Prospects Identification and Future Exploration Strategy in Palaeocene/Eocene Formations of Basement High and Adjoining Areas in Upper Assam Basin Based on Palaeoenvironment*

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Abstract

Identification of loci for hydrocarbon entrapment based on depositional environment is a well-known technique in hydrocarbon exploration. Depositional environment has a direct impact on shape, size and type of trap available in a particular area. Eocene-Palaeocene sediments (LK+Th and Langpar Formation) in the Basement High area of the Upper Assam Basin were deposited in shallow marine to fluvial conditions and considered as the highest potential sediments for hydrocarbon accumulation. More than 15 geological structures have been successfully explored in the Basement High and its adjoining area so far, with commercial production of hydrocarbon (Figure 1). However, reservoir quality, extent and productivity vary from place to place. The primary reason could be the depositional setting of the reservoir units. An attempt has been made to identify trap type in the present study likely to be available in Oil India's operational area as a guide for future exploration.

Study Area

The Upper Assam Basin is a well-known petroliferous sedimentary basin of India. Exploration for hydrocarbon started in 1866 and commercial oil was first discovered in 1889 in Digboi. The basin is bounded in the north by the Eastern Himalayas, in the east by the Mishmi Massif, in the south by the Naga-Patkai Hills, and in the west by the Mikir Hills and Shillong Plateau. A thick succession of sediment ranging in age from Cretaceous to Pleistocene has been deposited in the basin. Commercial hydrocarbon production from Palaeocene to Mio-Pliocene sediments have been established to date. The Basement High trend, running along the central part of the basin, is an important structural feature from the hydrocarbon entrapment point of view. The sediment thickness increases on either side

of the High. In this paper primary focus is on the depositional pattern of the hydrocarbon-rich Palaeocene-Eocene sediments of the Basement High and nearby areas of the Upper Assam Basin.

The study area covers about 4000 sq km with more than 175 wells drilled up to the Eocene/Palaeocene section. The main hydrocarbon potential is confined to the Langpar and lower part of Sylhet formations (Lakadong and Therria units). Generalized stratigraphic succession of the basin is presented in Figure 15. More than fifteen structures have been explored in the study area so far, with the establishment of successful commercial production. These sediments consist of thin multi-stacked clastic reservoirs which have good to very good reservoir quality and variable production potential. One reason for the variation in reservoir quality could be the depositional setting. An attempt has been made in the current study to understand the depositional environment of the main potential reservoir zones based on sand-shale ratio data, core data and log responses in the light of sequence stratigraphic concepts.

Approach

Based on sequence stratigraphic concepts, the entire LK+Th reservoirs section has been divided in four groups, with the top part of the Langpar Formation identified as one group (Figure 2). Palaeogeological maps have been prepared based on sand-shale ratios to get a clear picture on depositional pattern of these sediments (Figure 7, Figure 8, Figure 9, Figure 10). A wide variation of depositional environments of these sediments in the different structures have been observed in these maps. Tentative position of the paleoshoreline has also been identified to gain a better idea of the type of deposition. Based on depositional setting, four main depositional types have been identified to give a systematic approach for better understanding the play type pattern.

Type of Deposition

Fluvial Deposits

Deposition which takes place along a river course in the continental part of a basin is known as fluvial deposits. Mainly three types of fluvial deposits are found in a channel course: Alluvial Fan deposits, Braided deposits and Meandering deposits. Alluvial fans are typically lobate in plan view and wedge/lenticular in cross section (Figure 3).

In braided deposits, no very clear cut demarcation can be made with alluvial fan deposits, but in general they are less coarse than alluvial fan deposits and sometimes contain sedimentary structure. Braided rivers are characterized by large bedforms called bars. Bars are normally oriented with their long axis roughly parallel to current flow. Coarsest material is concentrated along the central axis and bottom of the bar, and grain size tends to decrease upwards and downstream; gamma-ray wireline log signature is blocky in nature.

Meandering deposits are characterized by a fining-upward grain size trend. There are five different types of deposition within the meandering stream system: 1) main channel, 2) point bars, 3) natural levees, 4) flood basin, and 5) oxbow lake meander cutoffs. Each of these sub-environments of the system generate deposits with characteristic grain sizes and sedimentary structures (Figure 4). The sand-shale ratio is very high compared to seaward deposits.

Delta Deposits

Delta deposition takes place in the mouth of a river where its flow runs into standing sea or lake water (Figure 5). A delta is a fan-shaped deposit of sediments at the exit of a river into a larger body of water (Figure 6). Normally medium- to fine-grained, well-sorted sandstone deposits are encountered with subangular to subrounded grain texture. The sand-shale ratio is relatively very high compared to seaward deposits.

Delta Front Deposits

Sediments deposited seaward of the shoreline of a delta are known as delta front deposits (Figure 6), where the coarsest marine sediments are found. This area can be reworked by waves. Delta front deposits represent the most dynamic part of a delta system. High variability of interaction between fluvial and marine processes within the delta front area suggests a complex architecture of delta front deposits. Sand-shale ratio is on the lower side.

Prodelta Deposits

Fine-grained silt/sand to clay deposition takes place further seaward of the delta front deposits (Figure 6). These muddy buildups are referred as the prodelta zone. Sand-shale ratio is much lower than the delta front deposits.

Depositional Environment and Play Type

Four main sub-groups have been studied in detail for depositional environment vis-a-vis trap geometry. All the groups have different geological settings as evident from the paleogeological maps. Deposition of Group-I sediments took place in a fluvial environment and the direction of channel flow was from the north-northeast (Figure 7). Accordingly, there is a strong possibility of encountering more fluvial braided and alluvial fan deposits towards the north-northeast direction. On the other hand, near the possible shoreline, deltaic, and further south-southwest, delta front and prodelta sediments should have been deposited.

The Group-II sediments show variation of environment from delta front to fluvial deposits (Figure 8). Extension of fluvial deposition can be expected up to the low relief of high mountain/foothills area in a north-northeastern direction. Deltaic sediments of the same channels

could be deposited near the shoreline area, however in the southwest of the study area and further southwest, deposition of delta front and prodelta deposits with average to poor-quality reservoir is highly probable.

The overlying Group-III sediments were deposited in a shallow marine environment in the study area (Figure 9). The position of the shoreline should be in the north/northeast of the Baghjan area. A deltaic/fluvial deposition should have taken place in the upstream channel direction. On the contrary, small deltafront/prodelta deposition is expected in the southwest direction.

The Group IV sediments were deposited in a nearshore environment in the southwest and fluvial environment in the northeast (Figure 10). Beyond deltaic deposition, obvious delta front and prodelta deposition towards the seaward direction is expected. But in the upstream channel direction, fluvial meandering and braided deposition should have been taken place until it encountered alluvial fan deposits beyond the Baghjan area.

One interesting point in regard to the uppermost sediments of Lk+Th is that the calcareous nature of the reservoir zone changes towards the northern part of the study area. If the same trend continues, then the possibility of encountering fluvial deposits further north is highly possible. But in the shallow marine part, delta front and prodelta deposition could have been a possibility. Due to data limitation, depositional environments northwest and southeast of Basement High area cannot be evaluated with confidence.

Discussion and Conclusions

It is evident that the depositional setting and corresponding reservoir quality of Palaeocene/Eocene sediments of the study area can be identified. Accordingly, the results of this study can be used as a guide for future exploration.

For Group I, fluvial deposits of mainly meandering origin were deposited throughout the study area. Therefore, braided and alluvial fan deposits are expected in the north-northeast part of the study area. Beyond the Kathaloni and Bhogpara areas (located southwest of the study area) the possibility of encountering deltaic deposits with very good reservoir characteristics and further seaward delta front deposits of small size structures with good to fair quality reservoir rock is a distinct possibility (Figure 11).

Figure 12 illustrates the depositional setting of Group II sediments. It is evident from the map that fluvial deposits of upstream channel characteristic should be present beyond the Baghjan area, towards the north-northeast. It is inferred that a possible deltaic deposition should have taken place near the shoreline area. Beyond this area, the possibility of encountering delta front and prodelta deposits are expected in the south, southwest and southeast directions.

Delta front and prodelta deposits dominate Group III sediments, so good sediment accumulation with good reservoir quality can be expected near the shoreline area and further in the upstream direction. With a similar depositional pattern, more braided and alluvial fan deposits are expected to the north-northeast of the Baghjan area (Figure 13).

Meandering and braided, deltaic to fluvial Group IV deposition took place throughout the study area. Thus there is the possibility of encountering fluvial (alluvial fan) deposits of large size in the upstream direction, and downstream relatively smaller delta front and prodelta deposits with variable reservoir quality. Large unexplored areas within the study area where fluvial channel deposits align along channel courses is highly probable (Figure 14).

The overlying sediments of LK+TH above Group IV also show changes in depositional pattern from a shallow marine quiet environment to fluvial, almost similar in trend to the underlying sediments of Group II.

The study suggests that there has been an increase in fluvial influence toward the north-northeast for all groups including the calcareous group. Thus the possibility of the existence of large continental deposits having very good reservoir quality beyond the Baghjan area is very high. A large part of the area between the Matimekhana/Khagorijan and Baghjan/Barekuri structures remain unexplored that hold prospects for all groups. In the western part of the study area small delta front/prodelta deposits with good to fair reservoir quality traps is expected, except for the Group I sediments.

Acknowledgement

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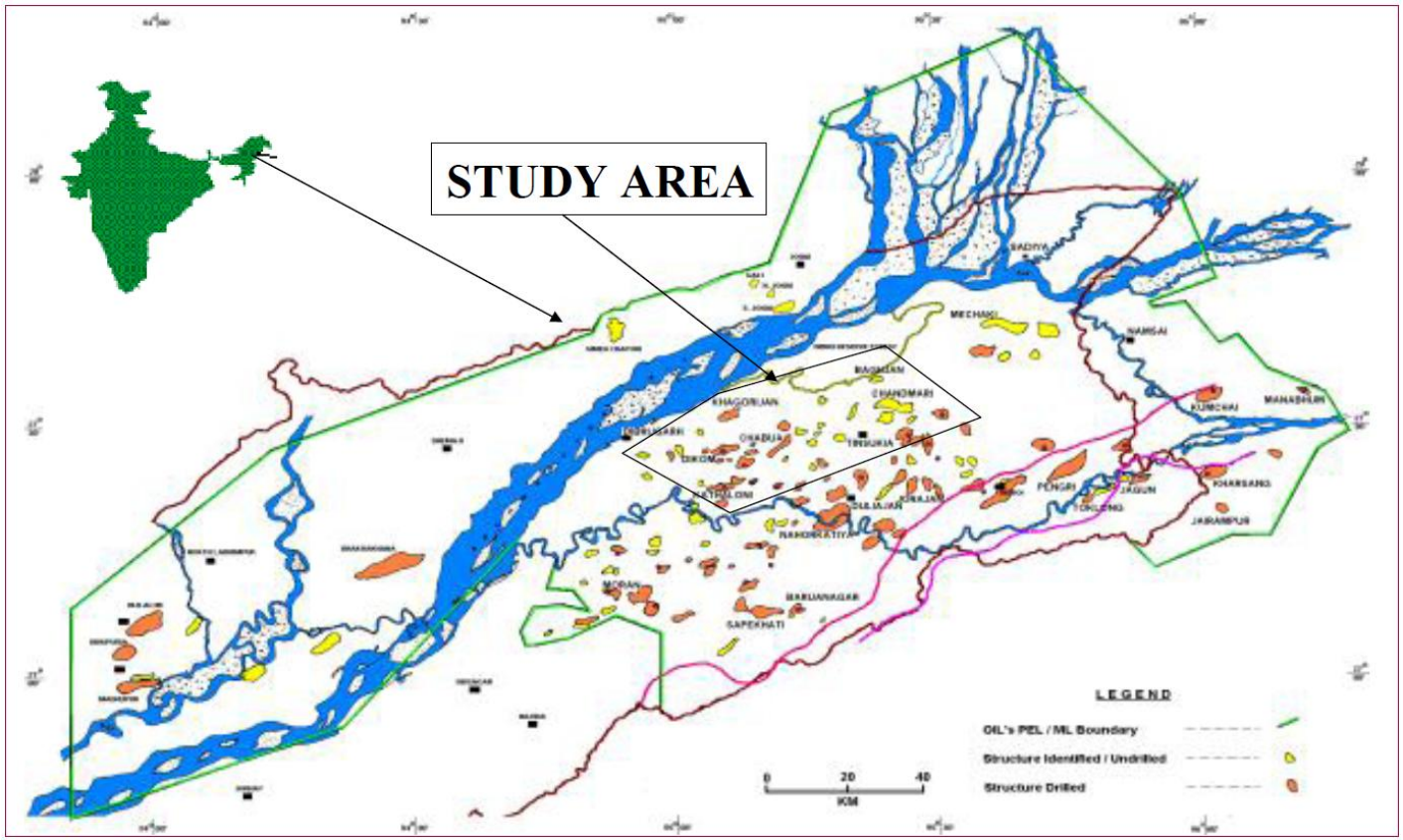

Figure 1. Study area location map.

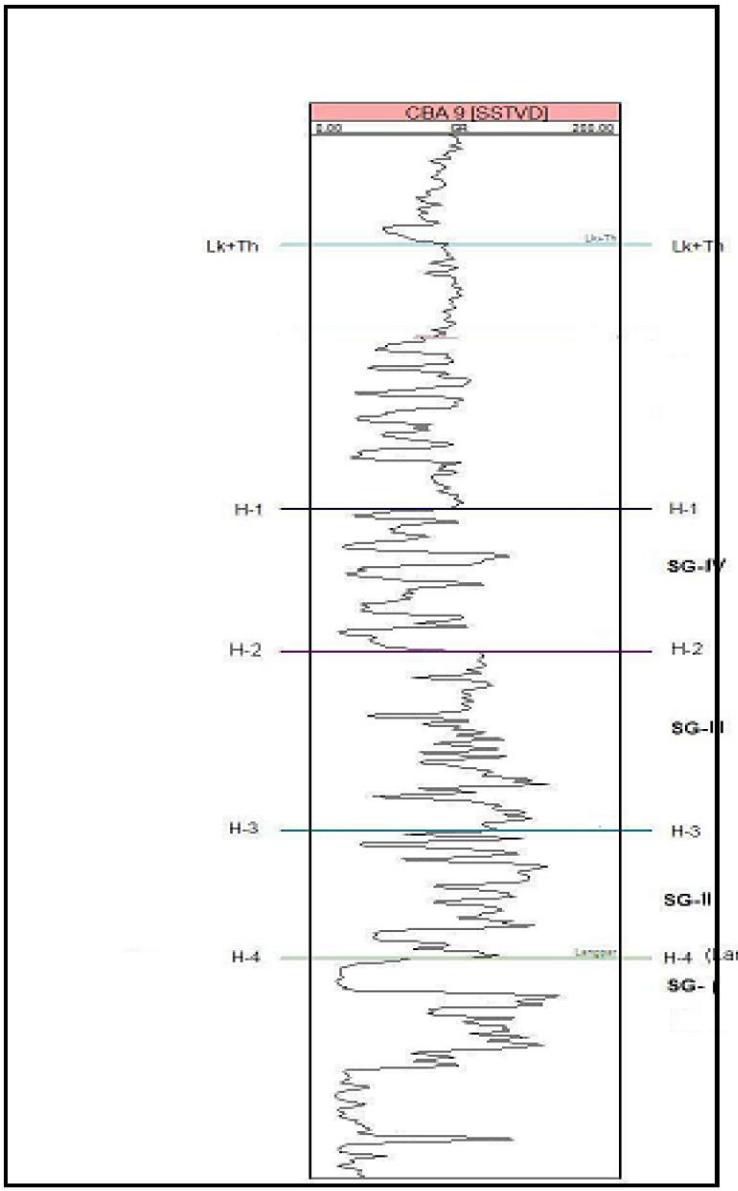

Figure 2. Sand group identification.

Figure 3. Aerial view of an alluvial fan.

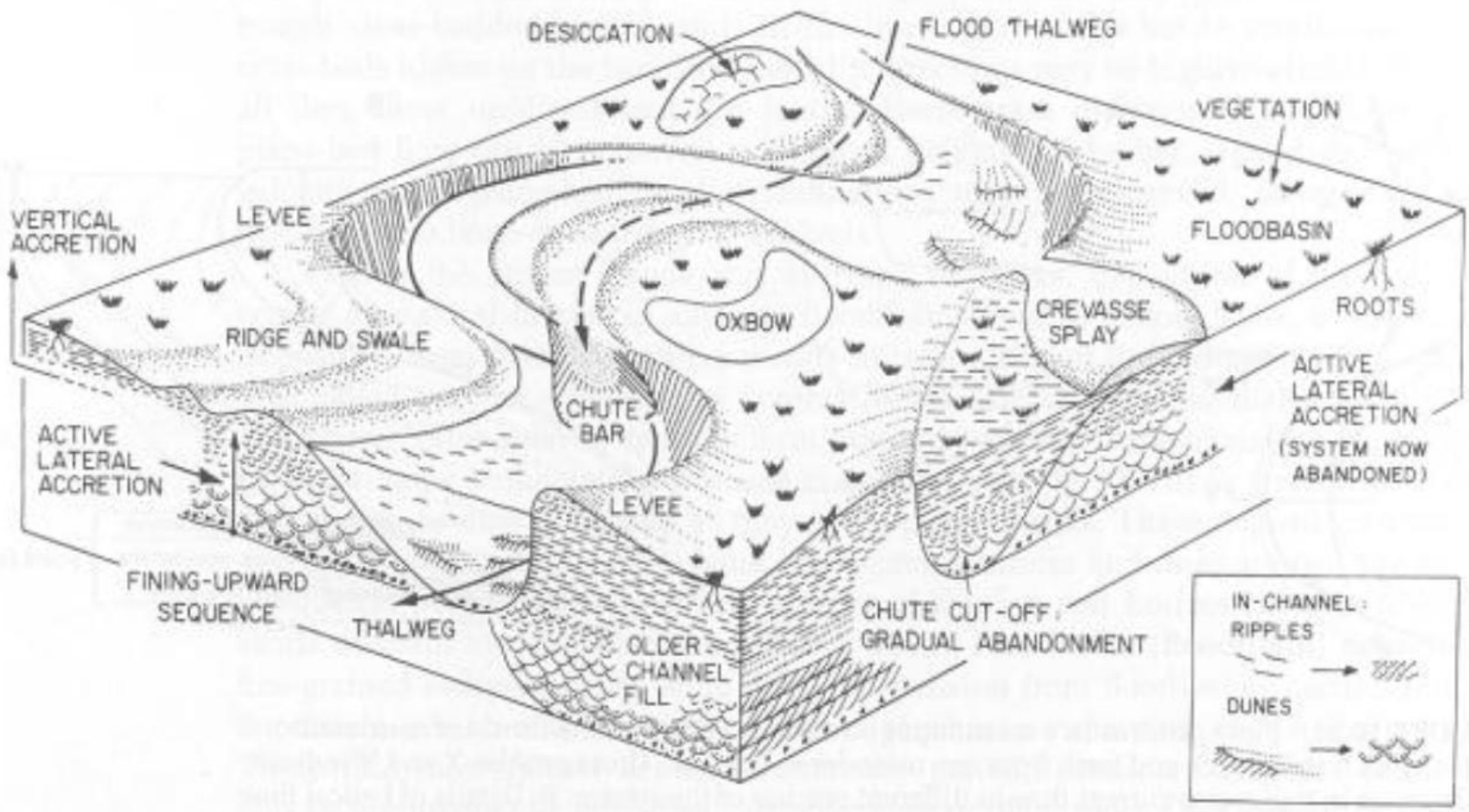

Figure 4. The morphological elements of a meandering-river system.

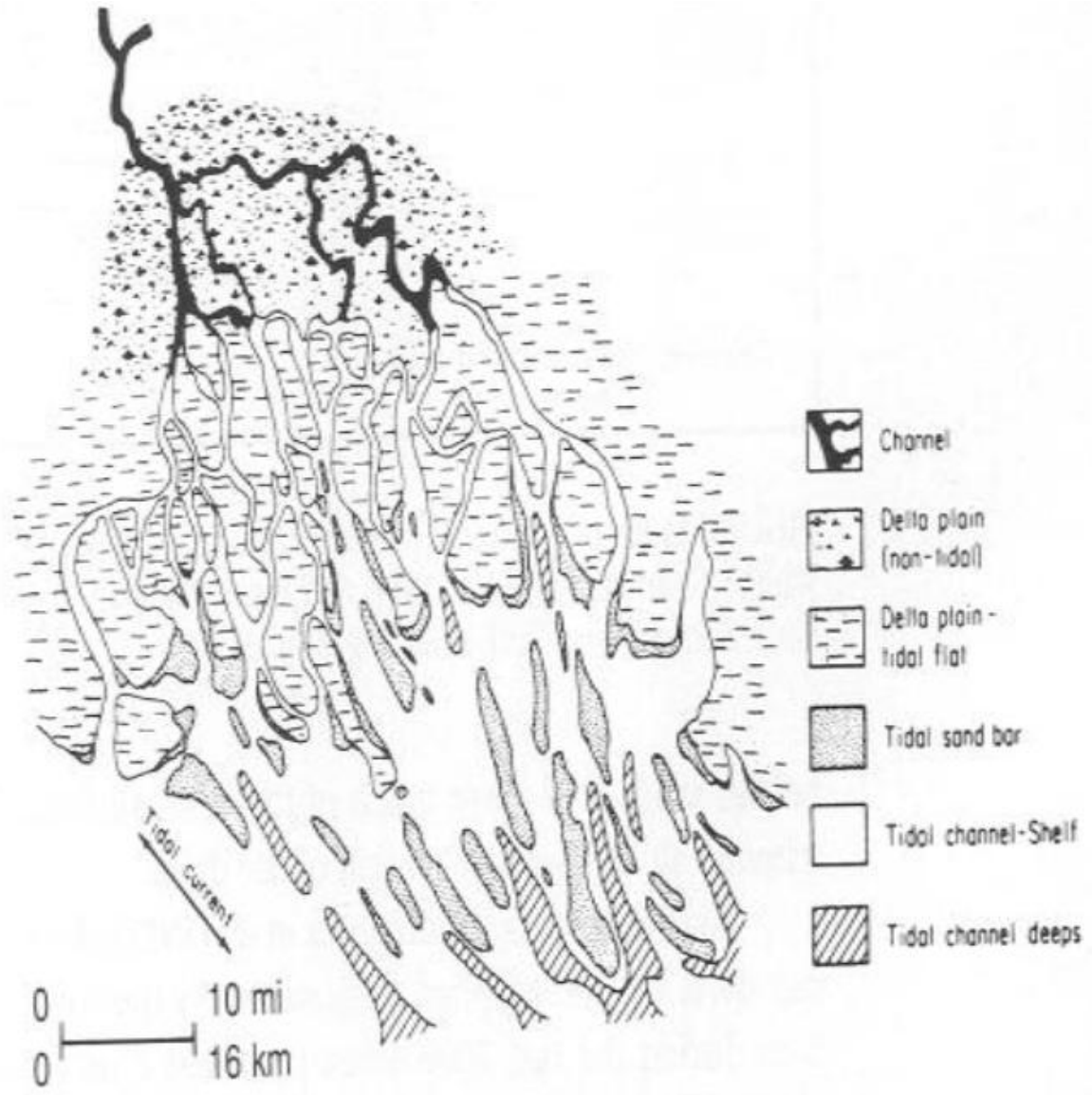

Figure 5. The modern tide-dominated delta.

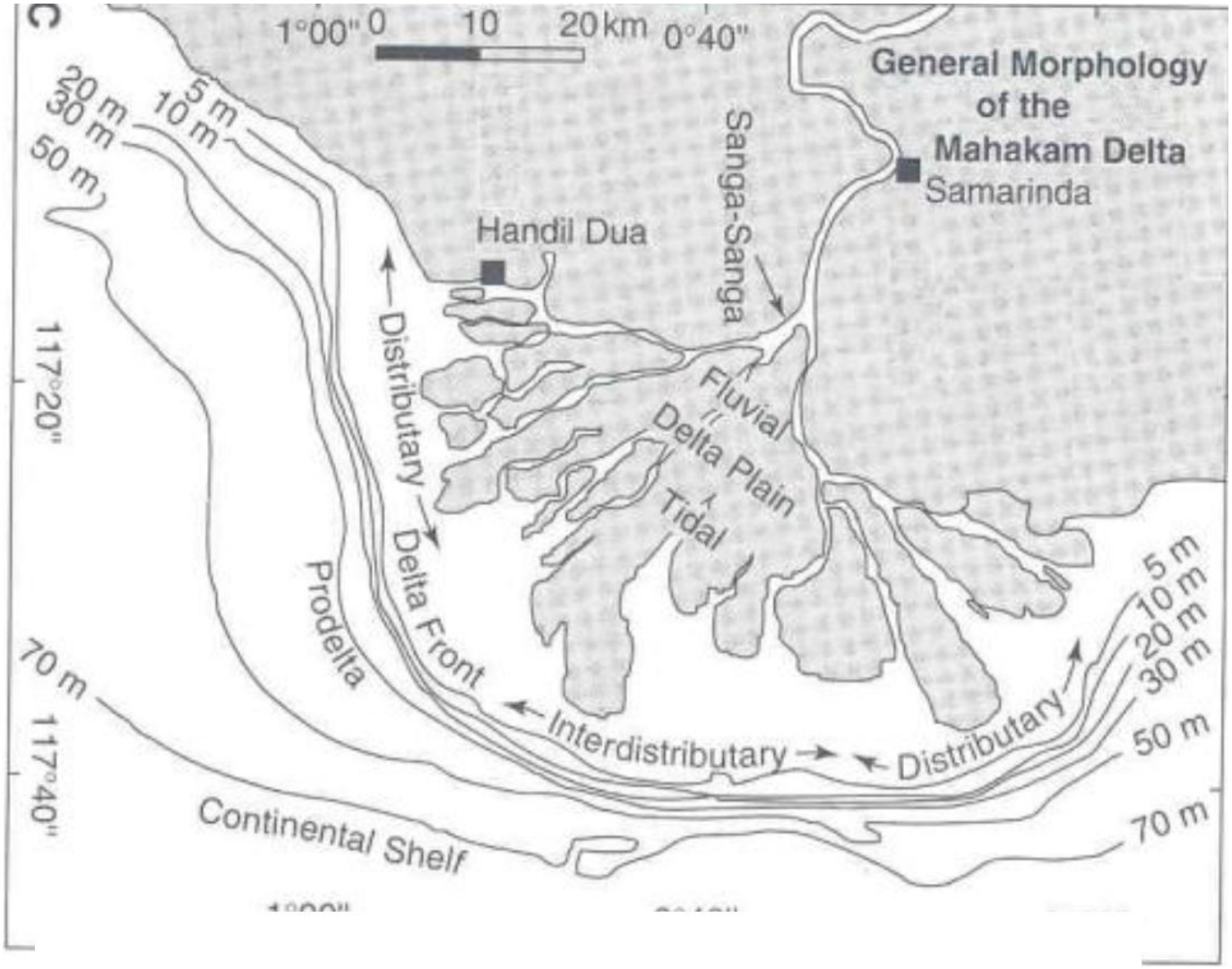

Figure 6. Deltaic systems of the Upper Cretaceous Maverick Basin, south Texas.

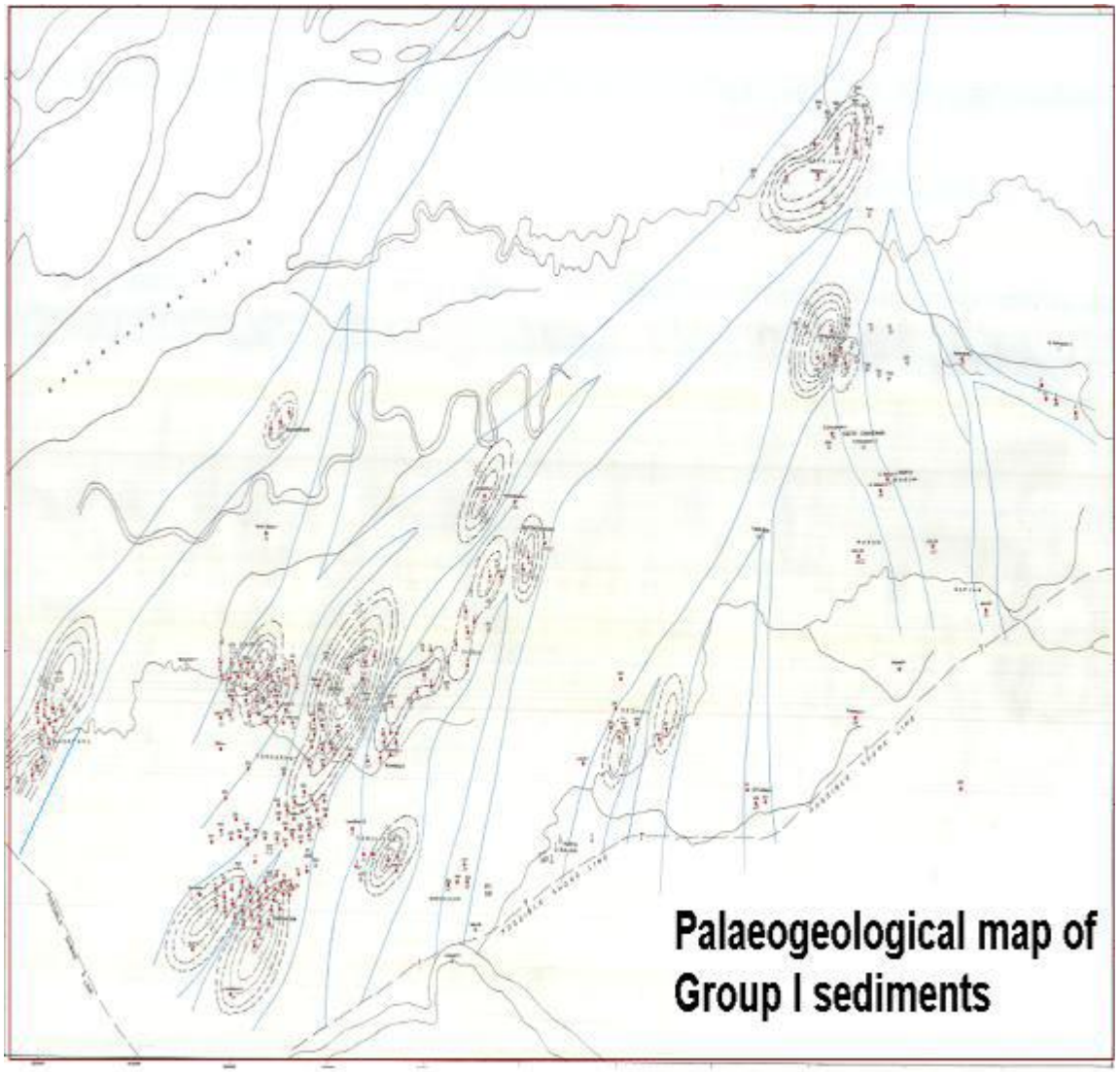

Figure 7. Palaeogeological map of Group I sediments.

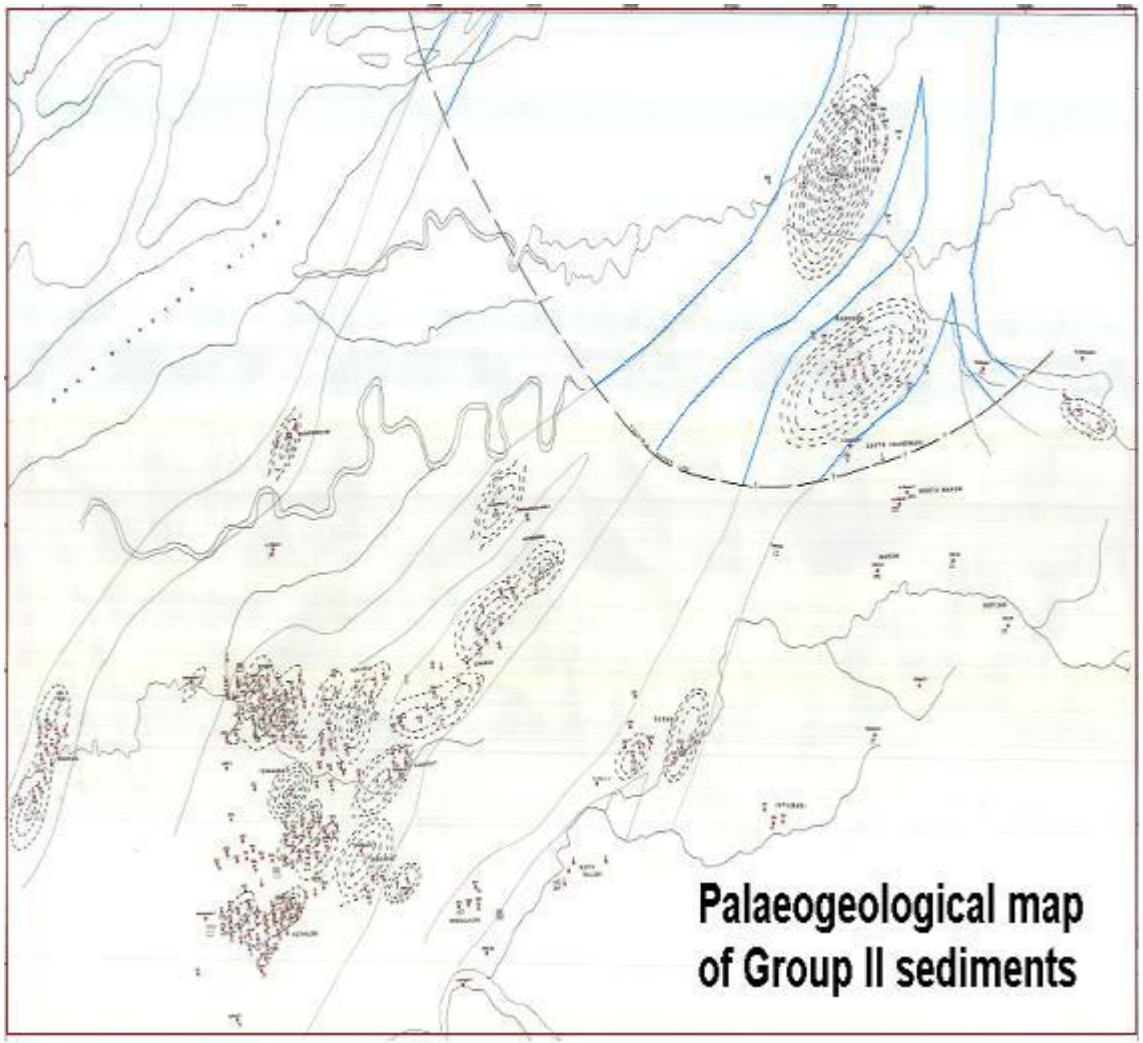

Figure 8. Palaeogeological map of Group II sediments.

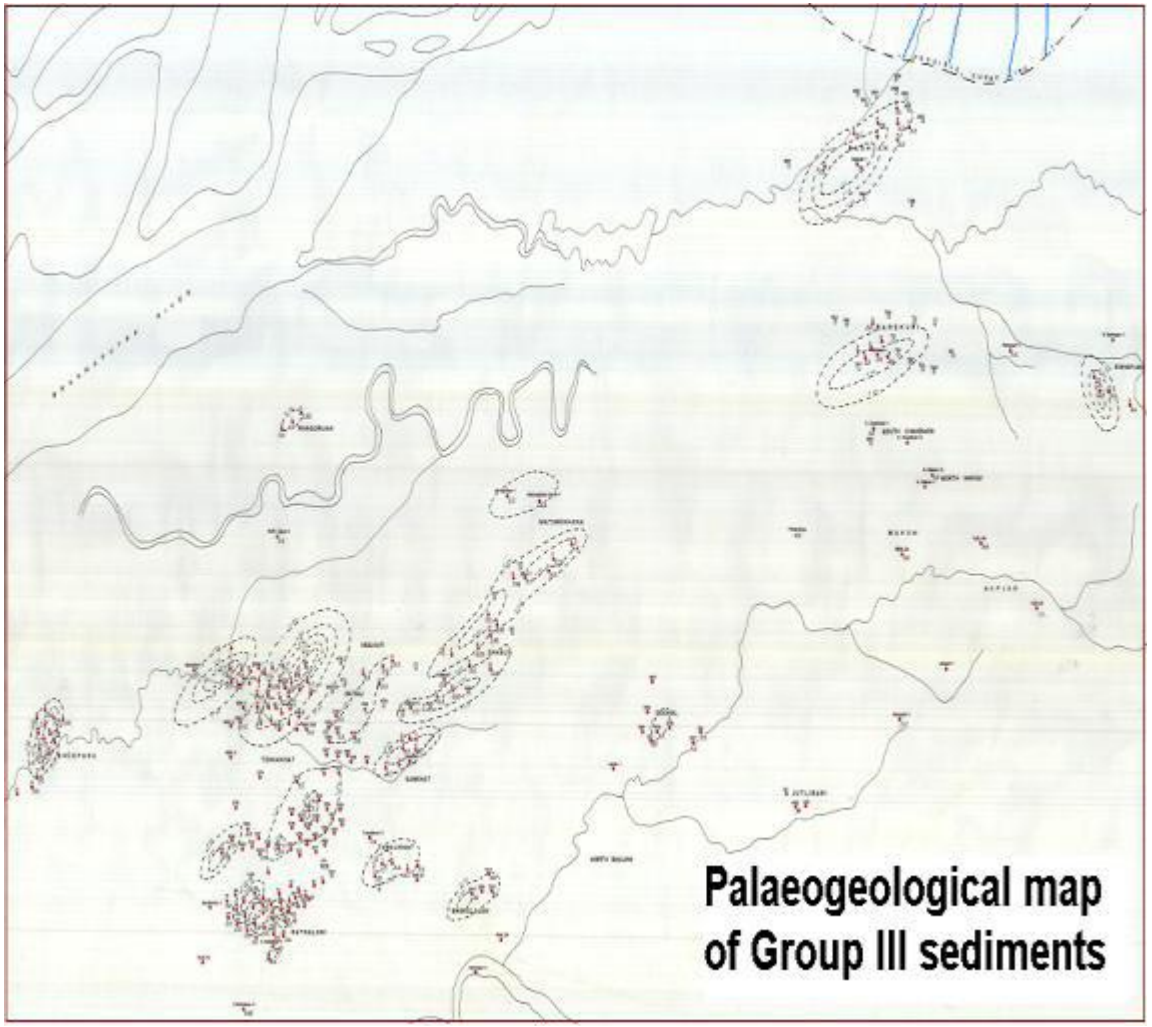

Figure 9. Palaeogeological map of Group III sediments.

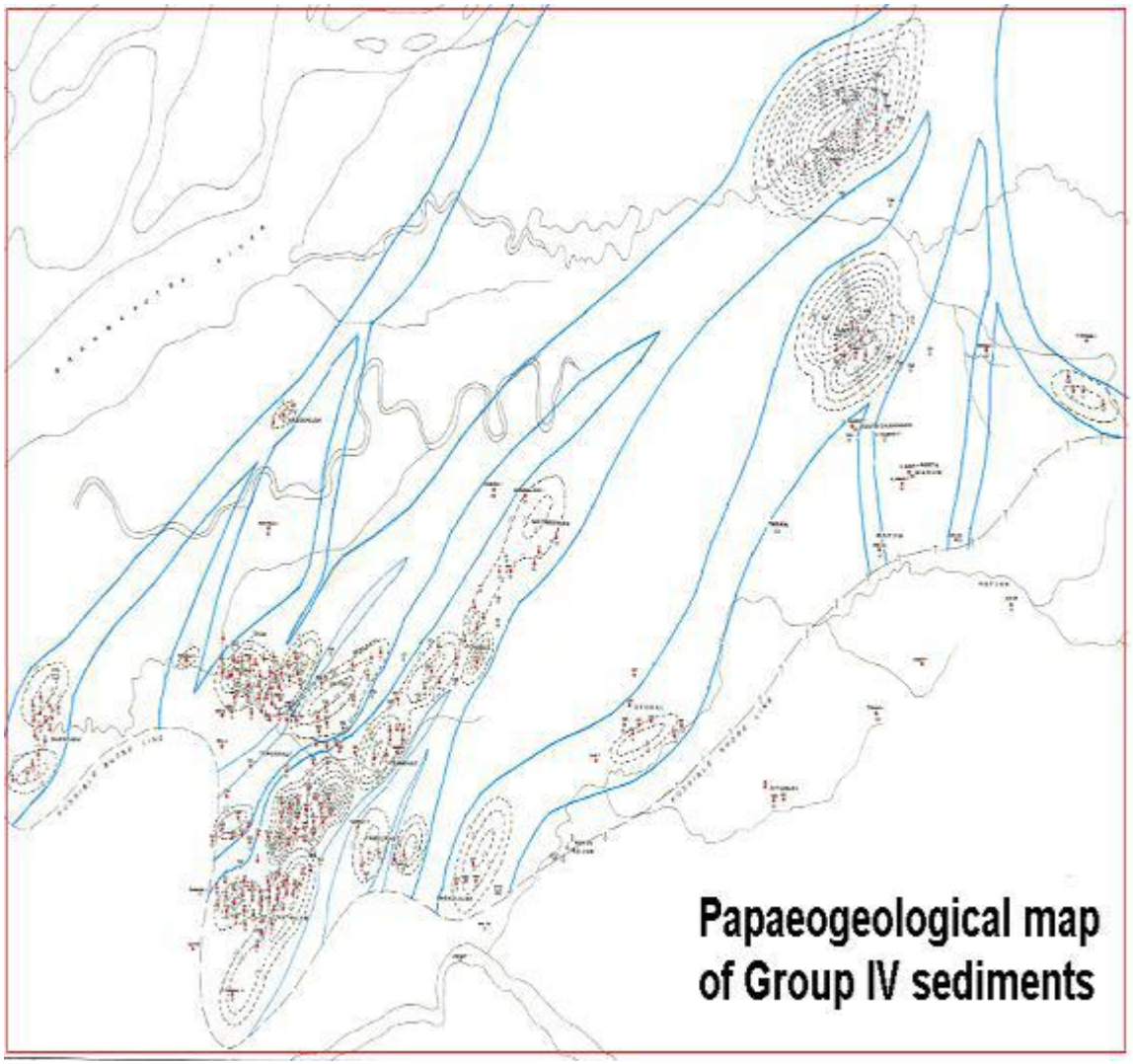

Figure 10. Palaeogeological map of Group IV sediments.

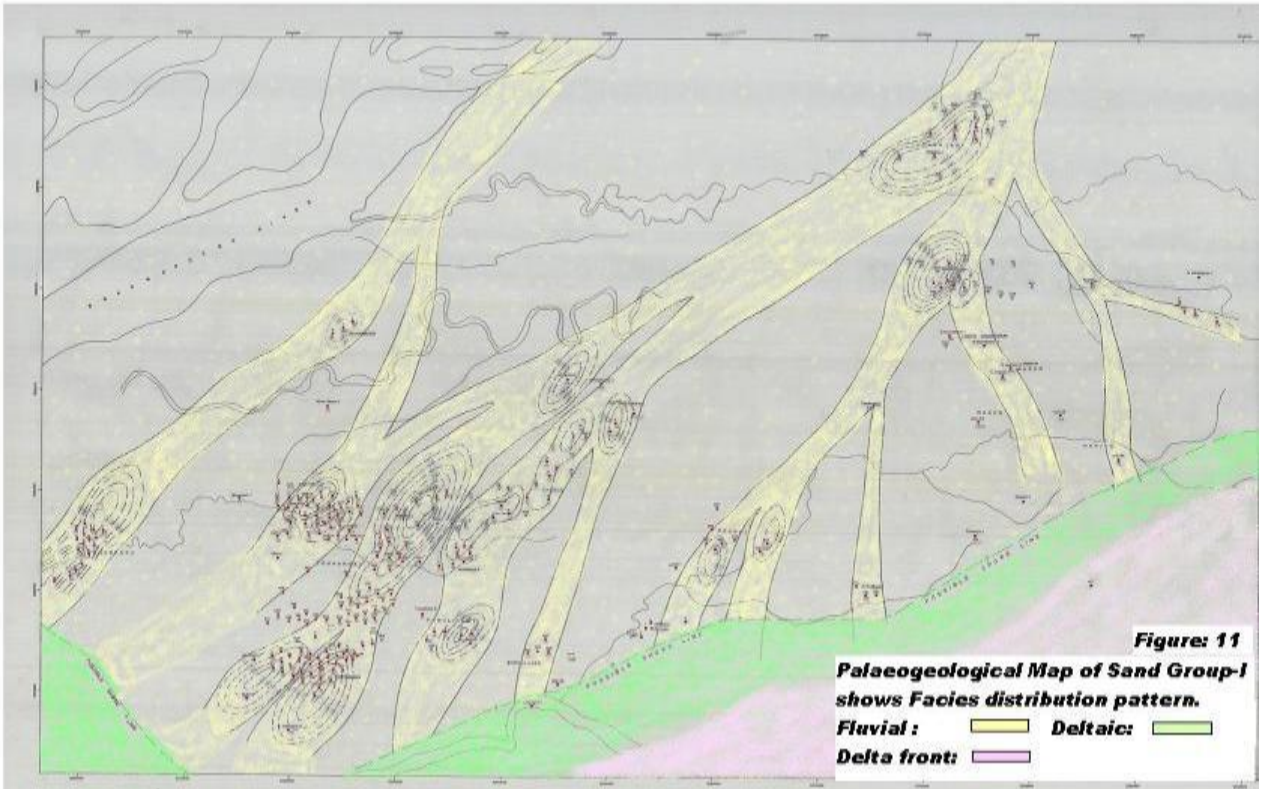

Figure 11. Facies distribution map of Group I sediments.

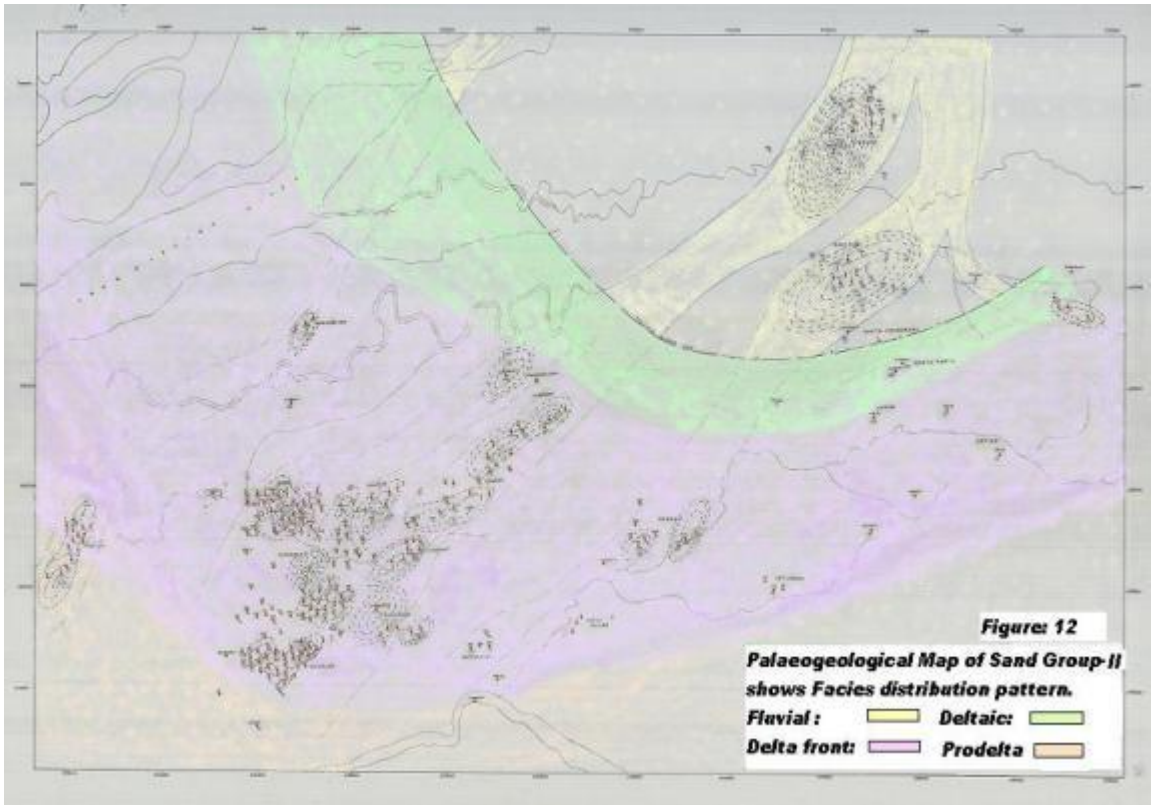

Figure 12. Facies distribution map of Group II sediments.

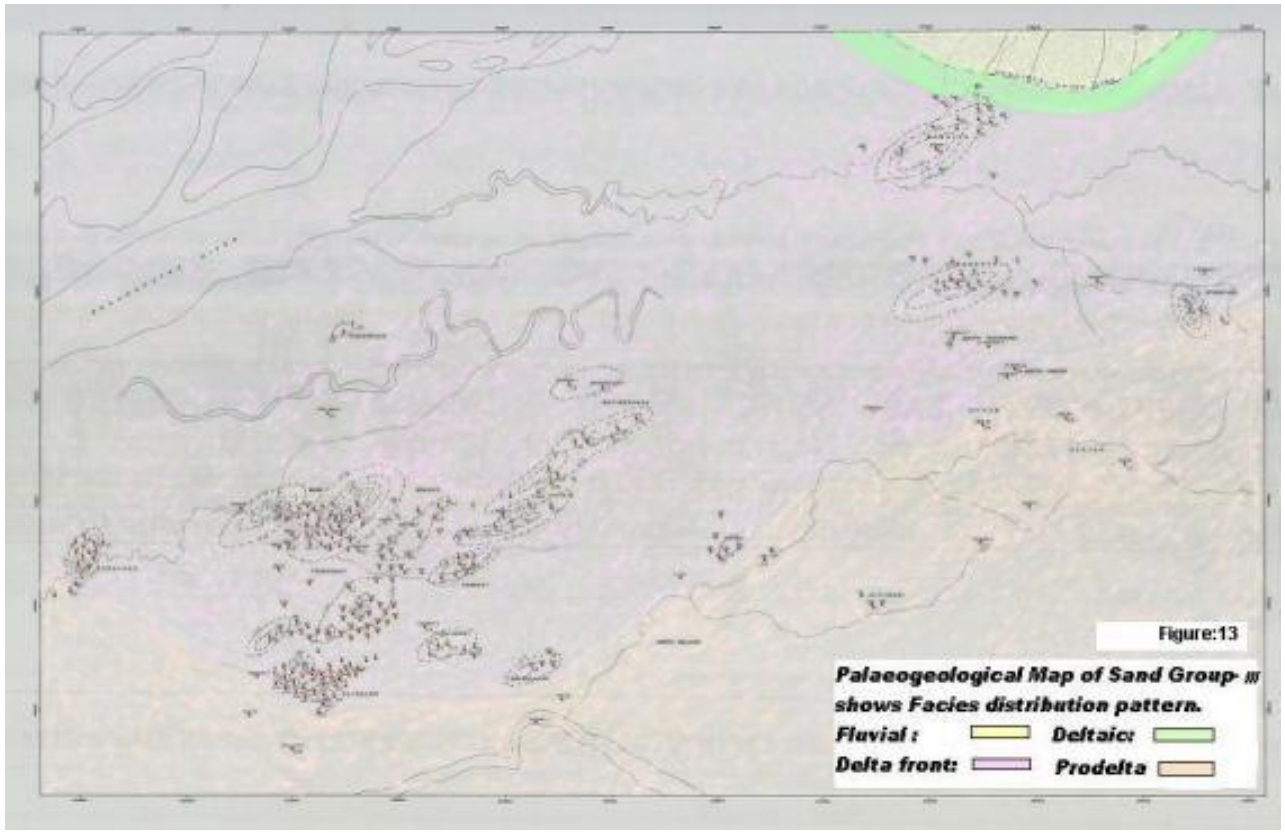

Figure 13. Facies distribution map of Group III sediments.

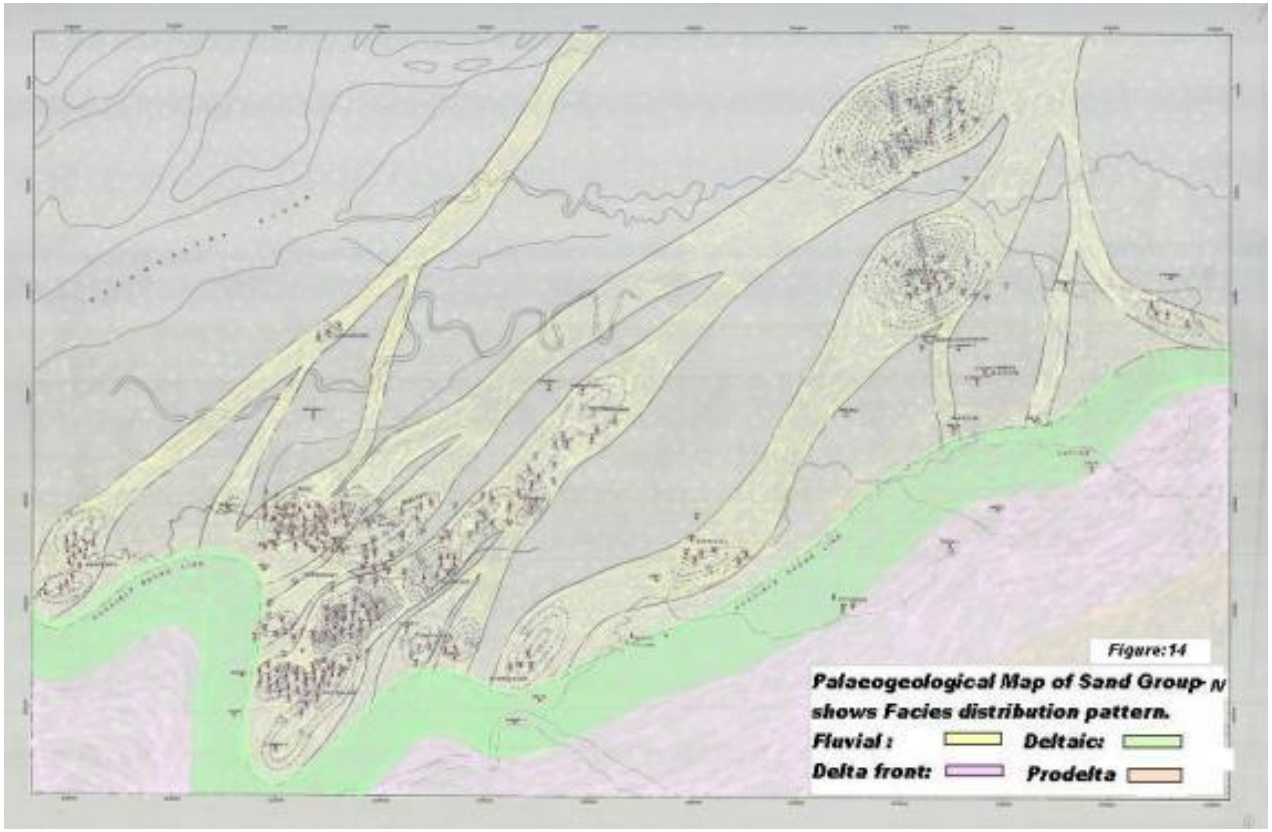

Figure 14. Facies distribution map of Group IV sediments.

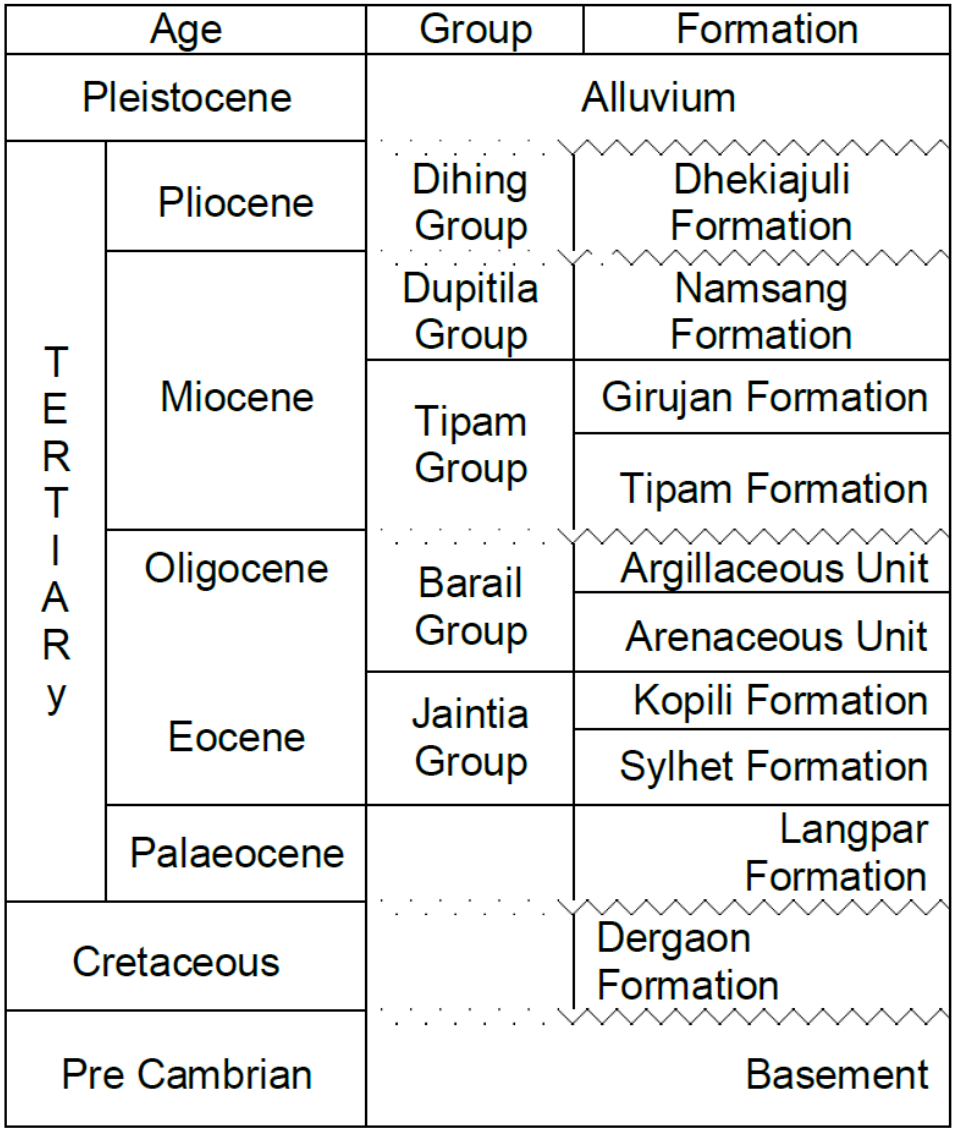

Figure 15. Generalized stratigraphic succession of Upper Assam Basin.