Hanoi depression—*Q.* cf. *lobbii*—*D. brachysepala*, in Southern Bacbo—*D. brachysepala*—*Bauhinia*, in Songca—*F. beauveriei*-*D. brachysepala*-*Salix varians*, in *Dipterocarpus*—*Leguminosites*, at Djilinh-Baoloc highland—*F. beauveriei*-*Dipterocarpus*-*D. brachysepala*, at Gialai—Kontum—*F. beauveriei*-*nacolosia*-*Leguminosites*, and in Western Nambo—*D. brachysepala*-*Q.* cf. *lobbii*-*Zizyphus miojuba*.

This assemblage consists of two ecological groups as follows :

The group of hygrophilous evergreen forest plants occupies about 90 per cent of the assemblage composition. Its main representatives are *Laurus*, *Persea*, *Laurophyllum* (Lauraceae), *Cercidiphyllum* sp. (Cercidiphyllaceae), *Liquidambar miosinica* Hu et Chaney (Altingiaceae), *Ulmus longifolia* Ung. (Ulmaceae), *Quercus* cf. *lobbii* Ett., *Q.* aff. *parceserrata* Sap. et Mar., *Q.* cf. *saravanensis*, *A. camus* and other species of *Quercus*, *Fagus*, *Castanea*, *Lithocarpus* (Fagaceae), *Betula*, *Alnus* (Betulaceae), *Diospyros brachysepala* A. Br. (Ebenaceae), many species of Myricaceae, Juglandaceae, Elaeocarpaceae, Anacardiaceae, Aceraceae, Sapindaceae, Alangiaceae, etc. In North Vietnam, the thermophilous plants are distributed only in the areas with rather high temperature region. These areas coincided usually with the basins that formed in the distributed areas of Paleozoic formations such as Songlo Songchay, Songhong, Songca, Songba trends. In these areas the remains of *Ficus* are very predominant.

In South Trungbo and Nambo, the main fossil plants of this assemblage are of tropical origin and belong to Dipterocarpaceae (18-23%), Moraceae (9.6=18, even 58%), Ebenaceae (5-13%), Myricaceae (5-6%), Juglandaceae (5%), Caesalpiniaceae (8%) and Olacaceae (8%). Generally, the tropical plants mentioned above in this assemblage reaches to 40 per cent. In this assemblage *Ficus beauveriei* Zeill., *Diospyros brachysepala* A. Br., *Dipterocarpus symmetriaefolius* Dzanh, *Dipterocarpus* sp., *Leguminosites* sp., *Dalbergia* sp. and *Anacolosia* sp. predominate.

The dominance of the circulated families is a characteristic feature of the humid subtropical evergreen forest vegetation distributing now at altitudes of less than 1,000 m in South of Trungbo and less than 800 m in Bacbo (Thai Van Trung, 1980). This group played a principal role in the formation of vegetation in Vietnam. The increasing number of resinous plants such as *Ficus*, *Liquidambar*, *Diospyros*, etc. indicates for the humid and hot environmental conditions. From the coal seams at Naduong, Hangmon, Yenbai, Baoloc region many fossil resins have been collected.

The group of swampy and tidal plants occupies about 10 per cent. It consists of *Arundo goepperti* (Muenst.) Heer, *Phragmites oeningensis* A. Br., *Typhalattissima* A. Br., *Potamogeton* sp., *Nelumbo protospeciosa* Sap., and also *Eugenia* sp., *Myrtophyl-*

lum sp., *Salix varians* Goepp., *S. angusta* A. Br., *Populus balsamoides* Goepp., etc.

### 5. The Late Miocene assemblage of the swampy vegetation or shrub savanna

This assemblage occurs in most regions of Bacbo and Northern Trungbo. In each region, this assemblage may be composed of somewhat different swampy plants (assemblage *Nelumbo protospeciosa*-*Graminiphyllum* et Naduong, Tuyenquang; *Nelumbo protospeciosa*-*Phragmites oeningensis* at Phanluong; *Phragmites* at Phutho, Vietthai), the flooded swampy plants (assemblage *Typha latissima*-*Phragmites oeningensis*-*Najas* at Donggiao) or shrub plants (assemblage *Pecopteris totangensis* at Hoanhbo).

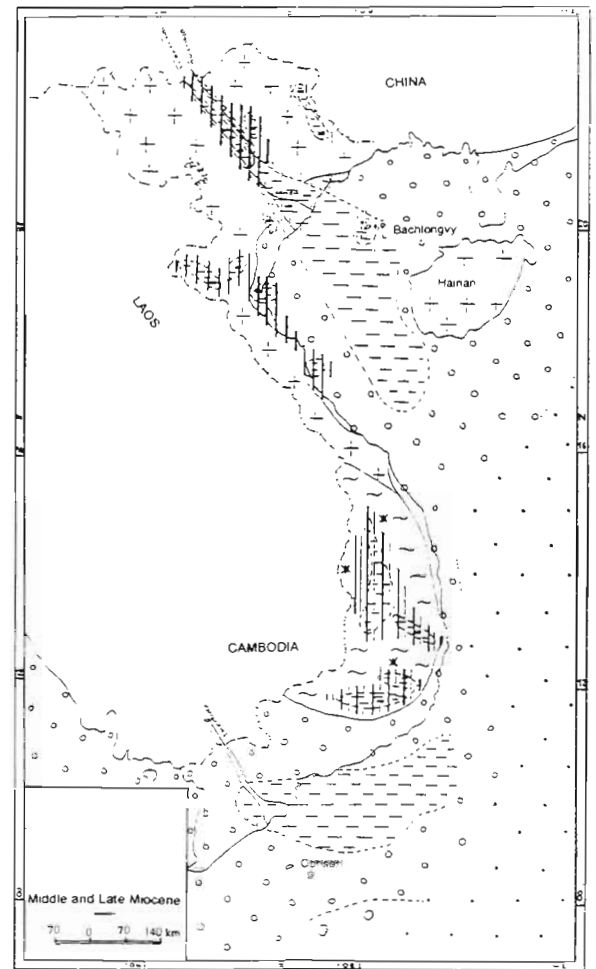
Aquatic plants (hydrophytes) occupying 36 per cent of the assemblage composition consist of Nelumbonaceae (*Nelumbo protospeciosa* Sap.), Najadaceae (*Najas* sp.), Typhaceae (*Typha latissima* A. Br.) and Nymphaeaceae (*Nymphaeites* sp.). Together with these plants, swampy herbaceous plants belonging to Poaceae (*Phragmites oeningensis* A. Br., *Graminiphyllum* sp.) have also been collected. The plants of the banks of lakes was very poor. The forest plants occupied less than 10 per cent of the assemblage composition belonging to Fagaceae (*Quercus*), Lauraceae (*Laurophyllum*, *Cinnamomum*), Altingiaceae (*Liquidambar*), Moraceae (*Ficus lanceolata* Heer).

### 6. The Pliocene assemblage of the warm temperate subtropical *Quercus*-dominated forest vegetation

In the different regions of North Vietnam composition of this assemblage is different. However, the dominant elements are species of *Quercus* of alpine zones are everywhere. They are usually the main components of each vegetative assemblage. The following local assemblage may be distinguished according to the different leading species: *Quercus lantenoisi* (at Naduong), *Quercus bonnierei*-*Nectandra* (at Vietthai), *Quercus lantenoisi*-*Phoebe pseudolanceolata* (at Phanluong), *Q. lantenoisi*-*Carpinus subcordata* (at Tuyenquang), *Q. bonnierei*-*Neolitsea magnifica* (at Hangmon), *Q. cf. gilva*-*Q. lantenoisi* (at Phutho). Together with the representatives of Fagaceae (49%), Lauraceae (21%), Betulaceae (3%), Juglandaceae (2%), etc. are also present. Among them, *Q. lantenoisi* Col. played a

dominated role. This species and its related ones occupy 10 per cent of the assemblage composition.

In South Vietnam this assemblage is found at Djilinh-Baoloc highland (assemblage *Q. lantenoisi*-*Ocotea heeri*-*Ficus beauveriei*), Gialai-Kontum (assemblage *Punica planchoni*-*Arbutus elegans*), Ba River Valley (assemblage *Q. cf. glauca*-*Ficus beauveriei*) and at Nambo (assemblage *Dalbergia*). This assemblage consists of 20-27 species belonging to 12 warm temperate subtropical families (40-46%), while the humid subtropical and tropico-original families were only 25-30 per cent. In the assemblage *Quercus lantensis* Col., *Q. cf. haugi* Col., *Q. cf. glauca* Thunb., *Arbutus elegans* Wat., *Punica planchoni* Sap. et Mar., *Dalbergia kontumensis* Dzanh, *D. cf. rectinervis* Ett., *D. bella* Heer, etc. are abundant. *Ficus beauveriei* Zeill. has also been col-



Text-figure 4—Paleogeographical scheme and distribution of vegetation types of Vietnam.



lected. The swampy and tidal aquatic plants were few (10%). They are *Nelumbo* sp., *Arundo* sp., *Phragmites* sp., rarely *Eugenia* sp. and *Salix* sp. They occur only in some regions.

### 7. The Pliocene assemblage of the swampy or swampy-forest vegetation

This assemblage is known only in Bacbo and Northern Trungbo. It includes a new type of phytocoenose of the swamps or flooded swamps known as—the swampy forest of *Glyptostrobus-Metasequoia*. The swamp or full flooded swamp vegetation are named as *Graminiphyllum-Nelumbo protospeciosa* (at Naduong, Tuyenquang, Yenbai) or *Phragmites oeningensis-Typha latissima* assemblage (at Hoanhbo, Vietthai, Bachlongvi). In these assemblages, the predominating swampy plants are *Arundo goepperti* (Muenst.) Heer, *Typha latissima* A. Br., as well as the coastal forms *Myrtophyllum* sp., *Saliciphyllum* sp. and Verbenaceae gen. indet. They occupy 60 per cent of the assemblage. At that time the forest plants distributed in the high land surrounding swamps are only in a very small percentage and composed of *Quercus* cf. *neriifolia* A. Br., *Q. lan-tenoisi* Col., *Fagus* cf. *stuxbergii* (Nath.) Tanai, *Ficus beauveriei* Zeill., *Aralia* sp., *Anona* sp., etc.

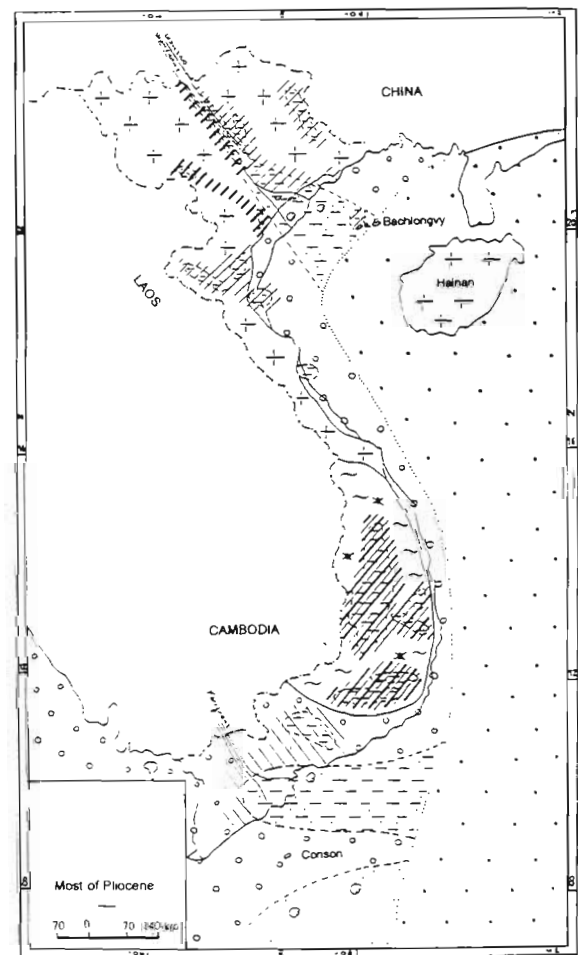
The assemblage of the swampy forest vegetation consists mainly of gymnosperms (Pinophytes) and Filices (Polypodiophytes) and is named as *Glyptostrobus-Metasequoia* assemblage. This assemblage is distributed at Phutho, Hangmon, Donggiao, in which *Glyptostrobus* cf. *carinatus* G. Pimenov, *Metasequoia* sp., *Taxus* aff. *baccata* L., *Pinus* sp., *Angiopteris* sp., *Pecopteris totangensis* Col. are commonly found. In dicotyledons, only xerophytic plants are found.

### 8. The Pliocene assemblage of warm temperate subtropical *Fagus*- and *Phoebe*-dominated forest vegetation

In North Vietnam (Bacbo and Northern Trungbo) this assemblage is distributed only in the trends Caobang-Langson (Caobang Naduong areas), Songlo-Songchay (Tuyenquang), Songhong (Yenbai), north margin of Hanoi depression (Hoanhbo), and Southwestern Bacbo (Donggiao). The common characteristic feature of this assemblage is the dominance of *Fagus* cf. *stuxbergii* (Nath.) Tanai, *Phoebe pseudolanceolata* Col., and then *Machilus*,

*Persea* cf. *pliocenica* (Sap.) Kolak. and *Quercus* cf. *gilva* Bl. successively. The following plants take part in the formation of assemblages: *Fagus* cf. *stuxbergii-Phoebe pseudolanceolata* (at Caobang, Naduong, Hoanhbo), *Machilus* cf. *nathorsti-Phoebe pseudolanceolata* (at Yenbai), *Q.* cf. *gilva-Persea pliocenica-Libocedrus* (at Donggiao). In this assemblage, the alpine subtropical plants belonging to Lauraceae (37%), Fagaceae (36%) and Betulaceae (5%), etc. predominate. The swampy plant *Phragmites* is distributed rather widely. The coastal plants *Myrtophyllum*, *Eugenia* and *Salix* were restricted in distribution.

At that time, in the different regions of South Vietnam the Early Pliocene assemblage of warm temperate subtropical *Quercus*-dominated forest vegetation was continuously developed. However,



Text-figure 5—Paleogeographical scheme and distribution of vegetation types of Vietnam.

many thermophilous representatives of *Ficus beauveriei* Zeill., *Dipterocarpus* sp., *Anacolosa* sp., etc. also occur in the assemblage.

### 9. The Late Pliocene-Early Pleistocene assemblage of the coastal (tidal) or mangrove vegetation

This assemblage is known only in Eastern Nambo and in the coastal region of Southern Trungbo. It consists of plants of the coastal (tidal) forest vegetation such as *Calophyllum* aff. *dongnaiense* Pierre, *Dalbergia bella* Heer, *D.* cf. *rectinervis* Ett., *Persea* sp., *Eugenia* cf. *pierrei* Gagn., *Cassia bicapsularis* L., etc. The representatives of the mangrove vegetation such as *Sonneratia*, *Rhizophora*, *Melaleuca*, etc. are also present in the assemblage.

### DEVELOPMENT OF EPOCHS OF THE NEOGENE AND NEOGENE-QUATERNARY FLORAS OF VIETNAM

From the composition and ecological components of the chrono-ecological vegetative assemblages, as well their position in stratigraphic sections, we may conclude that Neogene and Neogene-Quaternary floras of Vietnam are developed in 4 epochs relating with 4 epochs of the sedimentary deposition.

#### 1. Middle-Late Miocene Epoch

The plants of this epoch are known only in boreholes (at the depth of more than 3,000 m) of Hanoi depression. Thus it was the developmental epoch of humid subtropical vegetation, in which the dominance belonged to Moraceae, Anacardiaceae, Lauraceae, Poaceae, etc. In this epoch there were many resinous plants (*Ficus*, *Rhus*, *Zelkova*, *Pistacia*) and also thermophilous plants (*Populus*, *Cercidiphyllum crenatum* Ung., *Acer bilgendorffii* Nath., etc.). These forms are known from the Middle Miocene flora of Japan (Tertiary floras of Japan, 1963). However, most plants of this epoch occurred in the Late Miocene of Bacbo and Northern Trungbo (Trinh Dzan, 1973, 1982). That's why this epoch is considered to be a transition from Middle to Late Miocene in the development of flora and vegetation of Vietnam.

#### 2. Late Miocene Epoch

A very characteristic feature of this epoch is luxuriant and predominant development of humid subtropical vegetation in whole territory. It was the epoch of predominant development of the families Fagaceae, Lauraceae, Moraceae, Dipterocarpaceae. *Litsea* (Lauraceae), *Ficus* (Moraceae), *Dipterocarpus*, *Vatica* (Dipterocarpaceae), *Betula*, *Alnus* (Betulaceae), *Juglans* (Juglandaceae) and *Diospyros* (Ebenaceae) were dominant. The swampy plants (*Potamogeton*, *Nelumbo*, *Nymphaeites*, *Trapa*, *Typha*), plants of the coastal (tidal) regions (*Acrostichum*), as well as hygrophilous plants (*Arundo*, *Phragmites*, etc.) flourished periodically corresponding to the oscillating phases of relief.

The development of the forest vegetation exhibits a mosaic character of humid and dry subtropical forest vegetations (Mchedlishvili P.A., 1960; Tran Dinh Nhan, Trinh Dzan, 1975; Trinh Dzan, 1975, 1985, 1986). In this epoch, the flora of Naduong, Nagiao-Hopthanh was present in the beginning. In most areas the vegetation has gone through 4 phases of ecological successions: dry subtropical forest, swampy forest or mangrove, humid subtropical forest, and flooded swampy or shrub savanna vegetation. In Bacbo and Northern Trungbo this epoch consists of two development phases. In first phase at Naduong, Nagiao, Hopthanh regions and also at Thatkhe and Bayen as well, the floras were very rich and diverse, in which the xerophilous plants *Quercus* aff. *parceserrata* Sap. et Mar., *Laurophyllum* sp. 1, *Apocynophyllum* sp., *Ulmus longifolia* Ung. and many species of *Filices*, *Asplenium*, *Pecopteris totangensis* Col., etc. are abundant. At that time, at Tienhung Tienhai (Hanoi depression) the mangrove forests dominated by *Oleandra neriifolia* A. Br., *Acrostichum* sp., *Trapa* sp., etc. was present. In other regions (Caobang, Vanyen, Phanluong, Phorang, Hoanhbo, etc.) no vegetation of this epoch has ever been recorded.

After this phase, swamps became extended over most regions, in which the swampy vegetative assemblage with *Phragmites oeningensis* A. Br., *Arundo goepperti* (Muenst.) Heer or the swampy forest vegetative assemblage with the mesohygrophytes (*Juglans* cf. *zaisanica* Iljinsk., *Ficus beauveriei* Zeill. et Yenbai, Phanluong) were developed. At this time, in Hanoi depression the mangrove vegetation developed continuously. This is the developing

epoch of the second chrono-ecological vegetative assemblage. In the swamps there were usually freshwater bivalves of *Acuticosta caobangensis* Mod. (at Caobang), *Unio* sp. and *Anodonta* sp. (at Naduong) or marine representatives *Dosinia* aff. *exolenta* (L.) Pitar, *Macra*, etc. (in Hanoi depression). Gastropods were very rare and consist only of small sized *Viviparus*, *Tulotoma* (at Nadong and Yenbai).

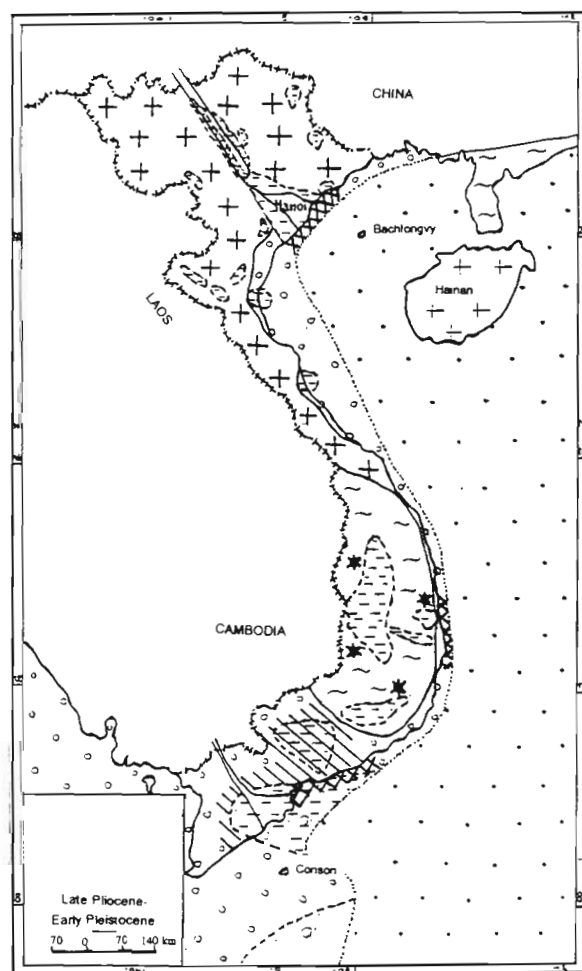
One of the characteristic features for this epoch is the development of the humid subtropical forest vegetation. In some regions, however, there are dry subtropical forests in the humid vegetation. This event indicated the mosaic character of the Late Miocene vegetation of Vietnam. At the end of this epoch the forest vegetation was replaced by the flooded swampy vegetation (5th assemblage) in which there were many aquatic plants such as *Nelumbo protospeciosa* Sap., *Nymphaeites* sp., *Najas* sp., *Typha latissima* A. Br., and also the hygrophilous plants as *Phragmites oeningensis* A. Br., *Arundo goepperti* (Muenst.) Heer. In swamps, there were also many bivalves *Oxynaiia jourdyi* Morelet, *Cuneopsis* sp., *Chamberlainia* sp., *Acuticosta caobangensis* Mod., *Schistodesmus* aff. *campreyianus* Baird. et Adams., *Pseudobaphia* cf. *biessiana* Hende, *Discomya* aff. *radulosa* Dronet et Chaper, *Unio* (*Nodularia*) cf. *continentalis* Haas, *Unio* cf. *baicalensis* Rammel, *Cristaria* sp., *Pilsbriocochia* sp., *Microdontia ovata* Haas, *Brotia* aff. *variabilis* (Benson), etc. (Tchelsov Iu. G., 1968; Tran Dinh Nhan & Trinh Dzanh, 1975; Trinh Dzanh, 1973, 1979, 1980).

Based on the dominance of Fagaceae (mainly *Quercus*), Moraceae (mainly *Ficus*), Juglandaceae, Lauraceae (mainly *Cinnamomum*), Salicaceae and Myrtaceae, the Late Miocene flora of Bacbo and northern Trungbo is similar to the Late Miocene floras of Yunnan (China), Japan and a part of North American flora (Colani M., 1920; Tertiary floras of Japan, 1963; Wolfe, 1964). Especially, the flora of Hanoi depression is rather similar to the Late Miocene flora of most region (Tcheco-slovakia) and of Mississippi River Valley (America) (Hurnik, 1973; Trinh Dzanh, 1973, 1979, 1986).

In southern Trungbo and Nambo the warm temperate subtropical phase of the Late Miocene epoch is not clearly known but it is possible that in the beginning of this epoch the warm temperate alpine forest (at high altitude of 800 m) with *Quercus*, *Cinnamomum* and *Persea* were distributed. At the

end of this epoch usually the tropical and humid subtropical forests that surrounded the swamps or valleys were present. In this forests *Ficus beauveriei* Zeill., *Dipterocarpus symmetriaefolius* Dzanh and other species of Dipterocarpaceae, Rhamnaceae, Fabaceae, etc are present. Together with the elements of Late Miocene flora of Bacbo and Northern Trungbo, in southern Trungbo and Nambo there were also elements from the Late Miocene floras of Thailand (Mae Sod Series-Endo S., 1964; Endo S. & Fujiyama, 1966) and Philippines (Sagada region-Smith W., 1924).

It needs emphasis that in Late Miocene Dipterocarpaceae were distributed only in Southern Trungbo and possibly they had not reached to Donghoi region. This event also determined the tropical character of South Vietnam flora.



Text-figure 6—Paleogeographical scheme and distribution of vegetation types of Vietnam.



### 3. Pliocene Epoch

In North Vietnam (Bacbo and Northern Trungbo) the Pliocene flora consists of main elements of second epoch, but was improved by many new taxa. In the flora Fagaceae, Lauraceae, Juglandaceae, Sapindaceae, etc. predominated. Among them, there were *Fagus* cf. *stuxbergii* (Nath.) Tanai, *Quercus* cf. *neriifolia* A. Br., *Q. lantenoisii* Col., *Q. bonnierii* Col., *Q. cf. saravanensis* A. Camus (Fagaceae), *Carpinus* cf. *cuspidens* (Sap.) Kolak., *Alnus kefersteinii* (Goepf.) Ung., *Carpinus subcordata* Nath. (Betulaceae), *Persea* cf. *pliocenica* (Laur.) Kolak., *Phoebe pseudolanceolata* Col., *Cinnamomum lanceolatum* Heer, *Cinnamomum polymorphum* A. Br., (Lauraceae), *Zelkova zelvovifolia* (Ung.) Buzek et Kotlaba (Ulmaceae), *Acer trilobatum* A. Br. et Agass. (Aceraceae), *Pistacia donzaoensis* Dzanh (Anacardiaceae), *Typha latissima* A. Br. (Typhaceae), etc. Many gymnosperms such as *Metasequoia* sp., *Glyptostrobus* cf. *carinatus* G. Pimenov, *Libocedrus lantenoisi* Laur., *Fokienia notoensis* Matsuo, *Pinus* sp., *Taxus* aff. *baccata* L., *Ginkgo* sp., appeared. There were many representatives of the recent flora such as *Bauhinia variegata* L., *Castanopsis tonkinensis* Seemen, *Quercus tomentosa* Willd, *Q. chapaensis* Luong, etc. In some localities they occurred in large percentage of the flora composition.

Generally, the vegetation of this epoch had gone through three phases of ecological succession : forest, swampy forest, and forest vegetation. In the beginning *Quercus* was very abundant. It played a key role in the concrete vegetative assemblages of the different regions : *Quercus lantenoisi* (at Caobang-Langson), *Q. bonnieri-Phoebe pseudolanceolata* or *lantenoisi-Carpinus subcordata* (at Songlo-Songchay), *Q. lantenoisi-Neolitsea magnifica* (at Hangmon), *Q. cf. neriifolia-Acer-Persea* cf. *pliocenica* (at Songca), etc. This early stage was developed only in Caobang, Naduong, Phanluong, Phorang, Tuyenquang, Yenbai, Phutho, Hoanhbo, Hanoi, Hangmon, Cuarao, Vietthai, Thachha and Donggiao and not known in other places. Later, warm temperate subtropical *Quercus* dominated forest vegetation was replaced by the swampy vegetation in type of *Nelumbo protospeciosa-Graminiphyllum-Phragmites oeningensis* or by the swampy forest vegetation in type of *Glyptostrobus-*

*Metasequoia-Typha latissima*. It was the development time of the seventh chrono-ecological vegetative assemblage, in which the flora was poor and the vegetation was rather monotonous. In Phanluong, Phorang, Xuanhoa, Cuarao, Khebo, Donphuc and Thachha there was no vegetation of this time. Among the molluscan fauna gastropods predominated. They are composed of both fresh-water and marine species such as *Viviparus* cf. *margaryaeformis* Mans., *V. cf. sturi* Neumayr, *V. cf. quadratus* (Benson), *V. cf. asperus* Mich., *Cinpangopaludina* cf. *baasi* Prasad, *Cerithium* sp., *Calliostoma* sp., etc. (Tchelsov Iu. G., 1968; Trinh Dzanh, 1979, 1990, 1994). The last phase of this epoch is the development time of 8th chrono-ecological vegetative assemblage. The taxa found in this assemblage are *Fagus* cf. *stuxbergii* (Nath.) Tanai, *Quercus* cf. *gilva* Bl., *Q. cf. saravanensis* A. Camus, *Phoebe pseudolanceolata* Col., *Machilus* cf. *nathorsti* Huz., *Persea* cf. *pliocenica* (Sap.) Kolak., *Cinnamomum*, *Carpinus subcordata* Nath., etc. The vegetation of this phase is present only in regions Caobang, Naduong, Tuyenquang, Yenbai, Hoanhbo and Donggiao. Thus, the characteristic features of this development epoch in North Vietnam are as follows : firstly, the development of flora was not equal in different regions. The development process was protracted in the regions occurring in southeast part of each line. Secondly, *Quercus* dominated everywhere in first time. The swampy forest comprising *Glyptostrobus-Metasequoia-Typha* appeared. Thirdly, many recent species presented, and *Fagus* cf. *stuxbergii* (Nath.) Tanai, *Phoebe pseudolanceolata* Col. and some others proliferated.

In South Vietnam (southern Trungbo and Nambo), the evergreen forest continued their development at Djilinh-Baoloc, Ba River Valley, Gialai-Kontum. In this area the forest vegetation of Nambo was also present. In the phytocoenosis structure of the flora there was a clear change after the adaptation to the more temperate climatic condition. The main composition of the flora includes warm temperate, temperate semi-xerophytic elements and the swampy, lacustrine plants of typical temperate character. At Djilinh-Baoloc, Lauraceae and Fagaceae occupied 50 per cent of the floristic composition. The main species are *Laurophyllum* sp. 1, *Ocotea heeri* (G. Gaudin) Takht., *Phoebe pseudolanceolata* Col.,

*Quercus lantenoisi* Col., *Q. cf. glauca* Thunb., *Q. cf. haugi* Col. Moraceae played an important role after Fagaceae. In Ba River Valley and in Gialai-Kontum the vegetation was in other status and in the floral composition Moraceae played the dominant role, but the families of tropical origin decreased (Dipterocarpaceae) or disappeared (Fabaceae, Caesalpinaceae). At Gialai-Kontum possibly only the temperate semi-xerophytic forests were distributed formed by the *Arbutus elegans* assemblage. At that time in western Nambo the mangrove forests appeared. Some elements of the recent flora such as *Quercus tomentosa* Willd, *Q. incana* Roxb., *Hopea*, *Shorea* also occur. The development of many recent species (*Carpinus viminea* Lindl. et Roxb., *Q. tomentosa* Willd, *Q. gilva* Bl., *Q. saravanensis* A. Camus, etc.), absence or declination of the forms of tropical origin (*Ficus*, *Dipterocarpus*, *Vatica*, *Anacolosia*, *Pittosporum*) which were replaced by the representatives of alpine flora (Betulaceae, some species of Fagaceae, and gymnosperms), indicate that in the territory of Vietnam there was a climatic change from humid subtropical in Late Miocene to warm temperate subtropical in Pliocene.

#### 4. Late Pliocene-Early Pleistocene

This is a transitional epoch in the development of Kainophyte of Vietnam. The vegetation of this epoch is known only in South Vietnam, exactly in Western Nambo, where together with the evergreen forests on land there were also the mangrove and tidal vegetation with *Calophyllum*, *Sonneratia*, *Melaleuca*, *Rhizophora*, etc. These vegetations were known in the coastal regions from Phanthiet to Camau area. The vegetation of this epoch indicates humid subtropical climatic condition in the territory.

#### CONCLUSIONS

In the Neogene and Neogene-Quaternary floras of Vietnam four epochs, viz., Middle-Late Miocene, Late Miocene, Pliocene and Pliocene- Early Pleistocene were developed. The first epoch was represented by a chrono-ecological vegetative assemblage of humid subtropical plants, the second by four assemblages of the dry and humid subtropical plants, the third by three assemblages of the warm temperate subtropical plants, the last by an assemblage of humid subtropical plants.

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