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Margin deltas in the northern part of the Red River basin

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Abstract. Margin deltas are the last ones that were formed in a shelf break zone, when a sea level has slowdown during last time of a forced regression and the beginning of the success transgression. The margin deltas are abruptly thickened in the zone of shelf break, became thinner landward and basinward. Because they were formed in the shelf edge, they have a relatively high sand/clay ratio, prone to turbidite.

In the northern part of the Red River basin, during the Miocene the margin deltas had developed eastward from the plot 103, i.e. from the borehole 103-TH-1X, 103-TG-1X and 103-HOL seaward.

An existence of the margin deltas in this region confirms a presence of the basin floor fans in the central part of basin - very important objects for oil-gas prospecting.

Keywords: Margin delta; Delta front deposit; Red River basin;

1. Introduction

When sea-level slowdowns in the transgression-regression cycle, especially due to lowering sea level, a shelf was exposed and a series of deltas were formed. A margin delta is the last one that was formed during the last time of lowstand stage and early time of the next transgression stage. There are some papers dealing with margin deltas [5, 6]. The margin deltas are well developed with a width of tens kilometers and thickness reached hundreds meters, their slope is about $3\text{-}6^0$. A study of margin deltas has an important role in prospecting and exploration oil and gas on the shelf. A presence of the margin deltas will help in determining whether there is a basin floor fan - an important object in oil and gas prospecting. Furthermore, themselves, they are also subject of prosperous potential of oil and gas. For the first study of margin deltas in the northern part of the Red River basin, the Miocene deposits in the northern part of the Red River basin - where a continental shelf was well developed and has a high potential of oil and gas - were chosen. The data used in this study was collected from Vietnam Petroleum Institute and other publications.

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2. Some characteristics, forming process and development of the margin deltas

Most of margin deltas were developed in a passive margin area. These deltas have a lob or multilob form and stretched along strike [5, 6]. The length of these margin deltas often reached 30-50 km and their width is of tens, or even hundred kilometers (Fig. 1).

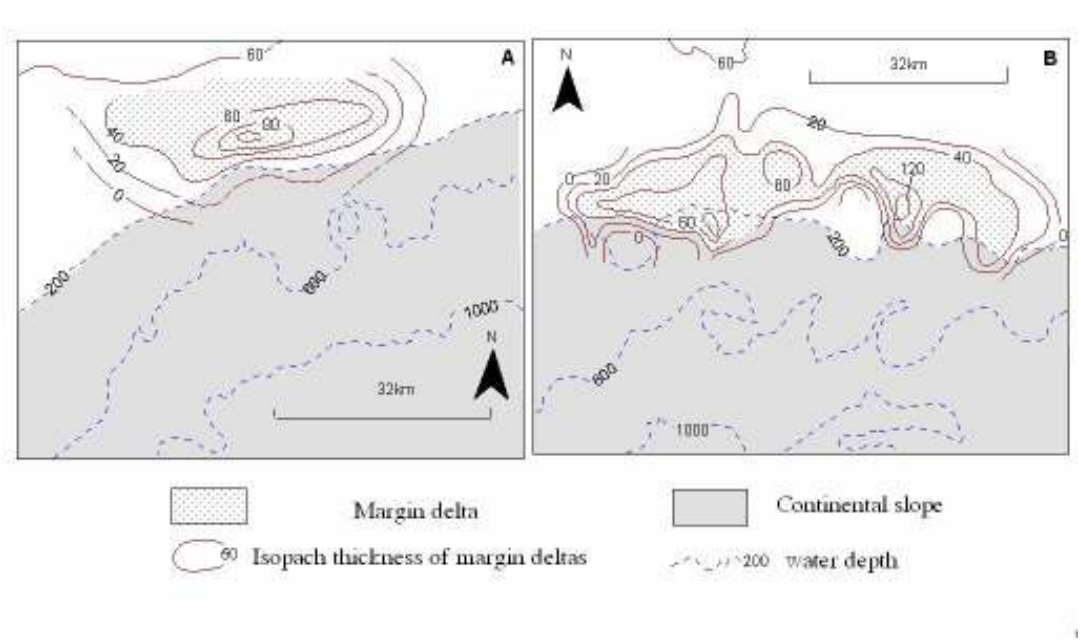

Fig. 1. Geometry of margin deltas: A-Mexican gulf, B-Mississippi (S.J. Porebski, R.J. Steel, 2001).

The thickness of the margin deltas is about 50-70m, even somewhere it reached more than 150m. On seismic profiling, their refections are from oblique to tangential form, dipping to the basin, ended by toplap under erosion plane. A key facies complex of the margin deltas is a complex of river mouth bars and delta front/slope deposits. Landward, a river mouth bars consist of fine to medium sands with a high thickness. These sands are more or less clean, wave bedding or parallel, plane or oblique bedding with a low slope. Delta front deposits are underlain by shelf deposits that were formed before and consist of thick sand layers. Because delta front deposits of margin delta are underlain by previous formed deltaic deposits, so normally they are consist of very thick sand layers and also turbidities.

Margin deltas are different from inner deltas by the following features:

- Margin deltas have a multilobe or accurate to lunate bodies while inner self deltas have a horsetail form.
- The size of clinoform wedges with a maximum thickness at shelf break is much more bigger than the inner or middle shelf delta, reached hundreds meters comparing to tens meters of the last.
- In dip direction, margin delta deposits are thicken as a clinoform wedge towards the shelf edge and became thin gradually down into upper slope deposits.
- Sigmoidal dip cross-section.
- The most distinctive feature of the margin delta is their strike-elongate form

along shelf edge and could reach 30-90 km. The isopach of the margin delta deposits have a strike elongate form and are augmented by faults.

- Landward these deposits are pinchout by onlap onto shelf shales and basinward the shelf delta deposits pinchout by downlap to hemipelagic shales.

- There is an evidence of shortenning in stratigraphy.

- The delta front/prodeltaic deposits of the margin delta are prone to turbidite.

- The abundance of so called soft deformation of the deposits related to the slope.

- The absence of a horstail paralic along shelf edge.

Margin delta forming process and evolution history are closely related to a forced regression of the sea level during the late time of the lowstand stage, beginning time of the transgression stage (Fig. 2).

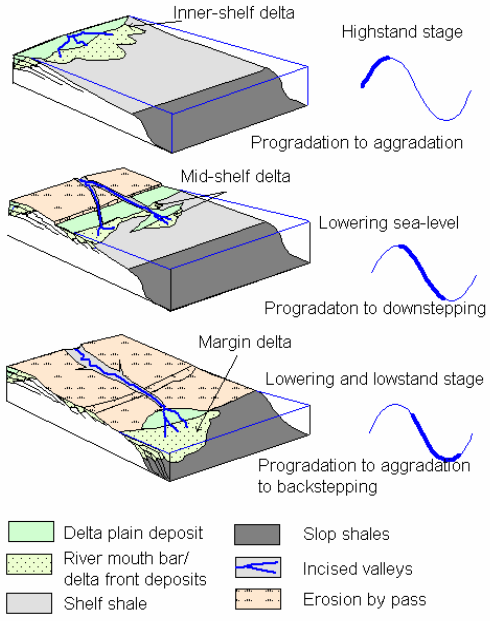

Fig. 2. Forming processe of a margin delta related to sea-level change (Porebski, Steel, 2001).

Margin delta deposits were formed in relatively deep water and are wide spread in the shelf area, where strong subsidence occurred. The margin deltas are composed of a series wedges, the upper boundary of which is a trace of sediment supply or of complex erosion/transgressive erosion. Because margin deltas are formed in the shelf break zone so their thickness is abruptly increased at the shelf break and deltaic clinoforms have bigger size compared to others. When deltas have reached to the shelf margin as a result of lowering sea-level, heterolithic delta front deposits with small bedding became more turbidite because supplied rivers will debouch directly to a slope area, which has a longer distance and higher slope, creating a good condition for a hyperpicnal flow. This is why the clinoforms of margin deltas have a bigger size compared to others.

3. Some geological characteristics of study area

The study area includes zones 102, 103, 104 and a west part of zone 107 (Fig. 3). The sea depth is from 40-50m to 80-100m. Oil and gas prospection and exploration in this area were started from an earlier time.

Since 80-s of the 20 century, a prospect was carried out more intensively. Foreign investors and Vietnamese prospectors had carried out thousands kilometers of 2D and hundreds kilometers of 3D seismic profiling. Many deep boreholes were set up for investigation oil-gas potential of the Vietnamese shelf. Although investigations in different zones were not at the same level but results of these investigations have revealed some geological characteristics and evolution of the Red River basin in general. Geochronologically, the Miocene deposits

were divided into 3 units as follow:

3.1. Phong Chau Formation (N_1^1 pch)

This formation was established in 1972 by Palustovich and Nguyen Ngoc Cu, based on cross-section from 1,820m to 3,000m of the borehole GK 100 in Phong Chau District, Thai Binh Province. This cross section is characterized by intercalated of medium to fine grained sandstones of grey to whitish, dark green color with silty sandstones with very thin stratification, from some millimeters to some centimeters, that formed an "eye" structure, lenses or wave and called a "striped" rock. A cement of sandstones is mainly carbonate with high content (25%). Secondary minerals are glauconite and pyrite. The thickness of formation reached 1,180m. The Phong Chau Formation is distributed mainly in Khoai Chau - Tien Hai area and developed to the Bac Bo Gulf (Borehole 103-TH). It is composed of sandstones, silty sandstones and claystones with some coal traces or thin limestones (borehole 103-TH, 103-HOL). Their cement is carbonate. Claystones are light grey, brownish red, parallel or wavy stratification. Their composition is composed mainly of kaolinite and illite.

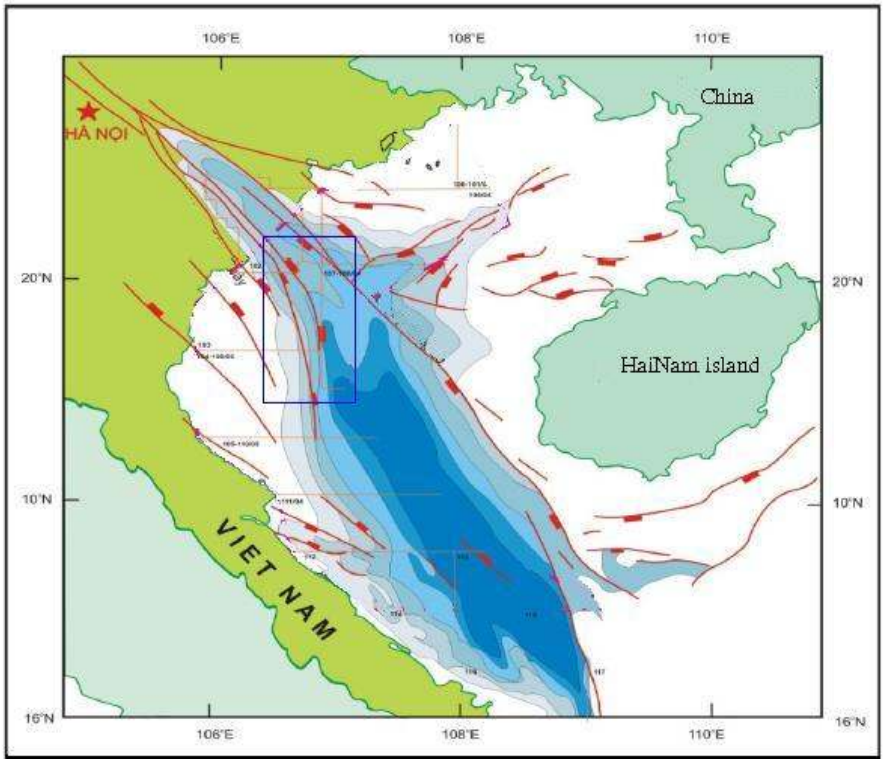

Fig.3. A study area.

In the seismic cross-sections, Phong Chau Formation is appeared as a parallel reflection with a good continuity. Based on palynological analysis, Phan Huy Quynh and Do Bat (1985, 1993, 1995) have established a complex of *Betula- Alnipollenites* and zone

Florschuetzia levipoli of early Miocene. Deposits of Phong Chau Formation were formed in the deltaic condition and shelf (Borehole 104), with some phases of transgression (borehole 100). Marine deposits increased seaward. They are underlain with unconformity by Dinh Cao Formation or older rocks.

3.2. Phu Cu Formation

The Phu Cu Formation was established by Golovenok V.K and Le Van Chan in 1966, who first time described this formation from borehole GK 2 (from 960m to 1,180m) in Phu Cu structure of Ha Noi Depression. However, at this time a bottom of this formation was not clear. The formation is consists of deposits that are characterized by clear cyclicity of medium sandstones, silty sandstones with thin stratification (wavy, lenses, cross bedding), silstones, claystones of massive structure, contain a lot of flora, bottom animals, foraminifers and thin beds of lignites. Sandstones are monominerals, well sorted and rounded. Beside turmaline, zircon as secondary minerals somewhere glauconite and garnet are occurred. Later, after careful check of all cross sections of Phu Cu Formation of the deep boreholes that penetrated across the whole formation, Phan Huy Quynh and Do Bat (1983) and Le Van Cu (1985) have divided the Phu Cu formation into 3 parts according to cyclicity point of view. Each part consists of sandstone, siltstone, claystone contain coal and flora fossils. Somewhere foraminifers and brackish molluscs are occurred.

The Phu Cu deposits are wide spread in Hanoi Depression. Its thickness became lower in Dong Quan area and higher seaward in Bac Bo Gulf. Deposits consist of sandstones, silty claystones, coals and somewhere thin layers of carbonates. Sandstones have a light grey to light green color. They are fine to medium grainsized, average to well sorted. Their typical feature is thin bedding. There are siderite nodules or glauconites (boreholes GK 100, 102, 110, 104). A carbonate cement of sandstone is abundant, clay cement is rare. Silty claystones are light grey to dark grey color, contain a little of carbonates, flora and coals (borehole GK 103-TH). The thickness of this formation is varies from 1,500m to 2,000m. This formation is distinguished by a high content of organic matter, about 0.86%wt, that reached a criterion of source rocks and in fact, in Hanoi Depression, oil and condensats were found in this formation.

On seismic cross-sections, deposits of this formation are displayed as a parallel or chaostic reflectors with high amplitude and frequency that related with coal bearing layers. Their Middle Miocene was established based on a complex of fossils: *Florshuetzia trilobata and Fl. Semilobata and Globorotralia mayeri, Orbulina universa.*

The Phu Cu Formation is conformably underlain by the Phong Chau Formation and was formed in the deltaic and shelf condition with some phases of marine transgressions. Seaward to the Bac Bo Gulf, these deposits have changed into underwater delta, delta front deposits.

3.3. Tien Hung Formation

The Tien Hung Formation was established by Golovenok V.K and Le Van Chan (1966) and its name - Tien Hung is a locality of Thai Binh Province, where its stratotype was established in the borehole GK-4 from 250m to 1,010m. The Tien Hung Formation consists of deposits that have very

clear cyclicity. Each cycle started by brecia, sandstones that changed into silstones, claystones with some lignite layers. The thickness of coarse deposits is thicker than finegrained deposits. The amount of observed cycles in this formation is 15-18. Sandstones and brecias are weekly cemented, bad sorted and rounded, contain many garnets. There are sandstones of whitish grey color contain siderites nodules in the lower part. The thickness of the formation in this borehole is about 760m.

Because of facies change, it is difficult to determine the boundary between Tien Hung and Phu Cu formations. In the lower part of Tien Hung Formation, Phan Huy Quynh and Do Bat (1985) have found a layer of grey sandstone, contains a marks of leaves that is quite widely occurred in the most boreholes in the Hanoi Depression. They consider it as a sign of change to continental condition after forming the Phu Cu Formation. The bottom of this sandstone is regarded as a lower boundary of the Tien Hung Formation. The Tien Hung Formation is widely distributed in most boreholes of the Hanoi Depression and offshore in Bac Bo Gulf. Sandstones of this formation have a thick to massive stratification, light grey color to greenish grey, average to bad sorted. Their cement is carbonate or clays. Silty claystones have a dark grey to light grey color, somewhere brownish grey, dark grey (Borehole 104, 102-HD), contain coals and fossils with glauconites and pyrites (boreholes 100, 103-TH). Total thickness of this formation is varied from 760m to 3,000m.

On seismic cross-sections, the Tien Hung Formation is displayed as a sequence with a weak stratification, high amplitude. The Tien Hung Formation has a contact with the underneath Phu Cu Formation by an unconformity that has a sign of regression in uplift zone with two phases of non-continuity reflectors. Fossils founded in the Tien Hung Formation consist of a mark of flora, spore and pollens, foraminifers and nanoplankton. A typical complex was found in medium sandstones such as *Quercus lobbii, Ziziphus.* This layer is occurred widely in the Hanoi Depression as well as in the North Vietnam such as in Tam Cha (Na Duong, Lang Son), Bach Long Vi, Trinh Quan (Phu Tho). The Late Miocene age of this formation was established based on a pollen spore complex: *Dacrydiumllex, Quercus, Florschuetzia trilobata, Acrosticum, Stenochlaena* as well as a foraminifer complex: *Pseudorotalia* sp., *Ammonia* sp.. Depositional environment of this formation is mainly deltaic with some phases of shallow marine and underwater deltas.

4. Sea-level fluctuation and formation of margin deltas in the northern part of the Red River basin

A study result on the Red River basin has revealed 8 transgression/regression cycles during the Miocene. There are 2 cycles in Early Miocene, and 3 cycles in Middle and Late Miocene [1, 2, 4]. Among these cycles, the ones in Middle Miocene are most developed. During transgression, the sea level was higher the recent one. The study on sea-level fluctuation in the region, characteristics of the upper surfaces of Upper, Middle and Lower Miocene deposits (Fig. 4), as well as study on lithological features, depositional facies, structures,... of the boreholes 102-CQ-1X, 102-HD-1X, 103-TH-1X, 103-TG-1X, and 103 HOL-1X, had revealed that in Early Miocene in northern part of the Red River basin, margin deltas have

developed only eastward from plot N^0 103, i.e. from borehole 103 HOL seaward. During Middle and Late Miocene, the margin deltas had developed eastward from borehole 103-TH-1X and 103-TG-1X. A slope of shelf during Late Miocene was 4-5^0 at borehole 103-TH-1X and 103-TG-1X and this was a shelf break.

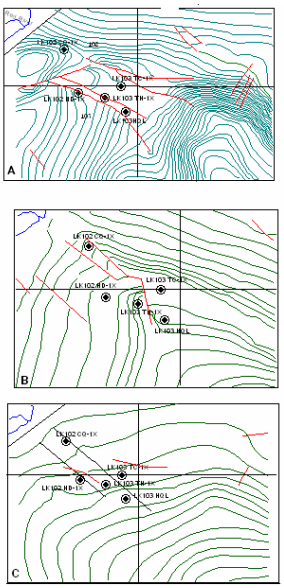

Fig. 4. Isoliths of the upper surfaces of Miocene deposits in the Northern part of the Red River basin. (*A-Lower Miocene; B-Middle Miocene; C-Upper Miocene)*

5. Some features of margin deltas in the northern part of the Red River basin

In the northern part of the Red River basin, margin deltas have developed eastward from the borehole 103-TH-1X. They are composed of river mouth bars and delta front deposits. According to obtained results from boreholes, in the study area the upper part of the second sequence of the Phong Chau Formation from borehole 103-TH-1X, second sequence of the Phong Chau Formation of borehole 103-TG-1X, upper part of the first sequence of the Phu Cu Formation (borehole 103-TH-1X and 103-TG-1X) are river mouth bars (Fig. 5). These river mouth bars consist of fine to medium grained sands (varied from 35% to 40%). Sands are clean, well to average sorted, light grey color. The cement are calcite, silic and clay, contain mica, glauconite. River mouth bar have a very thick sands (10-20m), coarsening upward. Bioturbation in the lower part is week and sands do not contain fossils, or some scared bivalves and flora. Sands have a parallel, wavy bedding or even massive structure. Their seismic specific features show divergent, not continuous with amplitude from average to high, low frequency and high speed (5.7km/s). The thickness of river mouth bars are of 15-20 to 30-40m. Geochronologically, the river mouth bars are overlain by delta front deposits. Delta front deposits became thinner in both sides and changed to claystone, silty claystone with thin stratification of inner or middle shelf deposits.

In the study area, delta front deposits are distributed as follow:

In the borehole 103TH-1X, delta front deposits are third sequence of the Phong Chau Formation, second sequence of the Phu Cu Formation and first sequence of the Tien Hung Formation. In the borehole 103-TG-1X, the sediments of the second and third sequences of the Phong Chau Formation, first and second sequences of the Phu Cu Formation and third sequence of the Tien Hung Formation are delta front deposits.

In the borehole 103-HOL, as the delta front deposits can be considered sediments of the third sequence of the Phu Cu Formation and third sequence of the Tien Hung Formation. These delta front deposits consist of silty sands, sandy silts, fine sands, poorly fossiliferous.

They composed the progradational wedges, thickness of which increased seaward (Fig. 7). The sand/clay ratio changed from 40% (103-TH-1X) to 35% (103-TG-1X).

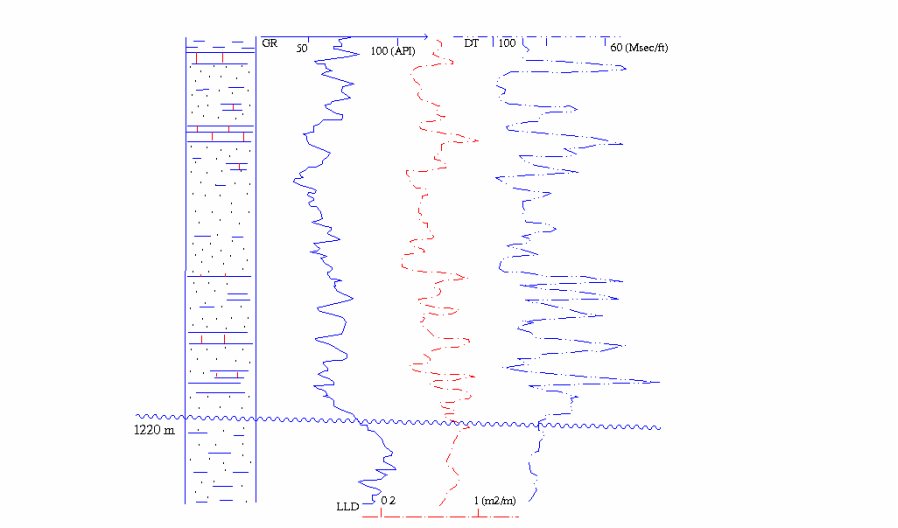

Fig. 5. Sand mouth bar and its well logs (Borehole 103-TH-1X).

The sands are clean, fine to medium grained, average to poorly sorted of light grey, grey color. These sands are weekly consolidated; they contain mica, pyrite, siderites, glauconites and montmorillonites. The sands are mostly feldspathic litharenite and litharenite. Most sand layers have a thickness from 10-20m to 60m (103-TH-1X), (Fig. 8). The amount of fossils in delta front deposits is much more abundant than in sand-mouth bar. Delta front deposits are thin bedded, parallel laminated to wavy. Thin beds of parallel laminated sands and thick clay mud layers, none or poorly bioturbated here is interpreted as delta front turbidites deposits (Fig. 6).

Most abundant phenomena in delta front deposits is a slump, that makes delta front deposits of margin delta are prone to turbidite and why a slump is a very typical characteristic of margin delta. Because when reached to the shelf edge a slope will be changed very quickly, creating a good condition for a slump to develop.

The well logs of the delta front deposits have a bell, tunnel, symmetric saw-tooth forms. On the seismic cross-sections, the delta front deposits show a mound, non continuous with a high to average amplitude and average frequency (Fig. 6 and 7), V=2.5-2.7km/s in the borehole 103-TG-1X and radiate and mound form, average continuity, high amplitude, V= 2.2-2.4km/s in the borehole 103-TH. Sands are stratified differently, some sandlayers in borehole 103-TH have a thickness over 20m, even reached 60m, in others they are thinner, less than 20m. Deposits contain foraminifers such as *Ammonia* sp., *Pseudorotala* sp., *Quinqueloculina* sp., *Cyclmmina* sp., *Globigerinoides* sp., and some spore and pollens: *Florschuetzia meridionalis, Florschuetzia levipolis, Florschuetzia trilobata*,... (103-TG-1X, 103-TH-1X).

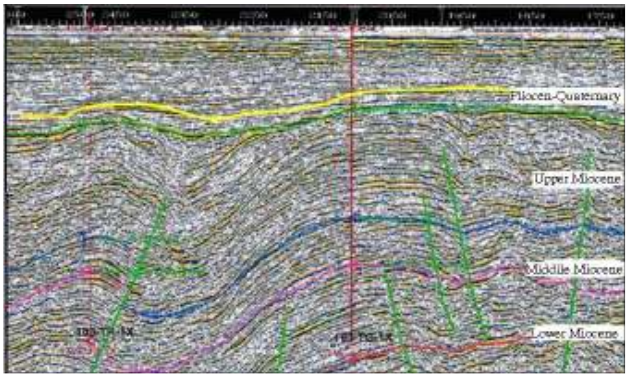

Fig. 6. Turbidites of the Upper Miocene (Cross-section GPGT93-201).

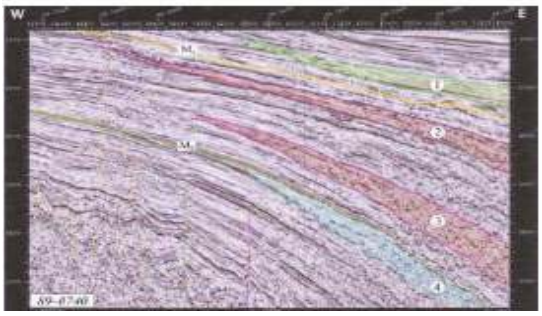

Fig. 7. Progradational wedge of the shelf-margin delta.

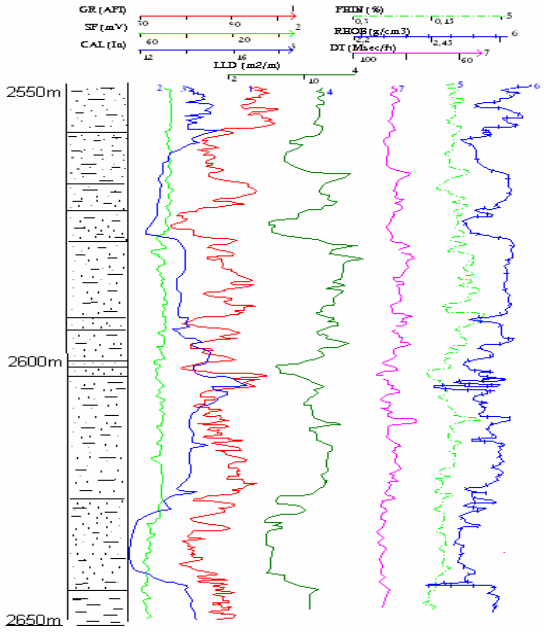

Fig.8. Delta front sands, sandy silts and well logs (borehole 103-TG-1X)

6. Conclusions

- In the northern part of the Red River basin, during the Miocene, margin deltas have developed eastward from the plot N^{0}103. These margin deltas were formed and developed at the end of the lowstand stage, beginning of the transgressive stage. A thickness of these delta deposits varied from 40-60 to 80-100m.

- An existence of the margin deltas in Miocene in the northern part of the Red River basin confirms a presence of basin floor fans in the central part of the Red River basin. These basin floor fans are important objects of oil-gas prospecting that need to take in account.

Acknowledgements

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