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Some Cenozoic hydrocarbon bearing basins on the continental shelf of Vietnam

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Abstract: Some offshore basins of Vietnam contain hydrocarbon accumulative traps not only in Tertiary sediments but also in fractured basement.

Pre-Cenozoic plays are related both to reservoirs of fractured basement and to source rock and topseal of Oligocene sediments. Consolidation of basement is demonstrated by Upper Jurassic-Eocene meta-molasses and plutonic-volcanic arcs (45–168 Ma) which are caused by the collision or convergence of the continents after the disappearance of the Tethys ocean.

Sedimentary basins on the continental shelf of Vietnam are filled by Oligocene-Miocene marine and deltaic sediments, related to rifting, spreading, sagging activities from which the East Vietnam Sea* (or South China Sea) was formed and widened.

The Song Hong (Bacbo) rift basin is characterized by Oligocene-Miocene high-constructive deltaic sediments, which are rich in humic matter. Oligocene and Miocene plays are predominant in clastic sediments.

The Cuulong sag basin is composed of Oligocene-Miocene fine clastic sediments in high-destructive deltaic facies, which are rich in sapropel. Fractured plutonic-volcanic basement developed into good petroleum traps. But Oligocene-Miocene plays are predominant in clastic sediments.

The Nam Conson rift basin has a complicated structure. The lower part of this basin is filled by Oligocene and early Miocene marine clastic sediments, but the upper part is predominant in marine platform and reef carbonates. There are both Oligocene-Miocene clastic plays and Miocene carbonate ones in this basin.

The Pliocene-Quaternary deposits are sand, mud and carbonate of shelf facies in back-arc basins. Their great thickness enhanced the geothermal gradient and provided good conditions for maturation and trapping of hydrocarbons.

INTRODUCTION

Most Cenozoic sedimentary basins of Vietnam in which hydrocarbons were discovered are distributed on the continental shelf. Some of them became important hydrocarbon-bearing basins not only in Tertiary sediments but also in the fractured basement.

Before 1975, the first oil field of Vietnam was discovered on the continental shelf (Mobil Oil, 1974). During the 1976–1989 period, there was a general survey of the whole shelf. The Bachho (White Tiger) field has been explored and have produced oil (Vietsovpetro). Industrial hydrocarbon flows were also found in some wells on other structures (Agip, Deminex, Vietsovpetro). The Tienhai gas field lies in the land part of Song Hong basin. The Daihung (Big Bear) field belongs to the Nam (South) Conson basin. Two big fields were found in the Cuulong basin. Since 1990, many hydrocarbon bearing structures, petroleum plays and new fields were discovered in both fractured plutonic-volcanic basement and in clastic and carbonate sediments (Vietsovpetro, Enterprise Oil, BP, Petronas, Pedco, BHP and others). Not only petroleum but also other geologic projects were carried out. This period was an active stage of investigation, search and exploration. There are many geologic and geophysical data from the study of Cenozoic formations which have been completed so far. Most of them led to hydrocarbon exploration reports carried out on each block or on various structures by contract. Basin analysis has important implications concerning the hydrocarbon plays of the sedimentary basins and may be applicable to petroleum traps of the Pre-Cenozoic basement.

* ***Footnote*** — *East Vietnam Sea is more widely known as the South China Sea.*

SYNOPSIS OF THE GEOLOGIC POSITION OF THE VIETNAM CONTINENTAL SHELF

The continental shelf of Vietnam is a large and complicated part of South East Asia. It is composed of various structural-formational units. Consolidated basement is demonstrated by pre-Cenozoic metasedimentary, metamorphic and magmatic rocks which extend from land to sea. Tertiary basins were filled up by sedimentary rocks in differential structures. The upper part forms a general cover over the whole shelf.

Present structural plan of South East Asia

South East Asia is the place which experienced the convergence of oceans (Indian, Pacific) with the continents (Australia, Asia). Its present plan consists of peninsulas, islands, volcanic arcs and marginal seas (Fig. 1).

The South and South-West margin is surrounded by the Andaman-Indonesian arc system with the Sumatra-Java-Timor deep trench and the forearc subduction zone of the Indian Ocean and Australian continent under the Sunda platform. The outer parts of the subduction system are the outer island arc, the inside is represented by the volcanic arc and back arc basins.

The Taiwan-Philippine arc system positioned in the east part. The Philippine eastern oceanic deep trench is the subducted zone of the Pacific ocean under the volcanic-island arc. The continental shelf is very steep and narrow, but continental basement is absent. In the backarc area, there are developed marginal seas of which the East Sea is the largest and most complicated backarc basin.

East Vietnam Sea (more widely known as the South China Sea) and its margin

The East Vietnam Sea not only appears to be a backarc basin on the Pliocene-Quaternary structural map, but it also abundantly traces various geodynamical stages. On its marginal zones there is a wide distribution of Late Jurassic-Eocene meta molasse and plutonic-volcanic complexes of volcanic-island arc type without oceanic formations. Sedimentary basins on the continental shelf are filled up by Oligocene-Miocene clastic and carbonate rocks in deltaic and marine facies, but in the central part of the East Sea, there is basalt (17–32 Ma) formed by sea-floor spreading. The continental shelf is characterized by Pliocene-Quaternary deposits. The neotectonic plan of the East Sea is demonstrated through 4 sectors with different characterizations (Fig. 2).

The central micro-ocean (marginal basin) is the deepest part (under 3,000–4,000 m). There are some submarine mountain ridges with ocean floor basalts (17–32 Ma). The direction and spreading history is indicated by magnetic anomalies and major rifts within the oceanic part with number from 5–6 to 10–11 (11–32 Ma). Moving from northeast to southwest there exists the Spratly and Paracel submarine micro-continents, and moving from east to west there are the Macclesfield bank and Reed bank. The Manila deep trench is the place from where oceanic crust of East Sea is subducted eastwards under the Taiwan-Luzon volcanic-island arc.

The eastern margin is characterized by convergence with the presence of the Taiwan-Luzon strong earthquake zone and volcanic arc. The continental shelf is narrow and steep, and nearby the oceanic trench without continental basement.

A transform margin from active in the east (Palawan) to passive in the west (Natuna) occupies the southern part.

The western-northwestern margin of East Vietnam Sea has many signatures of a divergent type. There are geomorphologic elements, such as continental shelf, slope and foot. Oligocene-Miocene basins are productions of rifting, spreading and sagging processes.

Present morphology of Vietnam continental shelf

The continental shelf of Vietnam is covered by Pliocene-Quaternary sediments with the thickness increasing towards the continental slope and foot. The Pliocene-Quaternary sedimentary cover is distributed in accordance with the structural plan of the present shelf (Fig. 3).

The Bacbo Gulf shelf part has a gentle and large corridor. Constructive process is predominant in the south of Doson beach; but in the north, destructive process is stronger. The basins are the Song Hong (Bacbo), western Leizhou (Luichow) and South (Nam) Hainan.

The Trungbo (central) shelf part has a steep and narrow corridor. There, destructive process is predominant. Some sedimentary basins are small and narrow, such as Eastern Quangda, Eastern Hue, Eastern Phukhanh.

The Dong Nambo shelf part is characterized by a very large and gentle corridor. Construction is dominant in the south, near Ca Mau; but in offshore Vung Tau the destruction is stronger. Cuulong and Nam Conson basins are considered to have high potential for hydrocarbons.

The Minh Hai-Phu Quoc shelf area is part of the Thailand-Malay Gulf with a gentle and large corridor. In Minh Hai, construction is dominant,

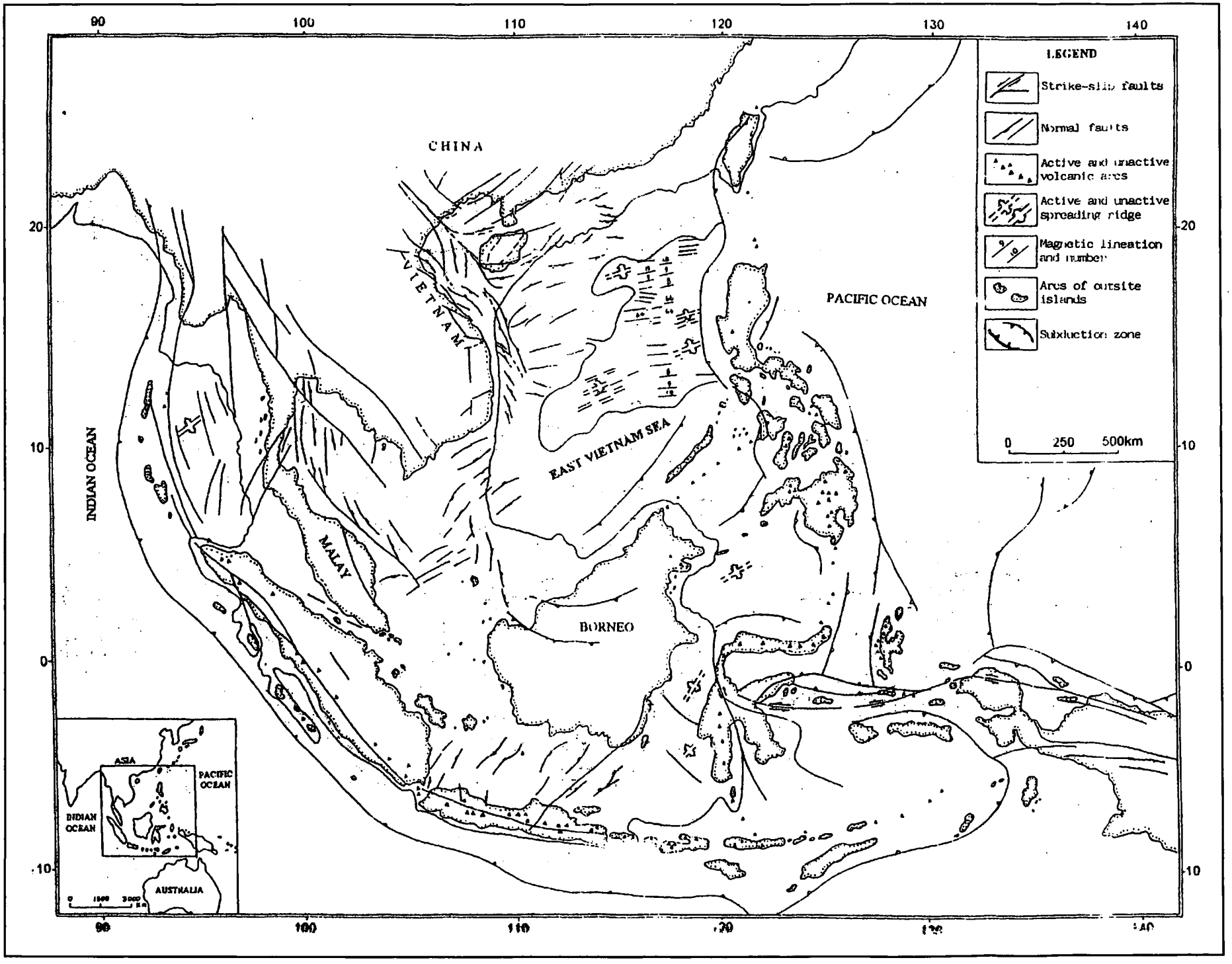
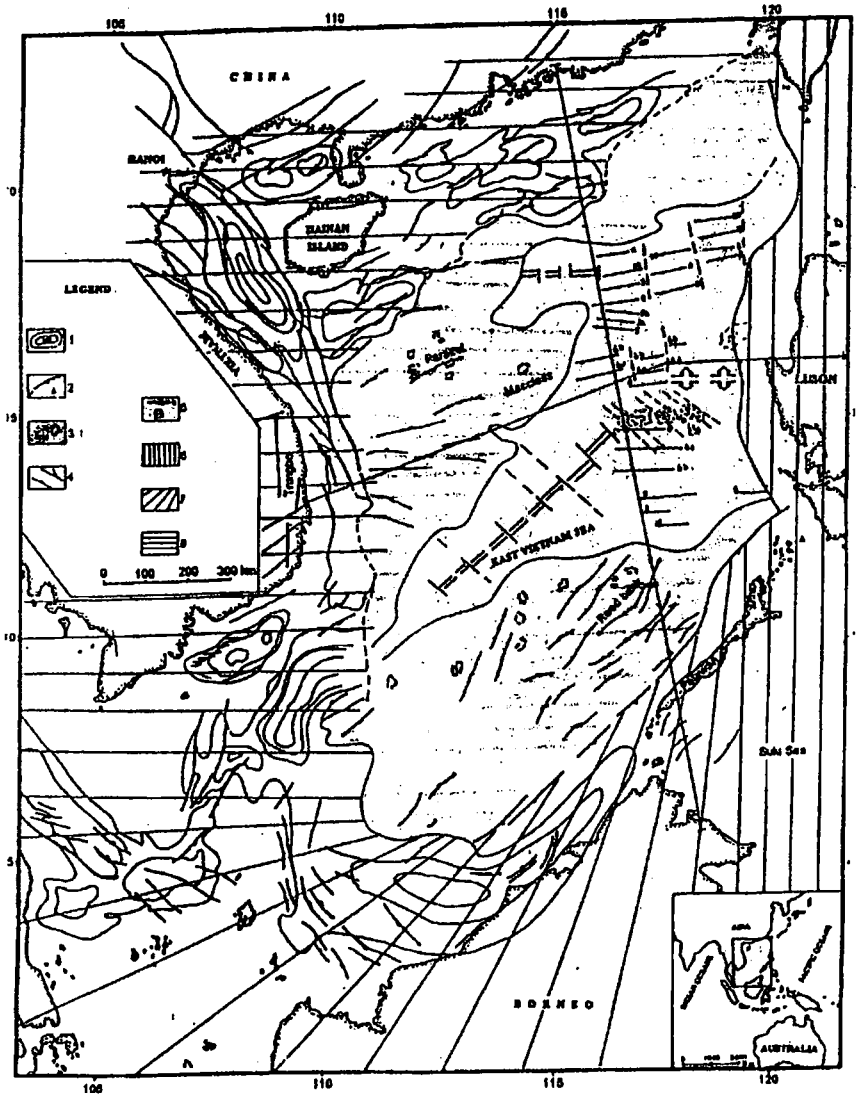
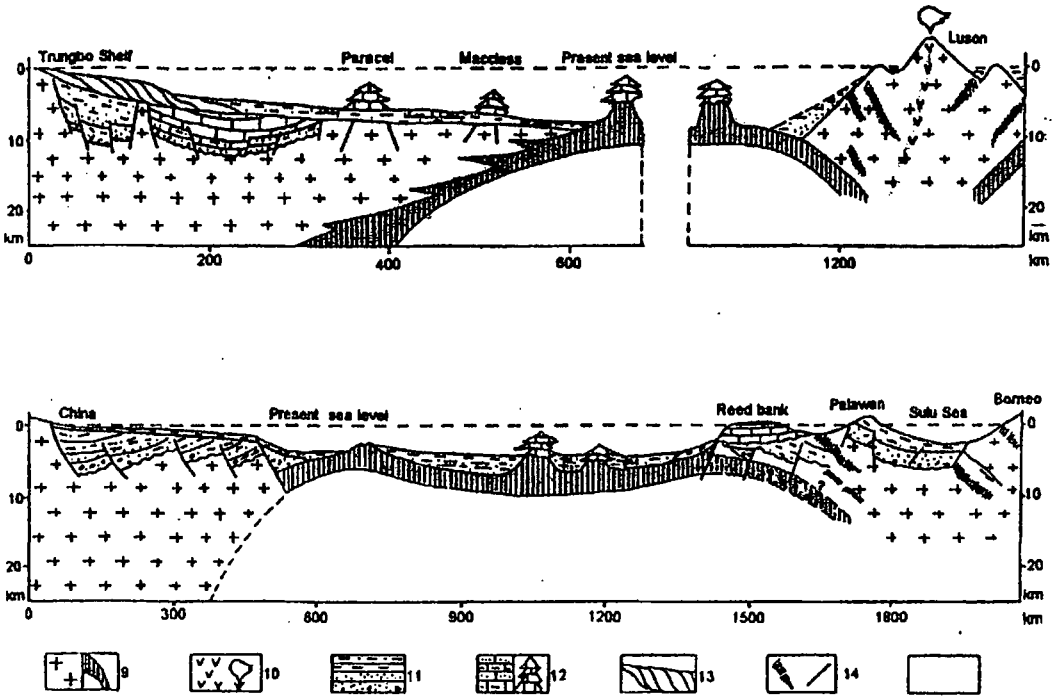


Figure 1. Present structural plan of South East Asia.





LEGEND

1-Tertiary sedimentary basin
2-Subduction and volcanic arc
3-Spreading and seamounts
4-Fault
5-Magnetic lineation
6-Active (Convergent) margin
7-Margin of oblique convergence & strike-slip faulting
8-Passive (Divergent) margin
9-Continental and Oceanic Crust
10-Volcanic and plutonic rocks
11-Clastic rocks
12-Carbonate and reef
13-Slope
14-Fault andOphiolite

Figure 2. Vietnam East Sea and its continental marginal types.

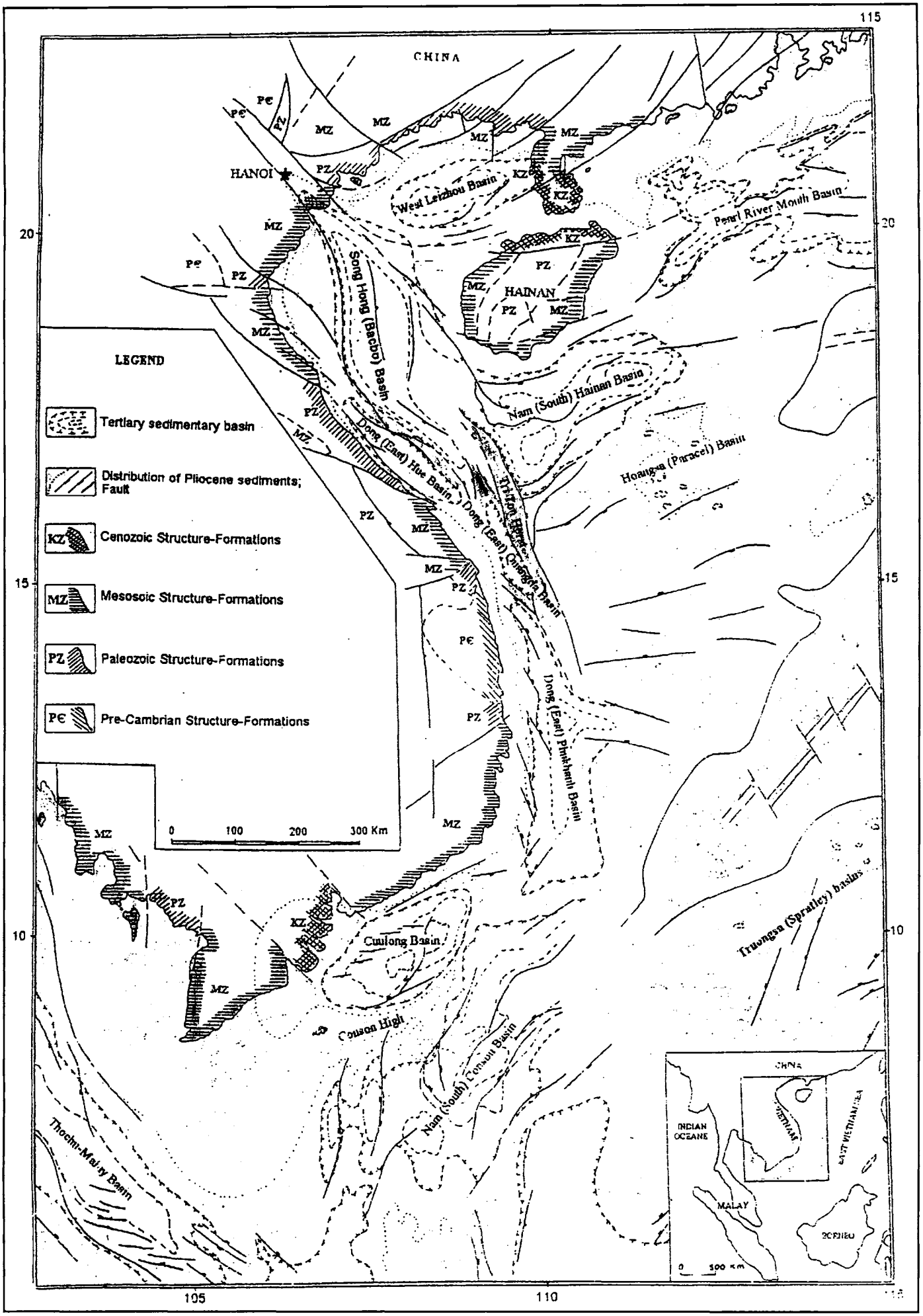


Figure 3. Continental shelf of Vietnam and its Tertiary sedimentary basins.

while in Phu Quoc-Kien Giang destruction is high. The Malay-Tho Chu basin is typical for Tertiary structure of the Gulf of Thailand.

BASIN ANALYSIS FOR CENOZOIC FORMATIONS ON THE CONTINENTAL SHELF OF VIETNAM

Geological and geophysical profiles and the geologic framework of the Vietnam continental shelf indicate clearly 3 Cenozoic geologic complexes that are related to different geodynamic phases (Fig. 4).

Paleocene-Eocene complexes are demonstrated by meta-sedimentary molasse and plutonic-volcanic arcs. Their distributions are restricted to the relicts of Late Mesozoic island arcs and intermontane structures.

Oligocene-Miocene megasequences, predominantly composed of clastic and carbonate sedimentary rocks in deltaic and marine facies are distributed in individual basins formed by rifting, spreading and sagging structures. These megasequences are typical of the sedimentary basins on the continental shelf of Vietnam.

Pliocene-Quaternary complexes are principally characterized by terrigenous and carbonate deposits (sand and mud) of shelf facies and by basalts in some places.

Basement consolidation of the Tertiary basins and the collision of continents

Consolidated basement of Tertiary sedimentary basins on the continental shelf of Vietnam is principally demonstrated by Pre-Cenozoic magmatic metamorphic and metasedimentary complexes. They are of Pre-Cenozoic structural-formational units extending from land to sea.

Pre-Cambrian metamorphic complexes are probably restricted to some places of Bachho, Tung Bo shelf basement. Paleozoic and Mesozoic formations are most widely distributed in consolidated basement of Tertiary basins. Among them, just only Upper Jurassic-Cretaceous (J_3-K) formations are identical in characteristics for the whole region of Indochina, South China and East Thailand. They are mostly composed of Upper Jurassic-Cretaceous (J_3-K) intremontane molasse and arc-type plutonic-volcanic rocks (45–168 Ma). Their composition and distribution correspond to the basement consolidation of sedimentary basins caused by the collision (or convergence) of the continents (Gondwana and Laurasia) after the disappearance of the Tethys ocean. In many wells, Paleocene-Eocene metasedimentary and volcanic sequences have been discovered. They are similar to Upper Jurassic-Cretaceous (J_3-K) metasedimentary and plutonic-volcanic complexes. These features indicate pre-rift formations which relate to the remaining stage of Late-Mesozoic convergent cycle.

Sedimentary basin types and extension processes of East Sea

Most of sedimentary basins on the continental shelf of Vietnam are filled by Oligocene-Miocene sediments which are mostly distributed in separate basin structures. The lower part of these basins is demonstrated by graben structures caused by normal faults or rifting or spreading. Those grabens became enlarged upward, to become sag basins. Deltaic basins are often generated on the rifting branches towards continent or land. The basins are directly connected to oceanic rifting or spreading branches of East Sea, which are filled mainly by marine sediments.

The sedimentary basins possessed linear structures along the continental rifting branches such as the Song Hong (Bacbo) and the Tho Chu-Malay basins, often filled by high-constructive deltaic sediments. Some nearrisometer or oval shaped basins resulted from sagging like Cuulong, Western Leizhou (Luichow) basins, filled by high-destructive deltaic sediments. The basins are situated near oceanic rifting or spreading branches such as the Nam Conson, South Hainan, Dong (East) Quangda basins, filled by marine sediments.

Song Hong (Bacbo) rifting basin with high-constructive deltaic accumulative type

The Song Hong (Bacbo) sedimentary basin possesses an elongated structure along a normal fault system from NW Hanoi to SE margin of the Bacbo Gulf (Fig. 5). The structure of the basin is controlled by a NW-SE normal fault system. Heterogeneous basement of basin is demonstrated by Paleozoic-Mesozoic formations. The sedimentary basin is filled up by Oligocene-Miocene terrigeneous materials with alluvial rhythmic type under the control of river branches.

Oligocene sediments are distributed in an elongated graben-type structure which is narrow in the coastal-plain part and is wide in the Bacbo Gulf part. The sedimentary section is characterized by an alternation of thick sandstone-siltstone beds with chaotic lamination, basal sand-conglomerate lenses and thin clay-siltstone beds with parallel lamination. They represent alluvial rhythms of progradation facies.

Miocene sediments are distributed in broad troughs from enlarged grabens. The vertical section indicates evidently alluvial rhythm structure by the alternation of chaotic sand-siltstone beds and

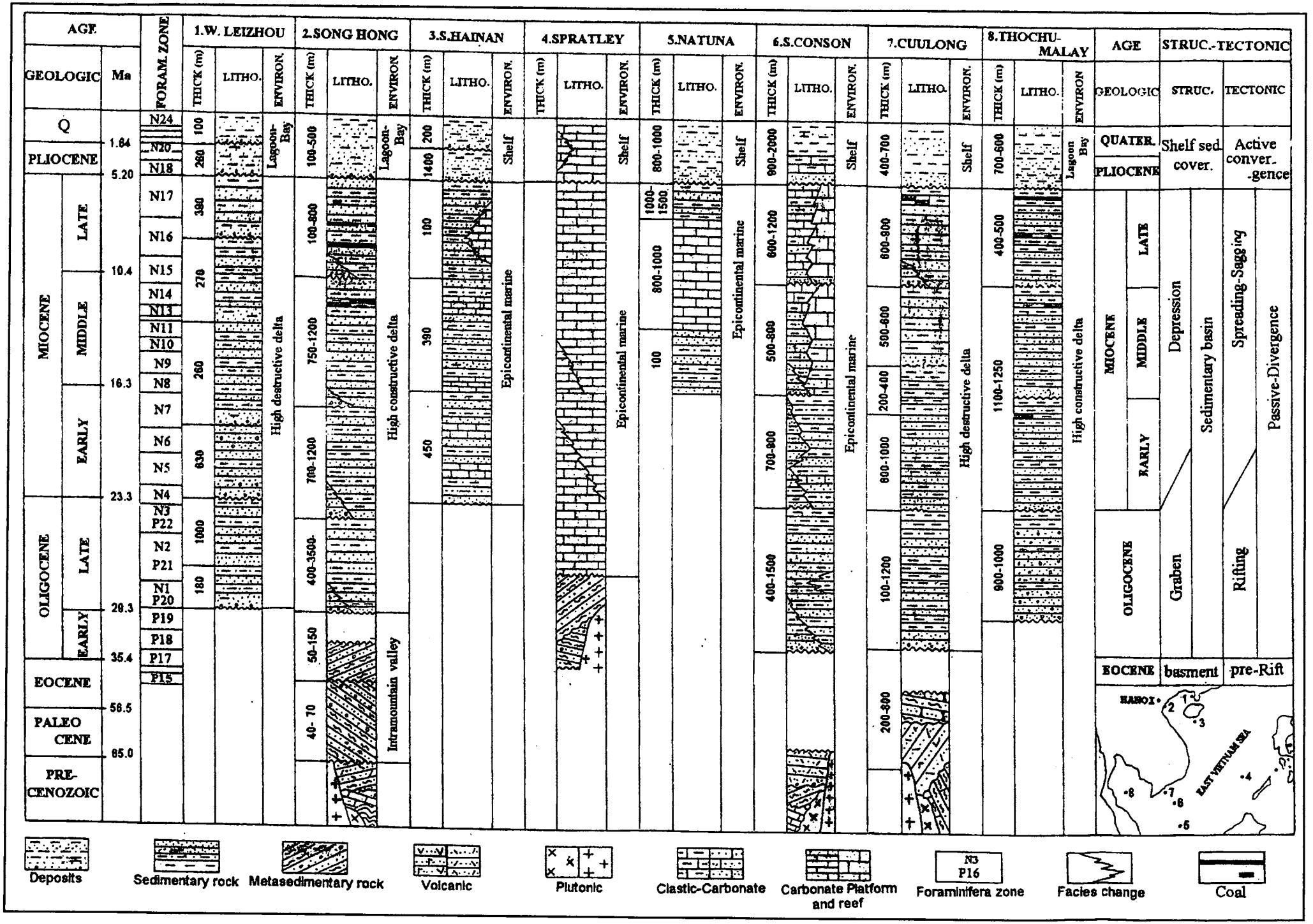


Figure 4. Cenozoic sedimentary sections.

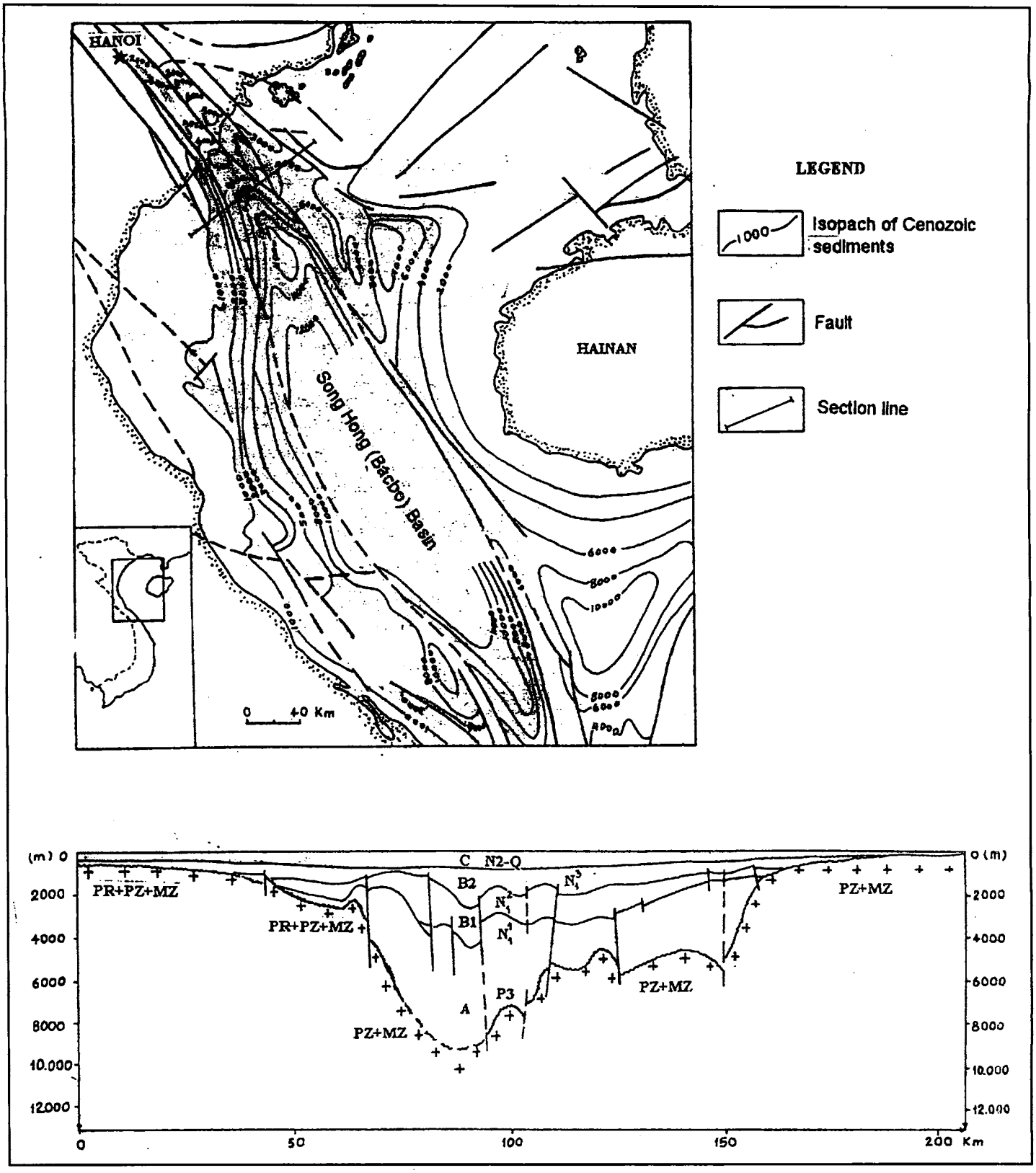


Figure 5. Song Hong (Bacbo) Basin.

parallel laminated clay-siltstone beds, and in some places of clay-coal lenses. Pro-deltaic or submarine-deltaic facies predominate in the Lower Miocene part, but the Middle Miocene sediments have a balance between deltafront, pro-deltaic and deltaic plain facies. The deltaic plain facies group is most predominant in the Upper Miocene (Fig. 6). Terrigeneous materials are mainly supplied by erosion of Pre-Cenozoic metasedimentary, metamorphic and magmatic formations from high land of upstream rivers in North Vietnam and South China mountains. Their distribution and accumulation are controlled by the downriver branches. Consequently, the Song Hong sedimentary basin is characterized by high-constructive deltaic facies.

Rifting process was caused by the break of consolidated Bacbo continental crust along deep normal faults. This made the intracraton rifting branch of East Sea extend toward the land. This branch was developed in the Oligocene to become a graben basin. Then, this basin changed to be a prolonged shallow depression in Miocene, sagging by bottom subsidence and diagenetic compression. Similar to the Song Hong basin, there is the Malay-Tho Chu rift with high-constructive deltaic sediments.

Cuulong sag basin of high-destructive deltaic accumulative type

The Cuulong basin, surrounded by Phan Rang-Vung Tau-Minh Hai coastal zone and submarine uplifted arc zone with Hon Khoai, Hon Trung, Con Son and Phu Qui islands, has an oval shape (Fig. 7). The heterogeneous basement of sedimentary basin is characterized mainly by plutonic-volcanic formations (48–162 Ma) and subordinate Jurassic-Eocene metasediments. The basin is filled mainly by Oligocene-Miocene fine-clastic rocks in rhythmic structures of lacustrine, estuarine, lagoonal facies with the tidal control.

Oligocene sediments are distributed in small grabens in the basin central zones, bounded by NE-SW and the E-W normal fault systems. These fault systems are developed within the Pre-Cenozoic basement to the top of Oligocene formations, and in some places, to the top of lower Miocene. The interbedding regular of thick claystone with thin fine sandstone and sand-siltstone demonstrates the estuarine and lacustrine-lagoonal rhythm with a low energy of current and high effect of tidal activities.

Miocene sediments are distributed in a large oval depression, caused by widening toward the flanks of the grabens and by subsidence of the basin. Lower Miocene formations are characterized mainly by thick beds of fine sandstone and sand-siltstone intercaleted with thin lenses of silt-claystone and claystone of tidal sandy facies. The Middle Miocene section consists of 2 sequences. The lower sequence is demonstrated by brown heterogeneous claystone beds and grey-greenish Rotalidea-claystone formation with Orbulina Universal indicating neritic facies of the submarine delta. The upper part is mainly of sandy sediment in tidal facies. Early and Middle Miocene sediments indicate a submarine deltaic or prodeltaic environment of neritic lagoon under the control of tide. The following late Miocene sediments are widely distributed further toward the plain to the west and south west of the basin. The Upper Miocene section is composed both of alluvial clastic sediments under river control and of neritic-lagoonal ones under tidal control (Fig. 8). The west-widening basin and lithologic characteristics of Late Miocene sediments suggest the beginning-activity of the Mekong river.

Most clay and clastic materials resulted from the weathering Mesozoic plutonic-volcanic blocks around the basin. Their distribution and accumulation were controlled by tide. The widening of the Cuulong basin toward the west plain is caused by constructive activity of the Mekong river of the Late Miocene stage. The accumulation caused by the river made the depositional environment change from destructive to constructive deltaic facies. But the sedimentary basin was still restricted within a neritic lagoon and the depositional process was predominantly controlled by tides. Thus, the Cuulong Oligocene-Miocene sedimentary basin is mainly a high-destructive delta under the control of tide.

The bottom subsidence of sedimentary basin in the Oligocene period was caused by the movement of basement blocks along deep normal faults. The subsidence of central basement blocks is stronger than the marginal ones and then the central grabens were filled up by thick sedimentary sequences. They caused a sagging processes to form the main basin. Such deposition can be possibly seen in Tertiary Western Leizhou (Luichow) basin.

Nam Conson spreading basin with marine accumulative type

The lateral structural plan of the Nam Conson basin is complicated and variable (Fig. 9). The sedimentary basin is limited on the west and northwest by the Conson-Hon Khoai swell composed of a plutonic-volcanic arc (45–168 Ma), to the south west by the Natuna arch of Mesozoic metasedimentary and plutonic-volcanic formations. The heterogeneous basement of the basin is characterized mainly by Mesozoic plutonic-volcanic and metasedimentary complexes and subordinate

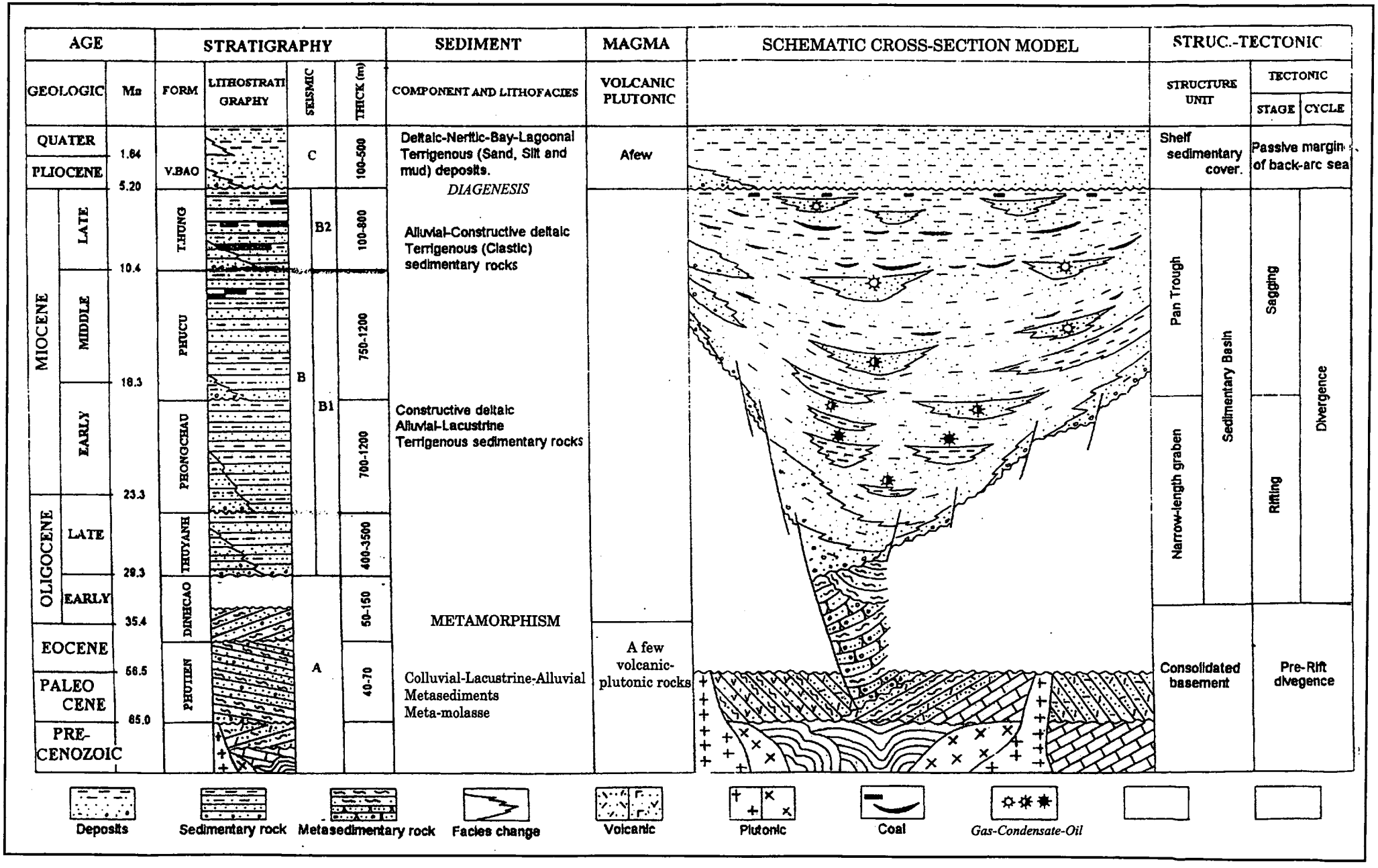


Figure 6. Structural-formational model of Song Hong (Bacbo) sedimentary basin.

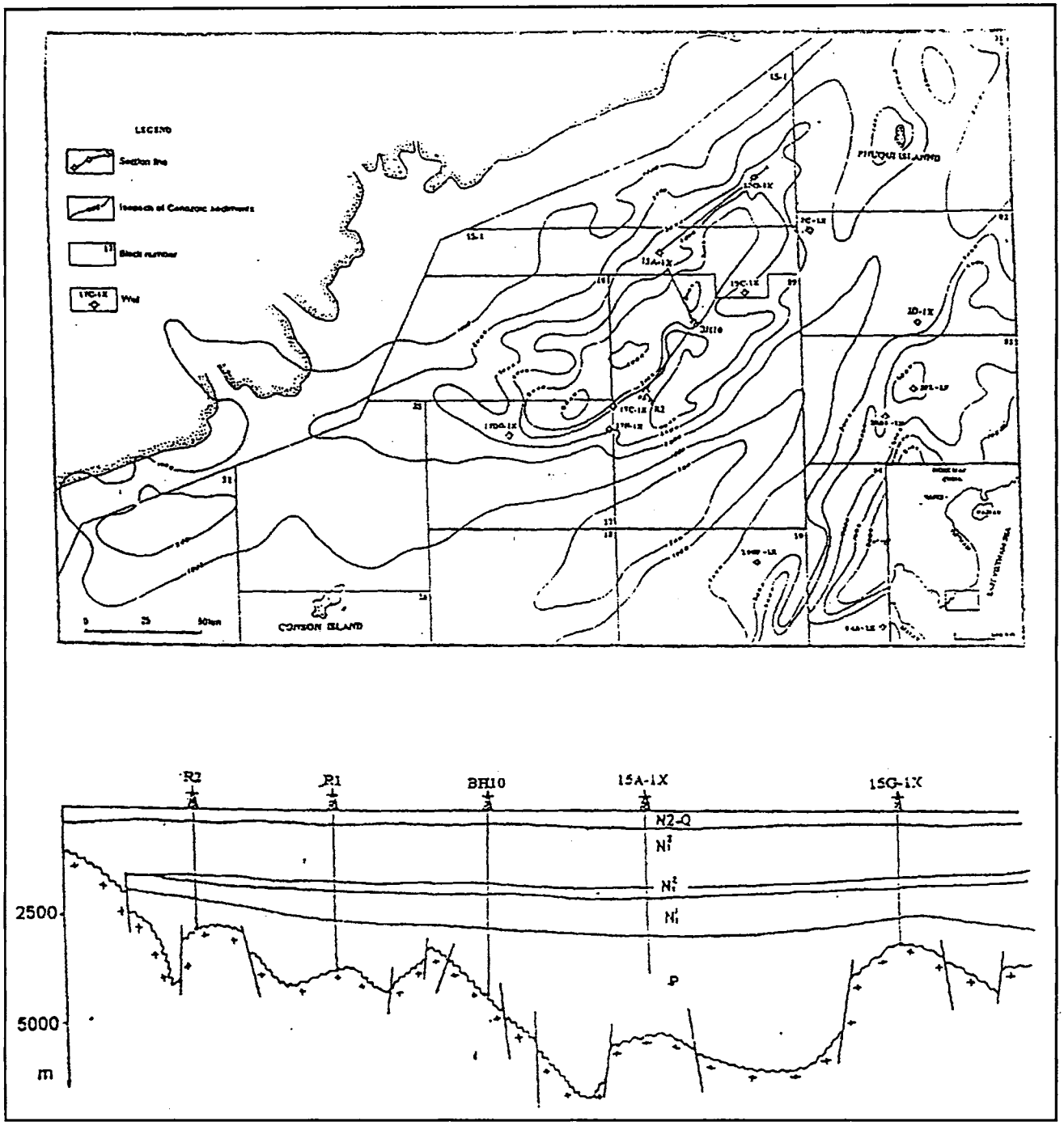


Figure 7. Cuulong Basin.

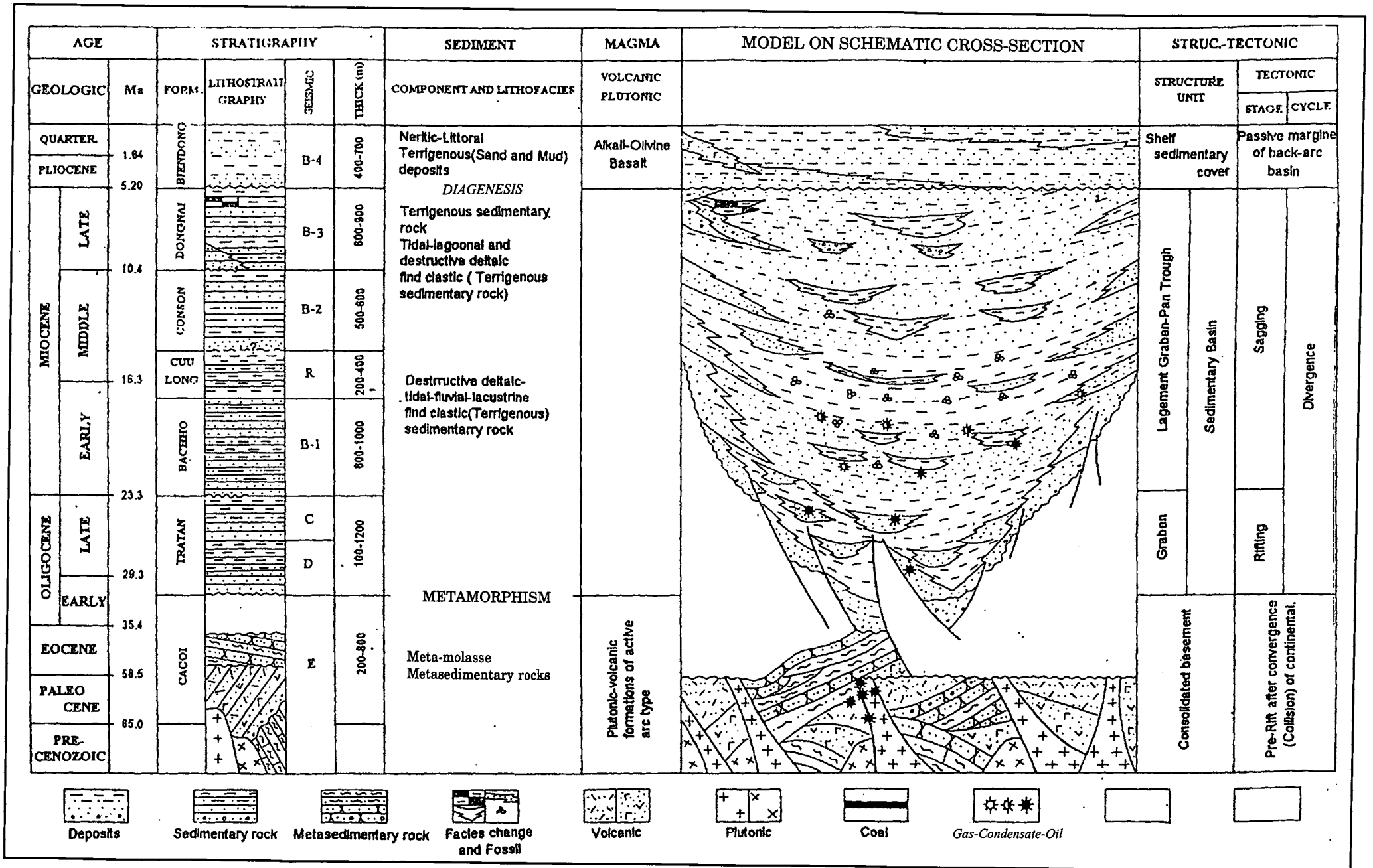


Figure 8. Structural-formational model of Cuulong sedimentary basin.

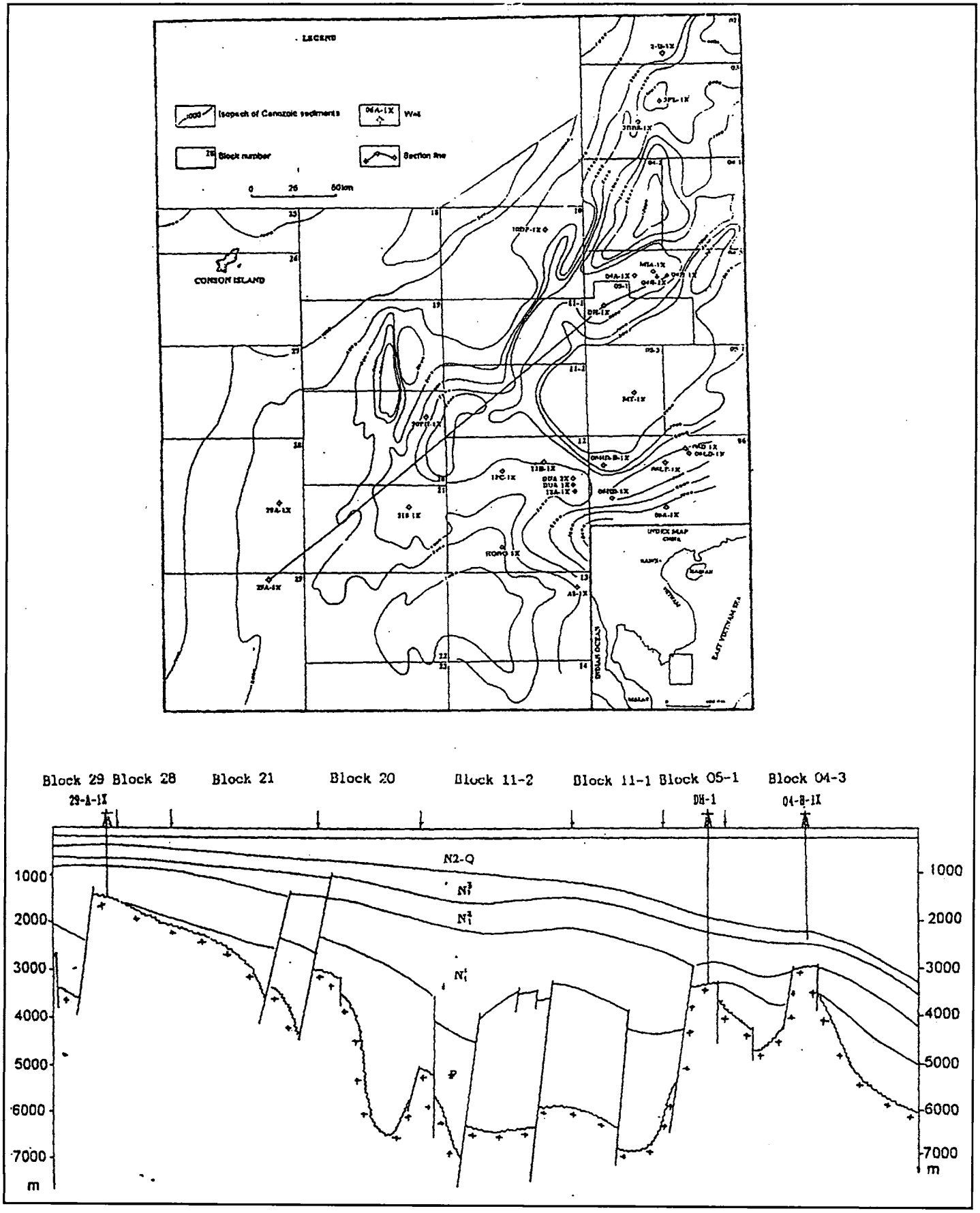


Figure 9. Nam Conson Basin.

Paleozoic formations. The interior structure is controlled by the NE-SW and the N-S normal fault systems, predominately trending NE-SW. The sag basin is filled up mainly by Oligocene-Miocene terrigeneous and carbonate sediments of neritic marine facies. Most fault systems extend up from the consolidated basement to the top of Oligocene formations, sometimes to the Lower Miocene formations.

The Oligocene sedimentary section is composed mainly of sand-siltstone and claystone and subordinate clastic carbonate and lime-claystone of neritic facies. The graben structure of the basin is caused by the relative movement of basement blocks along major normal faults, which relate to an oceanic rifting branch of the East-Sea.

Miocene sediments are widely distributed due to the enlargement of central grabens to the east and north-east of the basin along the spreading direction of the East Sea. They contain clastics and carbonates in the Lower Miocene part, but the Middle and Upper Miocene parts are characterized by reef and platform carbonates of neritic facies of warm-clean oceanic environment. Detrital and clay materials originated from the Conson-Natuna swells. But the carbonates are of authigenic materials deposited by biochemical process in the East Sea ocean. Most detrital carbonates are of intra-basin materials. The distribution of reef carbonates is related to uplifted structures on basement highs or probably on basalt (17–32 Ma), while the platform carbonates were distributed in central troughs of the basin (Fig. 10). Sedimentary interruption between Middle and Upper Miocene carbonate formation is confirmed by the abundance of karstic cave zones, dolomitization and weathered surfaces.

The Oligocene structure of the basin is demonstrated by complicated grabens, caused by relative movement of blocks along deep normal faults. These grabens widen toward the east and north-east, where they relate to the sprading axis of the East Vietnam Sea. The subsidence of the basin floor in the Miocene stage made a connection to the East Sea spreading micro-ocean. Probably, in the east and north-east of the basin there are encountered oceanic basalt ridges on which developed carbonate reefs. On the spreading branches of East Sea there are a number of marine basins such as South Hainan, East Quangda and East Phukhanh.

Pliocene-Quaternary shelf depositional cover of backarc basins

The Pliocene-Quaternary deposits are not limited to individual basins but are distributed over the whole present continental shelf. They are characterized by sand and mud, and in some places by carbonate reefs. Their distribution made a sedimentary cover over the whole shelf with thickness increasing towards the floor of the East Sea. Facies and thickness changes may be controlled by subsidence of the East Sea floor, caused by its subduction under the Luzon volcanic-island arc along the west Manila trench. Accompanied by continental uplift, there are scattered alkaline basalts, alkaline intrusives, reverse faults and marine inversions of nearshore limestone blocks.

HYDROCARBON PLAYS IN BASIN EVOLUTION

Basin analysis indicate important details of source, reservoir and seal rocks, which are influenced directly by basin evolution.

Sedimentary system and relative change of Cenozoic sea level

The Paleocene-Eocene formations of Vietnam relate to basement topography of upper Mesozoic structures formed by the consolidation of continents. Consolidation of the continental crust was caused by collision or convergence of the continents after the disappearance of the Tethys ocean. In this area the relative sea level was falling. There are only clastic sediments (molasse) and plutonic-volcanic complexes, which may represent reservoir sequences in the basin basement.

Oligocene-Miocene formations demonstrated transgressive phases. They define the relative rising of sea level which was controlled by rifting, spreading and sagging. There are lacustrine, deltaic marine formations, related to source, reservoir and cap rocks (Fig. 11).

The sea level changes and tectonic activities had influenced the trap formation and hydrocarbon distribution in the sedimentary basins.

Play attributes and hydrocarbon parameters

Many oil and gas fields were discovered in Tertiary basins on the continental shelf of Vietnam. They are not only in the sedimentary sequences but also in fractured basement.

Source rocks

Sedimentation system indicates a distribution of source rocks in some Tertiary basins on the continental shelf of Vietnam.

Oligocene and Miocene sediments of the Cuulong and Nam Conson basins consist of many fine clastic claystone and carbonate sequences in

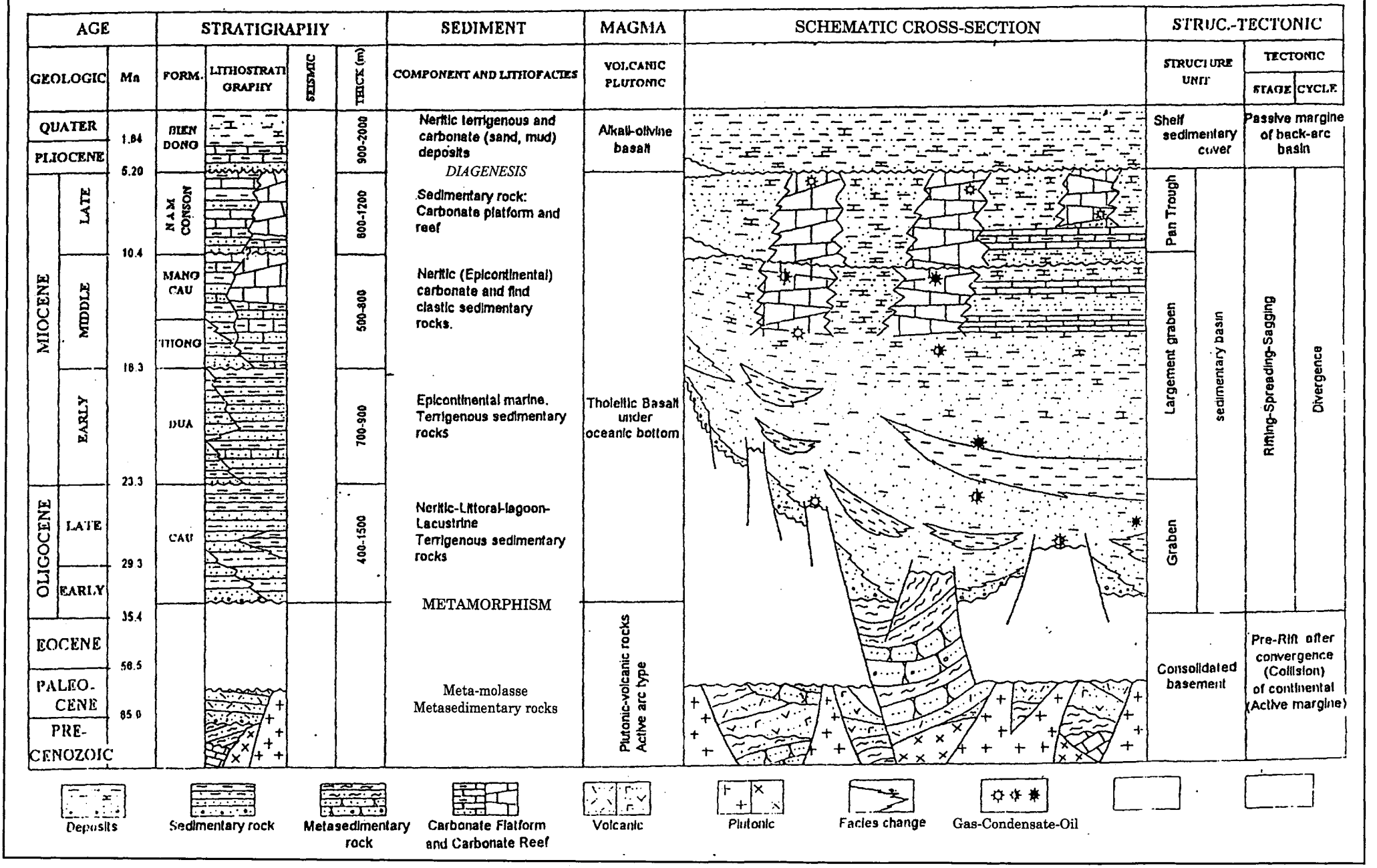


Figure 10. Structural-formational model of Nam Conson sedimentary basin.

lacustrine, estuarine, lagoonal, marine facies with great thickness. They are source rocks and have good potential for oil and gas. Based on geochemical analysis and environmental indications they are mainly composed of kerogen type II (Damolisap) in the Cuulong destructive deltaic basin and of kerogen type I and II in the Nam Conson marine basin. In the Bacbo construction deltaic basin the fine clastics and coal had a lot of humic matters of Kerogen type III.

Geochemical analysis shows that the Jurassic fine grained sediments of the Cuulong basin environs have a potential for hydrocarbon with TOC up to 0.4–0.8%.

Reservoir rocks

Important reservoir sequences of these basins are fractured compacted rocks of basement highs, clastics of Oligocene and Miocene formations and carbonate build ups of Miocene reefs.

Fractured porosity of plutonic-volcanic basement highs varies from 4–6% to 20–22%. Crude oil in fractured basement has better quality than in Tertiary sediments. Discovered oil in plutonic basement highs (quartz diorite, granodiorite, granite) of the Bachho (White Tiger) field shows that the thickness of the fractured reservoir zones can reach 1,000–1,500 meters. Fractured plutonic highs proved the existence of commercial oil in many structures of other blocks (15-C; 02-C). Commercial oil of good quality was discovered in the fractured volcanic sequence of Rong (Dragon) field. There may be carbonate reservoirs of Paleozoic formations.

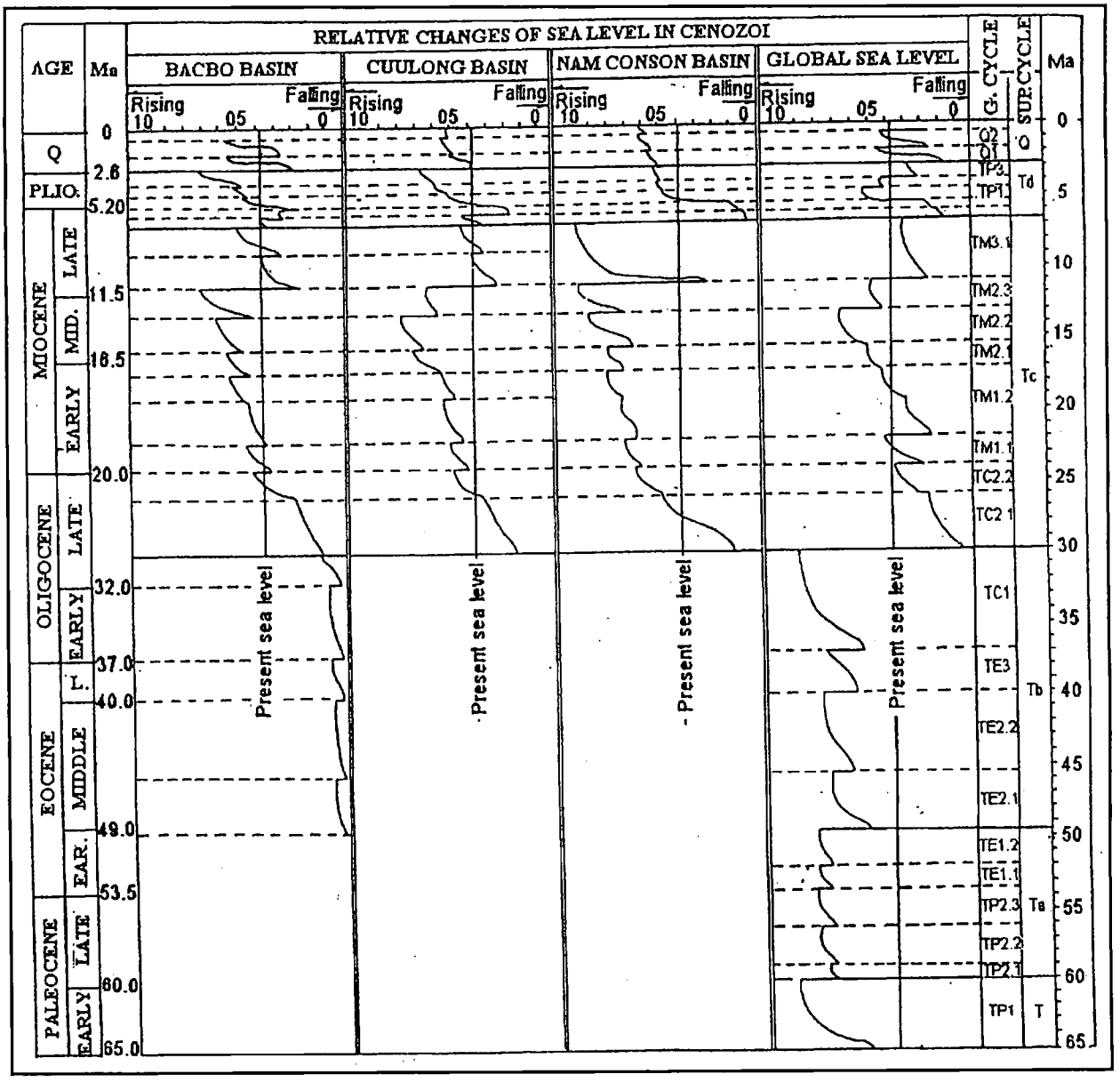


Figure 11. Relative changes of sea level.

Reservoirs of Miocene clastic sequences (porosity 10–24%) generally have better quality then the Oligocene reservoirs (4–16%) in total sedimentary basins on the continental shelf of Vietnam. Carbonate reservoirs in the Nam Conson basin are Middle-upper Miocene build-ups. Their porosity is varies from 12–15% to 30–35%.

Cap rocks or top seal

Cap rocks of the hydrocarbon traps could have originated from intra-basin shale sequences. Cap rocks are fine clastics and claystone sequences of Oligocene-Miocene formations. Cap rocks in the Cuulong basin generally have better quality than ones in Bacbo basin. Miocene and Pliocene formations of the Nam Conson basin consist of lime-clay sequences of neritic marine facies which act as good cap rocks.

Trapping

Hydrocarbons in Cenozoic basins on the continental shelf of Vietnam generally have accumulated in both structural and non-structural traps. The structural traps exist as anticlines on basement highs. There are many structural straps in Tertiary basins, some of them became big fields: Bachho, Rong, Daihung, Cuulong etc. There are many stratigraphic, deposition, fault (non-structural) and combination traps in Oligocene-Miocene formations of these basins.

Migration

Hydrocarbon migration in these basins occurred immediately after hydrocarbon formation conclusively synthesized in Miocene sediments of Cuulong and Bacbo basins, and in Miocene-Pliocene sediments of the Nam Conson basin. Lateral migration is caused by influence of basement structure up-dip towards the basin edge, while vertical migration followed the fault zones directly from the source rock.

Some oil discoveries in fractured volcanic-plutonic basement of Back Ho, Rong fields show that oil migrated vertically from deep source rocks underneath through faults reaching the formation.

Hydrocarbon plays

Many oil and gas fields were discovered in Tertiary basin on the continental shelf of Vietnam. A great deal of hydrocarbon plays and prospects are determined in Tertiary basins on the continental shelf of Vietnam.

Pre-Cenozoic plays in fractured basement of sedimentary basins

Hydrocarbons discovered in fractured plutonic-volcanic basement of the Cuulong basin have better quality than that in Oligocene and Miocene sediments. Pre-Cenozoic petroleum plays of the Cuulong basin are characterized by plutonic-volcanic fractured reservoirs in the basement. Commercial oil flows from fractured reservoirs in the plutonic basement of the Bachho (09-BH) and Cuulong (15-C) structures have better quality and are stronger than those in the Oligocene and Miocene plays. Volcanic reservoirs in fractured basalts of the Rong (09-R) field, containing commercial petroleum is better and bigger than those in Oligocene-Miocene clastics. Hydrocarbon may have migrated along deep faults from Oligocene source rocks or, probably from Jurassic source rocks (Fig. 12).

A possible Paleozoic carbonate play may occur in the fractured basement of the Malay-Tho Chu basin. However a Permian carbonate play was only discovered onshore Thailand.

Oligocene and Miocene plays of clastic sediments

Clastic plays belonging to Oligocene and Miocene sediments are mainly distributed in the Cuulong, Song Hong and Nam Conson basins. Oligocene and Miocene plays of the Cuulong basin are discovered in many structures (09-BH; 09-R; 17-C; 15-A; 01-RB; 16-BD; 16-BV; 16-TD etc.). The Oligocene play is characterized by clastic reservoir with porosity 8–14%: source rocks of Kerogen type II and TOC from 0.5–0.8 to 2.5–3.0 and local seal sequences. The Miocene play of this basin has lower Miocene clastic reservoir with porosity 12–22% and regional topseal of Middle Miocene claystone sequences. Source rocks of the Miocene play may be Oligocene-Miocene claystone sequences. Clastic plays of the Song Hong basin are indicated in the TienHai field. The Oligocene play of the basin has clastic reservoir with poor-fair porosity (4–9%), local topseal and source rock of kerogen type III (Humic). The Miocene play of this basin is demonstrated by a good reservoir, but a poor local topseal (Fig. 13).

Oligocene and lower Miocene plays are indicated by clastic sedimentary sequences of the Nam Conson basin. The main reservoirs are connected to primary porosity varying from 5–6% to 18–22%, declining with depth. Source rocks may be both Oligocene claystone and Miocene lime-claystone with kerogen type I–II. Seal formation includes claystone and lime-claystone sequences.

Miocene plays of carbonate sediments

Miocene carbonate plays have been discovered principally in the Nam Conson basin. These plays are characterized mainly by build-up carbonate reservoirs with skeletal and karstic porosities

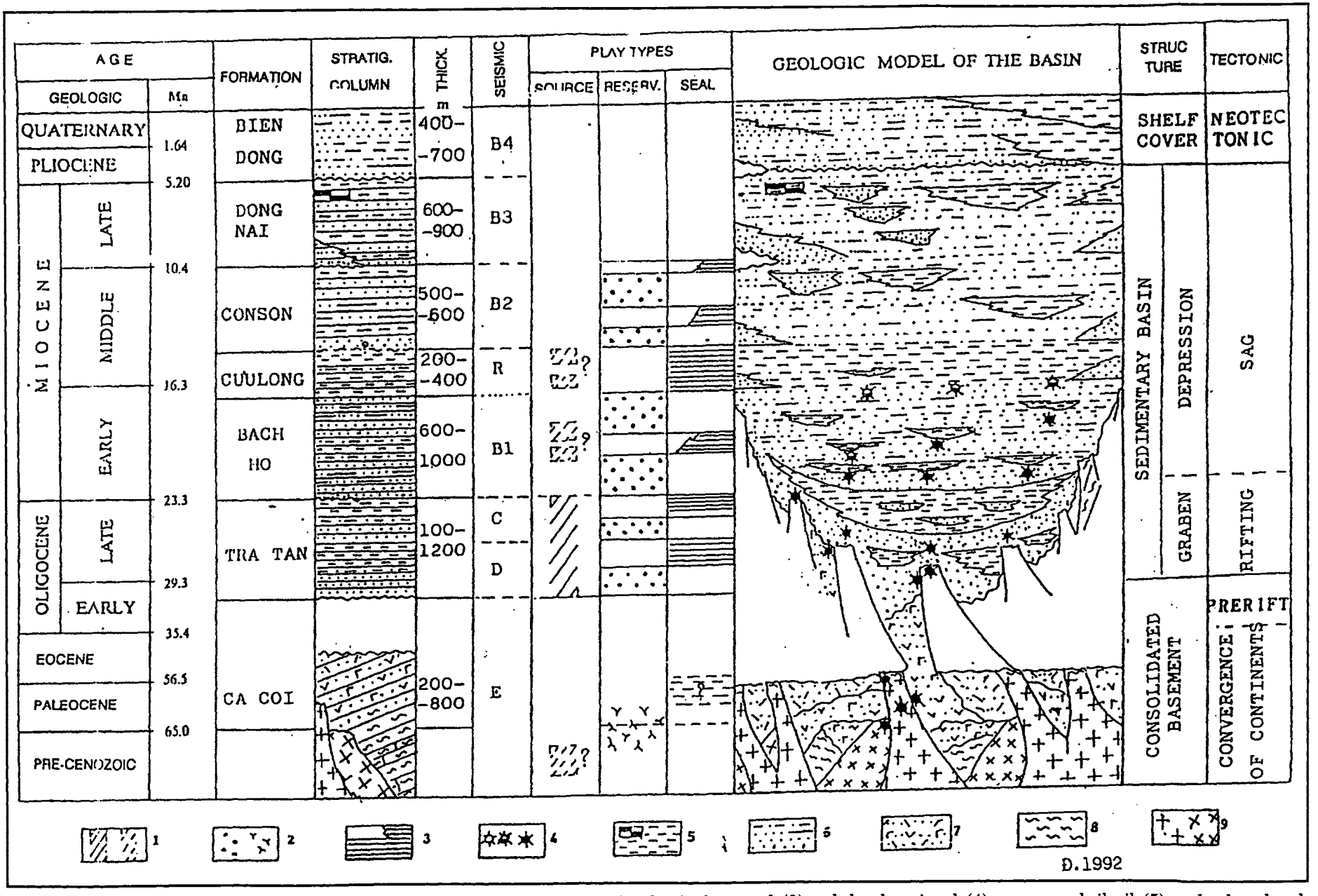


Figure 12. Petroleum plays of Cuulong (Mekong) basin. (1) source; (2) reservoir: clastic, fractured; (3) seal: local, regional; (4) gas, gas and oil, oil; (5) mudrock and coal; (6) clastic rocks; (7) Mesozoic volcanic rocks; (8) Mz sediment; (9) Mz plutonic

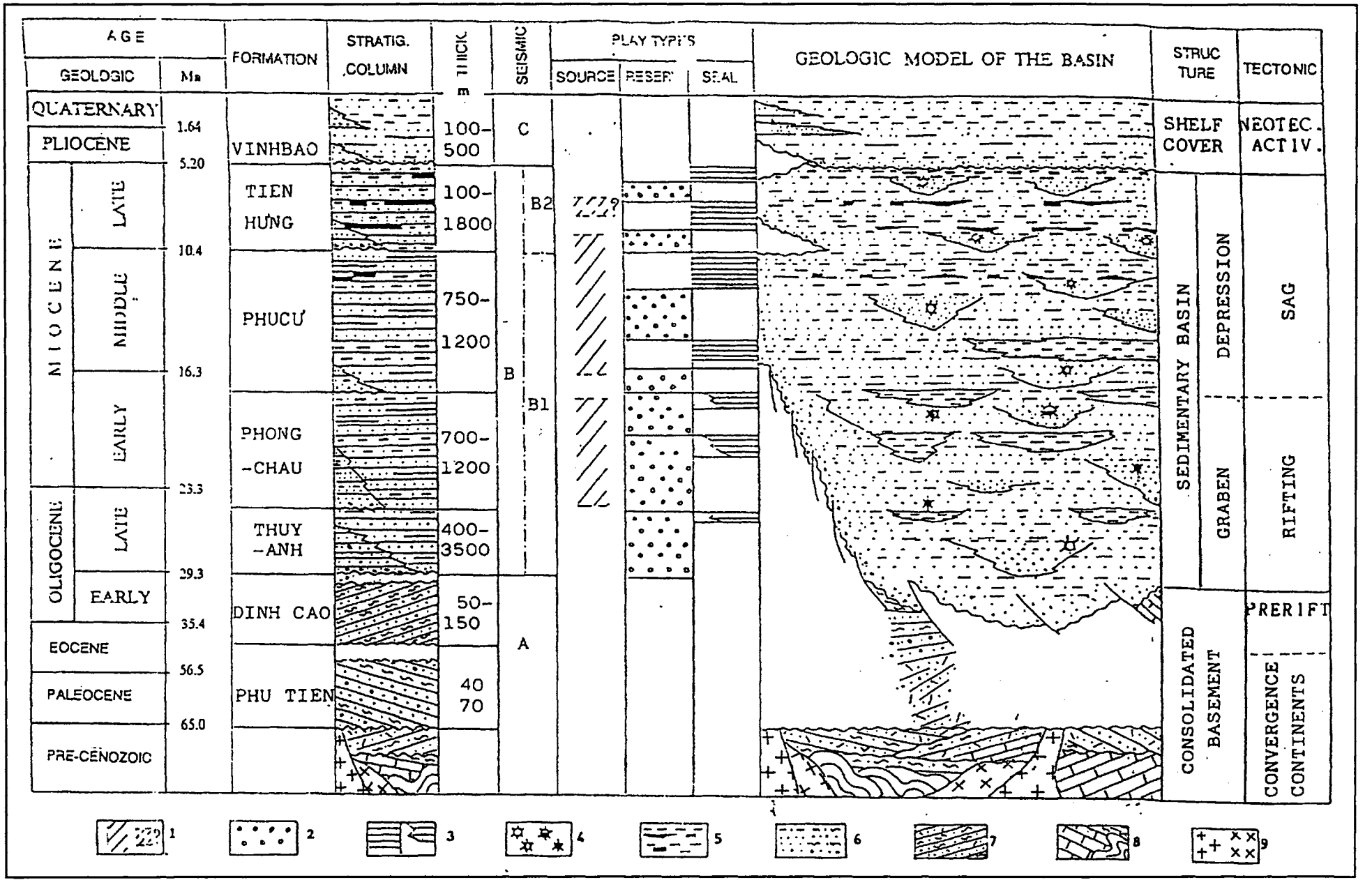


Figure 13. Petroleum plays of Songhong (Bacbo) basin. (1) source; (2) reservoir; (3) seal; (4) gas, condensate, oil; (5) mudrocks and coal; (6) clastic rocks; (7) Mesozoic formations; (8) Paleozoic and older formations; (9) plutonic types.

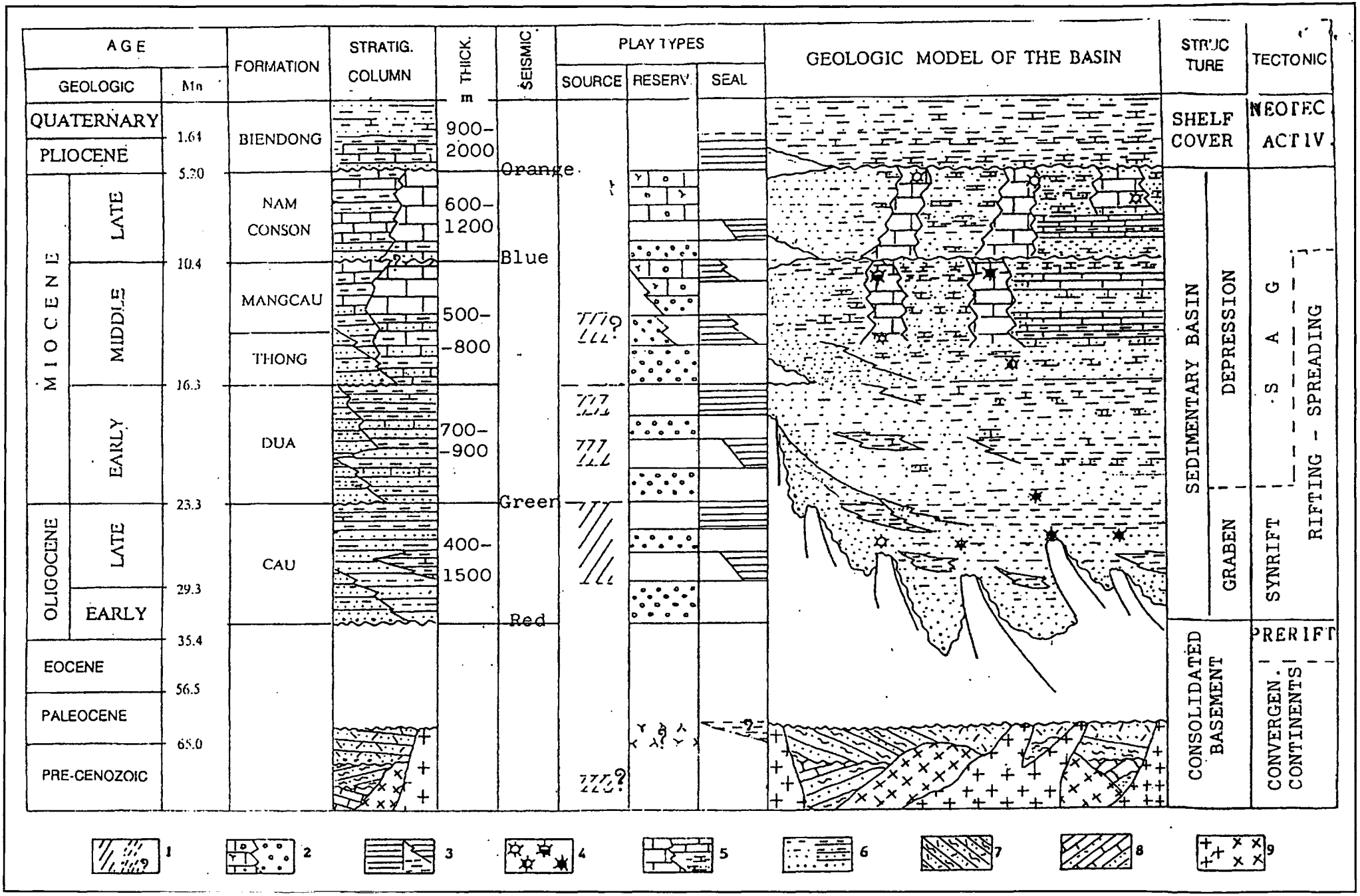


Figure 14. Petroleum plays of Nam Conson basin. (1) source; (2) reservoir: carbonate, clastic; (3) seal; (4) gas, condensate, oil; (5) reef and platform carbonate; (6) clastic and clay; (7) Mesozoic; (8) Paleozoic; (9) plutonic.

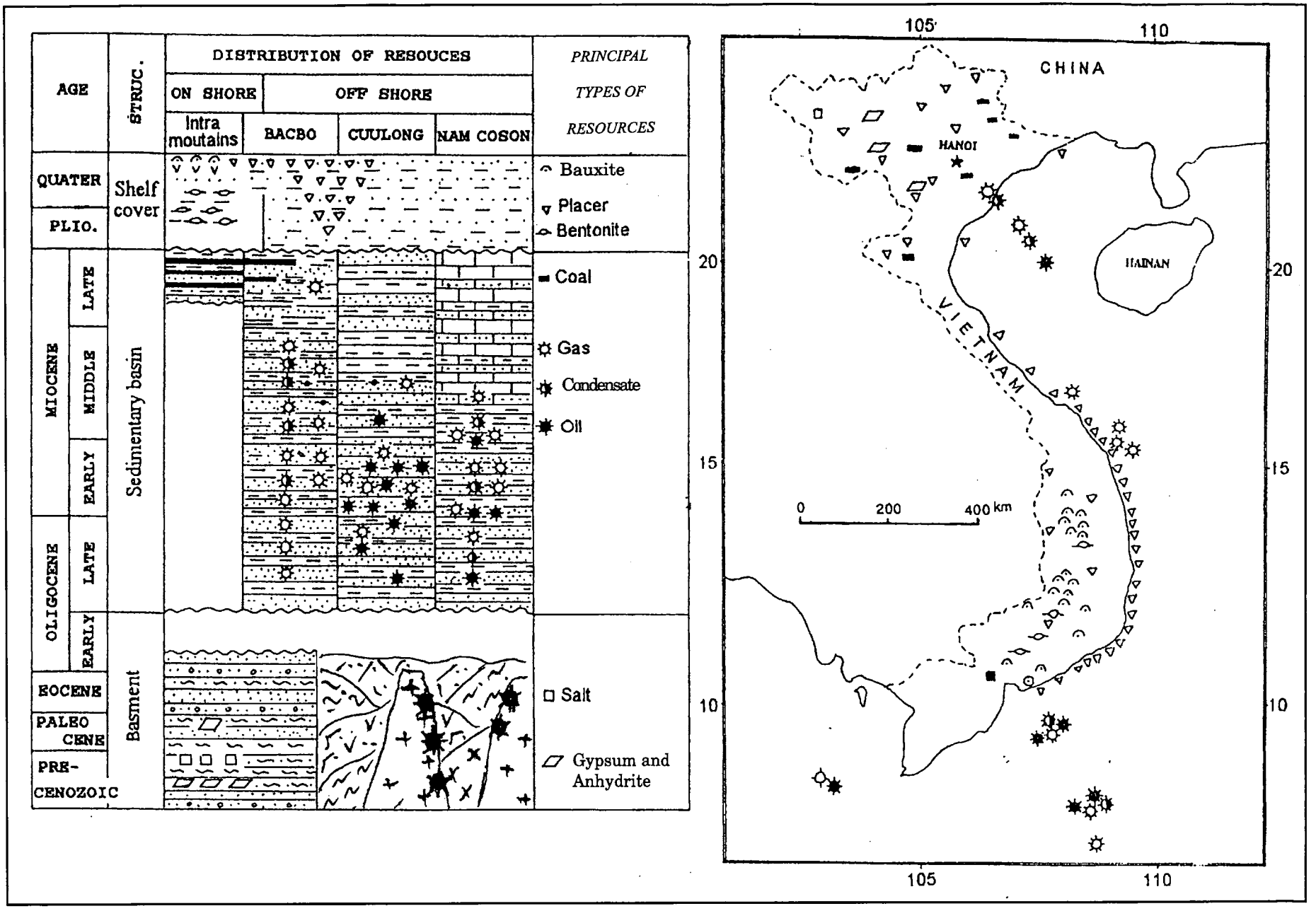


Figure 15. Distribution of resources on shelf of Vietnam.

varying from 10–15% to 30–35% (Fig. 14). Probably the seal rocks of these plays are Pliocene lime-claystone and claystone thick sequences. Sapropel generation is connected to type I and II organisms.

Hydrocarbon field distribution

Many hydrocarbon fields have been discovered on the continental shelf of Vietnam. Field size distribution depends on hydrocarbon plays with their prospects and was made to find description of characteristic of hydrocarbon trapping habitat in a basin.

There are many discovered fields and a great number of hydrocarbon bearing structures in the Cuulong basin. The Back Ho (White Tiger) field consists of Pre-Cenozoic plutonic play in fractured basement highs, and Oligocene and Miocene clastic plays in sedimentary basin. The Back Ho field has a lot of prospects with many types of hydrocarbon traps. The Pre-Cenozoic basement play of the Rong (Dragon) field is demonstrated by fractured volcanic reservoir and there are many trapping types belonging to Oligocene and Miocene plays. Commercial oil was discovered in fractured plutonic basement of the Cuulong structure (15-C). Both pre-Cenozoic fractured and Oligocene, Miocene clastic reservoirs with hydrocarbon discoveries found in different structures of the Cuulong basin such as Cam (17-C), Tam Dao (16-TD), Bavi (16-BV), Baden (16-BD), Tratan (15-A), Ngocbich (02-C) etc. (Fig. 15).

Many hydrocarbon fields have been discovered in the Nam Conson basin. There are many hydrocarbon discoveries in different structures such as: Daihung (Big Bear: 05-DH), Tuongvi (06-A), Lantay (06-LT), Lan Do (06-LD). There are build-up carbonate reservoirs besides fractured basement and structures in clastic rocks (Fig. 16).

The Tien Hai gas and condensate field is distributed on the land part of the Song Hong basin. The Oligocene play of this field is characterized by clastic reservoir with combination traps. Gas and condensate were discovered in some wells of other structures of the Song Hong basin (103-TG; 103-TH; 107-PA) (Fig. 17).

There may be many undiscovered fields in Tertiary sedimentary basins on the continental shelf of Vietnam especially in their basement.

CONCLUSIONS

There are many hydrocarbon bearing basins on the continental shelf of Vietnam. The formation of these basins together with their petroleum fields is related to rifting, spreading and sagging processes to form and to wide East Sea.

The Song Hong (Bacbo) basin is formed on the rift toward the continent branch and filled up by high constructive deltaic sediments. The TienHai gas and condensate field has been discovered in the land part of this basin with Oligocene and Miocene clastic plays. Many other hydrocarbon bearing structures on the Bacbo Gulf are discovered. A great hope of Oligocene and Lower Miocene plays occurs deeper than 3,000 metres in the Bacbo Gulf.

The Cuulong (Mekong) basin is a great petroleum province. Its formation is related to intra-cratonic sagging caused by blocks moving along normal faults and filled up by high-destructive deltaic sediments. There are many of petroleum fields and many hydrocarbon bearing structures in this basin. The Pre-Cenozoic oil plays are demonstrated by fractured reservoirs of the Bachho (09-BH) plutonic, Rong (09-R) volcanic and Cuulong (15-C) plutonic-volcanic basement. They have better quality than Oligocene and Miocene clastic plays. A great number of other hydrocarbon bearing structures have been discovered with commercial flows.

Nam (South) Conson basin is a complicated structure of a spreading branch, filled up of marine sediments. There are many build-up carbonate traps. Oil and gas has been discovered in many structures; some of them became hydrocarbon fields. In the central, east and north-east parts, there are hydrocarbon plays with good source, reservoir and seal attributes. Although there are many discovered hydrocarbon fields and structures, the continental shelf of Vietnam is a large area and many new fields have yet to be discovered.

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