INDONESIAN PETROLEUM ASSOCIATION
Proceedings of the International Symposium on Sequence Stratigraphy in SE Asia, May 1995

SEISMIC STRATIGRAPHY OF EOCENE BERIUN SANDS OF WEST BUNGALUN, EAST KALIMANTAN, INDONESIA : A CONTRIBUTION TO THE PALEOGENE STRATIGRAPHICAL KNOWLEDGE OF THE KUTEI BASIN

Awang Harun Satyana*
Elan Biantoro*

ABSTRACT

The Kutei Basin, East Kalimantan, is the largest and deepest Tertiary basin in Indonesia. The basin was formed in the early Tertiary and contains up to 12,000 meters of sediments in its deepest part. Basin subsidence during the early Eocene to early Oligocene resulted in the accumulation of a generally transgressive sequences of sediments throughout the Kutei Basin. In the latest Oligocene, regressive deltaic sedimentation began and became the dominant depositional regime in the basin. These Neogene deltaic deposits constitute the reservoir rocks of the prolific fields in the Kutei Basin. However, hydrocarbon accumulations have never been discovered in the Paleogene sediments of the Kutei Basin, although Paleogene accumulations occur in the Tanjung Field in the adjacent Barito Basin to the south. Accordingly, the Paleogene sediments of the Kutei Basin have not been extensively studied.

The Eocene Beriun sands of the West Bungalun area, Northeast Kutei Basin, are the reservoir-quality rocks equivalent to the hydrocarbon-bearing Tanjung sands of the Barito Basin. Multiple vintages of seismic data (1971-1993) were used to reveal the subsurficial nature and distribution of the Beriun Formation. On seismic data, the Beriun sands can be recognized by their distinctive amplitude and velocity characteristics, as compared to other units within the formation. Seismic stratigraphic interpretation shows that the Beriun Formation consists of at least three seismic stratigraphic sequences. Deposition of these sediments was contemporaneous with, and affected by, growth faulting, resulting in varying sedimentary thicknesses laterally. Based on this seismic sequence study, we suggest that the Beriun sediments were deposited as fan delta deposits in an extensional tectonic regime. This study supports that the Beriun sands are potential reservoir rocks in the Kutei Basin.

* PERTAMINA - Jakarta

INTRODUCTION

Paleogene sediments in the Tertiary basins of Kalimantan, except for the Barito Basin in S.E. Kalimantan, have have not been studied in detail because of poor hydrocarbon exploration results. The prolific fields in the Kutei Basin are reservoired in Neogene (middle to late Miocene) deltaic reservoirs and are located on and near the present-day Mahakam River delta (Figure 1). Beyond these areas, the majority of the onshore area of the Kutei Basin contains Paleogene-aged sediments. Numerous hydrocarbon exploration programs have been conducted in the area of Paleogene sediments in the Kutei Basin. Several companies have farmed in the area, studied, surveyed and drilled several wells without success. On the other hand, the Paleogene sediments in the Barito Basin, located to the south of the Kutei Basin, contain a significant amount of oil, primarily within the giant Tanjung oil field. The Kutei Basin shared a similiar history with the Barito Basin in Paleogene time. Why have the exploration efforts in the Paleogene sediments of the Kutei Basin not been as successful as their counterparts in the Barito Basin ?

This paper presents some preliminary work on the Paleogene sediments of the Kutei Basin using seismic stratigraphy. The Eocene Beriun sands of West Bungalun, N.E. Kutei Basin, which are equivalent to the hydrocarbon-bearing Tanjung sands in the Barito Basin, are examined in an attempt to determine the nature and distribution of these sandstones.

REGIONAL SETTING

The Kutei Basin, mostly located in East Kalimantan,

is the largest (covers some 165,000 sq. kms) and the deepest (contains up to 12,000 meters of sediments) Tertiary basin in Indonesia. The basin is bounded on the north and south by the WNW to ESE trending borders of Mangkalihat Ridge and Adang Flexure, respectively. These borders separate the Kutei Basin from the Tarakan Basin to the north and Barito Basin to the south. To the west and northwest, the Kutei Basin is bounded by the Kuching High of the Central Range. To the east, the basin extends into the Strait of Makassar (Figure 1).

Presently, the structural style of the Kutei Basin is dominated by a series of tightly folded, NNE - SSW trending folds and faults that parallel the arcuate coastal line and are know as the Samarinda Anticlinorium (Figure 1). These features dominate the eastern part of the basin and are also identifiable offshore. Not as much is known about the structure of the western basin area, and although large structures are evident, a similarity in structural trend and style is not apparent from the available data (Ott, 1987). The origin of folds and faults in the Kutei Basin has become "a debate of decades"; some of the suggested mechanisms include gravitational sliding (van Bemmelen, 1949; Rose and Hartono, 1978; Ott, 1987), a transpressional force couple of the Mangkalihat and Adang wrench faults (Biantoro et al., 1992), compressional force propagation due to micro-continent collision to the east of Sulawesi (van de Weerd and Armin, 1992), and detachment folds on overpressured sediment (Chambers and Daley, 1995).

The Tertiary stratigraphic succession within the basin occurred in two distinct phases (Figure 2). During the first phase (late Paleocene to Oligocene time), the basin subsidence initiated due to basement rifting (Weimer, 1975). The basin was the site of deposition of a siliciclastic sequence, much of which was shale, deposited in marginal to open marine environments (Mangkupa Formation). Some coarser siliciclastics (Beriun Formation) are locally associated with the shale sequence indicating an interruption of basin subsidence by basin uplifting. The basin subsided rapidly after the deposition of the Beriun sands, mostly through sagging, resulting in the deposition of marine shales of the Atan Formation and carbonates of the Kedango Formation. Subsequent tectonic events uplifted parts of the basin margin by the late Oligocene and the Sembulu volcanics were deposited in the eastern basin area.

The second stratigraphic phase was contemporaneous with the basin uplifting and inversion that started in early Miocene time. During that time, a vast series of alluvial and deltaic deposits were deposited in the basin and prograded from west to east (Pamaluan, Pulu balang, Balikpapan, Kampung Baru Formations). This sedimentary pattern continues to the present day, expressed by the modern delta complex at the mouth of the Mahakam River, East Kalimantan.

EXPLORATION HISTORY AND DATABASE

The West Bungalun area, comprising the Karangan, Mayung, Beriun, Maau, Mangkupa, Tapian Danau, Tapian Langsat, Benderang and Sawang Benua regions, is located to the NW of Sangatta Field in the NE Kutei Basin (Figure 1). Exploration in this area is presently operated by PERTAMINA. To the west of this area, the Runtu area is currently being explored by LASMO.

The first exploration efforts in the West Bungalun area were regional geological investigations undertaken in the Sangkulirang-Karangan-Mangkupa areas by the Dutch geologists of BPM (predecessor of Royal Dutch Shell). Kaltim Shell investigated the area in 1972-1973. Aeromagnetic and gravity surveys were conducted in 1971 and 1978, respectively. PERTAMINA started exploring the area in 1973 and undertook numerous detailed surveys through the following years. Most recently, a geo-seismic survey was conducted in 1993. Seismic surveys in West Bungalun area were carried out by PERTAMINA starting in 1973 through 1974, 1980, and 1981. The most recent survey was acquired in 1993. A geochemical-microseep survey was conducted contemporaneous with the seismic survey in 1993. To date, there has been no exploration wells drilled in the West Bungalun area. The nearest wells are three dry exploration wells situated 50-75 kms to the west of the Bungalun area drilled by Mobil in the Semayang Area (the eastern half of the Semayang area now is worked by LASMO) in 1980's. This paper is mainly based on interpretation work of the most recent seismic data (1993 vintage) with 3000% fold coverage.

SEISMIC STRATIGRAPHIC FRAMEWORK

On seismic data, the Beriun Formation of the West Bungalun area is characterized by an anomalous amplitude pattern in that it shows much stronger

amplitude than the intervening formations (Mangkupa and Atan-Kedango formations). Velocity analysis of the Beriun Formation shows an inverse velocity phenomena (fast to slow). These anomalous amplitudes and inverse velocity indicate that the Beriun Formation is dominated by coarser clastics than the formations above and below.

Preliminary seismic stratigraphic work on the middle Eocene Beriun Formation shows that the formation can be divided into at least three seismic sequences (Figures 3, 4). The deepest sequence (sequence A) is bounded at the base by the top of Mangkupa Formation. Strong amplitudes, interpreted as sands in the lower part of the sequence A, form a retrogradational parasequence set indicating a transgressive systems tract (TST). These sands are terminated by a maximum flooding surface (MFS) characterized by overlying downlapping reflection terminations. A highstand systems tract (HST) constitutes the upper part of the sequence A.

Seismic sequence B is bounded at the base by SB-1 and at the top by SB-2. This sequence is much thinner than sequence A. SB-1 is characterized by onlap terminations that now appear to be downlap terminations due to subsequent structural inversion. Sequence B consists of transgressive and highstand systems tracts separated by a maximum flooding surface. The sequence was uplifted coeval with the initial deposition of sequence C, and the resulting erosion on SB-2 formed an incised valley.

Seismic sequence C is bounded at the base by SB-2 and at the top by the top of the Beriun Formation. Sedimentation started with lowstand sands (LST) deposited within incised valleys along of SB-2. These lowstand sands were blanketed by a transgressive sand. This is interpreted from recognizing a transgressive surface characterized by seismic onlap. A highstand systems tract constitutes the uppermost part of the Beriun Formation.

Beriun sediments were deposited in an extensional and subsiding tectonic regime with interruption of compressional-uplifting events which occurred several times. A time-isopach map of Beriun clastics was made to infer areal distribution and possible sedimentary provenance (Figure 5). The map shows that the sedimentary thicknesses are generally controlled by extensional faults. The deposition of the sediments was contemporaneous with, and affected by, growth faulting, which accumulated thicker sediments on the downthrown side of the fault. Away from the main faults, the sediment thickness decreases. The areal distribution of the Beriun sediments exhibits a fan shape. This geometry and the decrease of thickness of Beriun clastics away from the main fault are characteristics of fan delta deposits, similar to fan deltas in Brazilian rift basins detailed by Brown and Fisher (1977) (Figures 6, 7).

The upward deepening in environments from the Beriun sands into deep marine shales of the overlying Atam Formation suggests that the Berium fan-delta was deposited in a overall transgressive setting.

PETROLEUM POTENTIAL

A geochemical-microseep survey conducted in 1993 confirmed the presence of high C5+ hydrocarbons and crude oil derived from Eocene sources in the West Bungalun area. These hydrocarbons were likely sourced by the latest Paleocene to early Eocene carbonaceous shales of Mangkupa Formation. Good-quality reservoir rocks are present within the Beriun sands. Surficial data show that the sandstones are clean, well-sorted and quartzitic. The marine shales of the Beriun, Atan and Kedango Formations overlie the Beriun sands and could provide a good seal. Structural and stratigraphic traps are present in the area. Roll-over structures on the hanging walls of growth faults were favorably positioned to entrap migrated hydrocarbon from underlying Mangkupa source rocks. There is also potential for stratigraphic trapping associated with pinchouts, truncations, and incised-valley fills. Generation and migration of hydrocarbons from Mangkupa shales likely started in the late Miocene and oil could have been trapped in structures that formed contemporaneous with the deposition of the Beriun sediments in the middle Eocene time.

CONCLUSIONS

Preliminary work applying seismic stratigraphy to the Eocene Beriun Formation of West Bungalun, Northeast Kutei Basin, shows that the formation consists of at least three seismic stratigraphic sequences. The sequences are mainly composed of transgressive and highstand systems tracts. Sedimentary and tectonic characteristics indicate that the Beriun sediments were deposited as fan delta deposits. This study supports that the Beriun sands in

the West Bungalun area are potential reservoir rocks that could contain structurally or stratigraphically trapped hydrocarbons from a mature Paleogene-Eocene source.

ACKNOWLEDGEMENTS

We thank PERTAMINA management for giving us an opportunity to participate in the symposium and permission to disclose this data. This paper originated as a poster in the symposium and received encouragement from Chuck Caughey of ASAMERA to be written as a paper. Syahrani, Suharto, Putut and Agung drafted the illustrations. Isna typed the manuscript. Lanny Satyana improved the English language.

REFERENCES CITED

Biantoro, E., Muritno, B.P., and Mamuaya, J.M.B, 1992, Inversion Fault as Major Structural Control in the Northern Part of Kutei Basin, Proceedings IPA 21st. annual convention.

Biantoro, E., Priantono, T.S., and Mamuaya, J.M.B., 1994, Potensi Reservoir Eosen Daerah Bungalun Barat, Cekungan Kutai Utara: Prediksi dari Interpretasi Seismik, Proceedings HAGI 19th. annual convention, p.355-373.

Brown, L.F., Jr., and Fisher, W.L., 1977, Seismic Stratigraphic Interpretation of Depositional Systems: Examples from Brazilian Rift and Pull Apart Basin in Payton, C.E., ed., Seismic Stratigraphy - Applications to Hydrocarbon Exploration - AAPG Memoir 26, AAPG, Tulsa, p.213-248.

Chambers, J.L.C. and Daley, T.E., 1995, A Tectonic Model for the Onshore Kutei Basin, East Kalimantan, Based on an Integrated Geological and Geophysical Interpretation, Proceedings IPA 24th. annual convention.

Courteney, S., Cockcroft, P., Lorentz, R., Miller, R., Ott, H.L., Prijosoesilo,P., Suhendan, A.R., Wight, A.W.R., Wiman, S.K., and Phoa, R.S.K, 1991, Indonesia Oil and Gas Fields Atlas, Indonesia Petroleum Association, Jakarta.

Mitchum, R.M., Jr., Vail, P.R., and Thompson, S., III, 1977, Seismic Stratigraphy and Global Changes of Sea Level, Part 2: The Depositional Sequenc as a Basic Unit for Stratigraphic Analysis in Payton, C.E., ed., Seismic Stratigraphy-Applications to Hydrocarbon Exploration-AAPG Memoir 26, AAPG, Tulsa, p.53-62.

Myers, K., 1991, Introduction to Sequence Stratigraphy Course Notes Module I Concepts and Principles of Sequence Stratigraphy, Stratigraphic Studies Group, British Petroleum, London, unpubl.

Ott, H.L., 1987, The Kutei Basin - A Unique Structural History, Proceedings IPA 16th. annual convention, p.307-316.

PERTAMINA and P.T. Gondwana, 1985, Report on Geological Investigation for Hydrocarbon Possibilities, Beriun Area, East Kalimantan, P.T. Gondwana, Jakarta, unpubl.

Rose, R. and Hartono, P., 1978, Geological Evolution of the Tertiary Kutei Melawi Basin Kalimantna Indonesia, Proceedings IPA 7th. annual convention, p.225-251.

Sardjono, S., Imanhardjo, D.N., Hardjono, and Muritno, B.P., 1991, Technical Memorandum Evaluasi Prospek Hidrokarbon Daerah Benderang, Tapian Langsat, dan Tapian Danau, Sangatta-Bungalun, Kalimantan Timur, Eksplorasi PERTAMINA DAK, Balikpapan, unpubl.

Umar, L., Purnomo, E., Bachtiar, A., 1987, Prospek Hidrokarbon Batupasir Formasi Beriun di Daerah Sangatta-Bungalun Cekungan Kutai, Proceedings IAGI 16th. annual convention.

Vail, P.R. and Mitchum, R.M., Jr., 1977, Seismic Stratigraphy and Global Changes of Sea Level, Part 1: Overview in Payton, C.E., ed., Seismic Stratigraphy-Applications to Hydrocarbon Exploration-AAPG Memoir 26, AAPG, Tulsa, p.51-52.

van Bemmelen, R.W., 1949, The Geology of Indonesia, vol. 1A - General Geology of Indonesia and Adjacent Archipelagoes, Government Printing Office, The Hague.

van de Weerd, A.A. and Armin, R.A., 1992, Origin and Evolution of the Tertiary Hydrocarbon Bearing Basins in Kalimantan (Borneo), Indonesia, The AAPG Bull., v.76, no.11, p.1778-1803.

Weimer, R.J., 1975, Impressions of the Geology of the Mahakam Delta Complex and Petroleum Exploration, Geologi Indonesia, v.2, no.2, p.45-47.

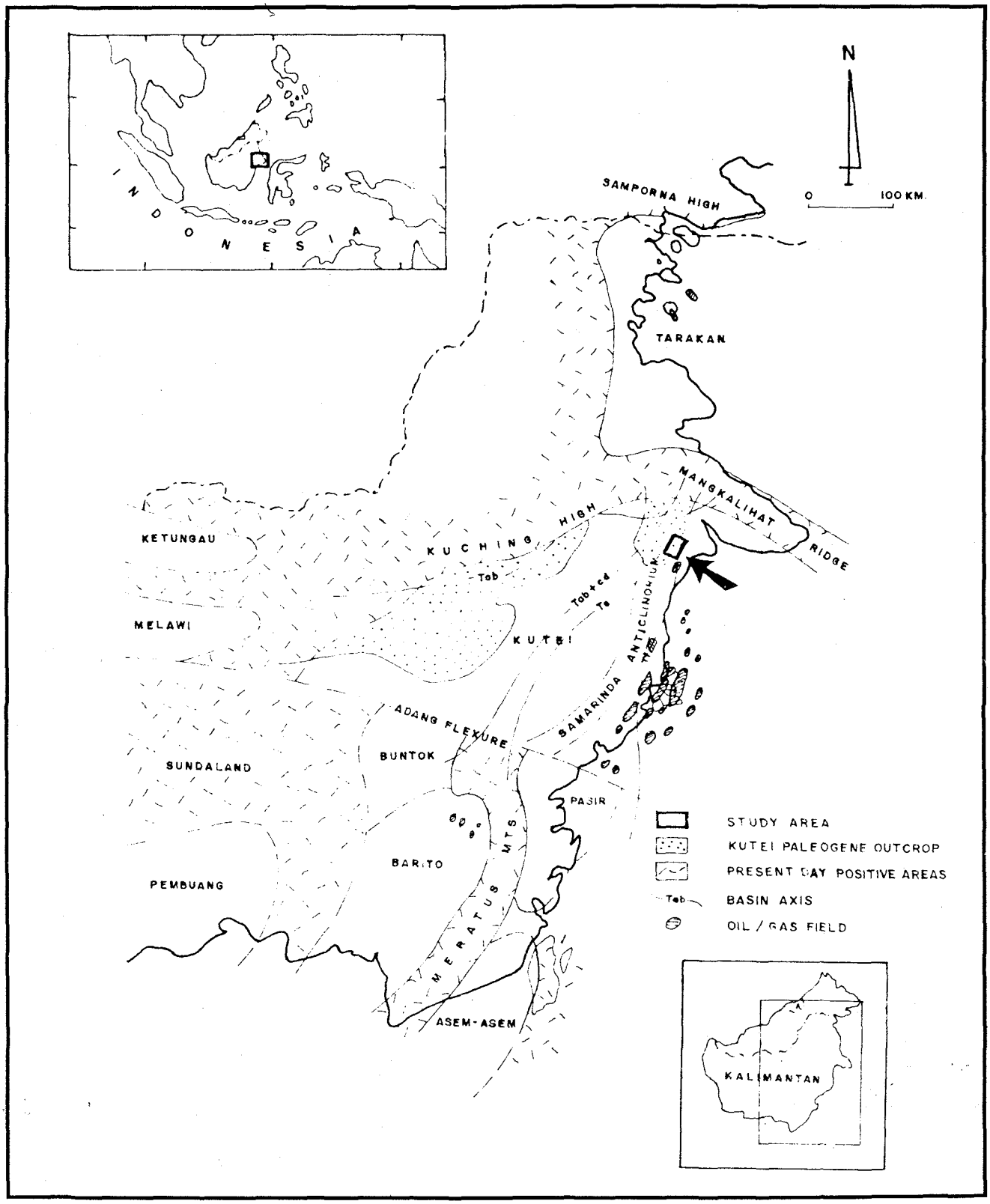

FIGURE 1 - Map showing the physiographic setting of the study area and the Kalimantan region, Paleogene outcrops in Kutei Basin, oil and gas fields, and evolution of the Kutei basinal axis during the Tertiary.

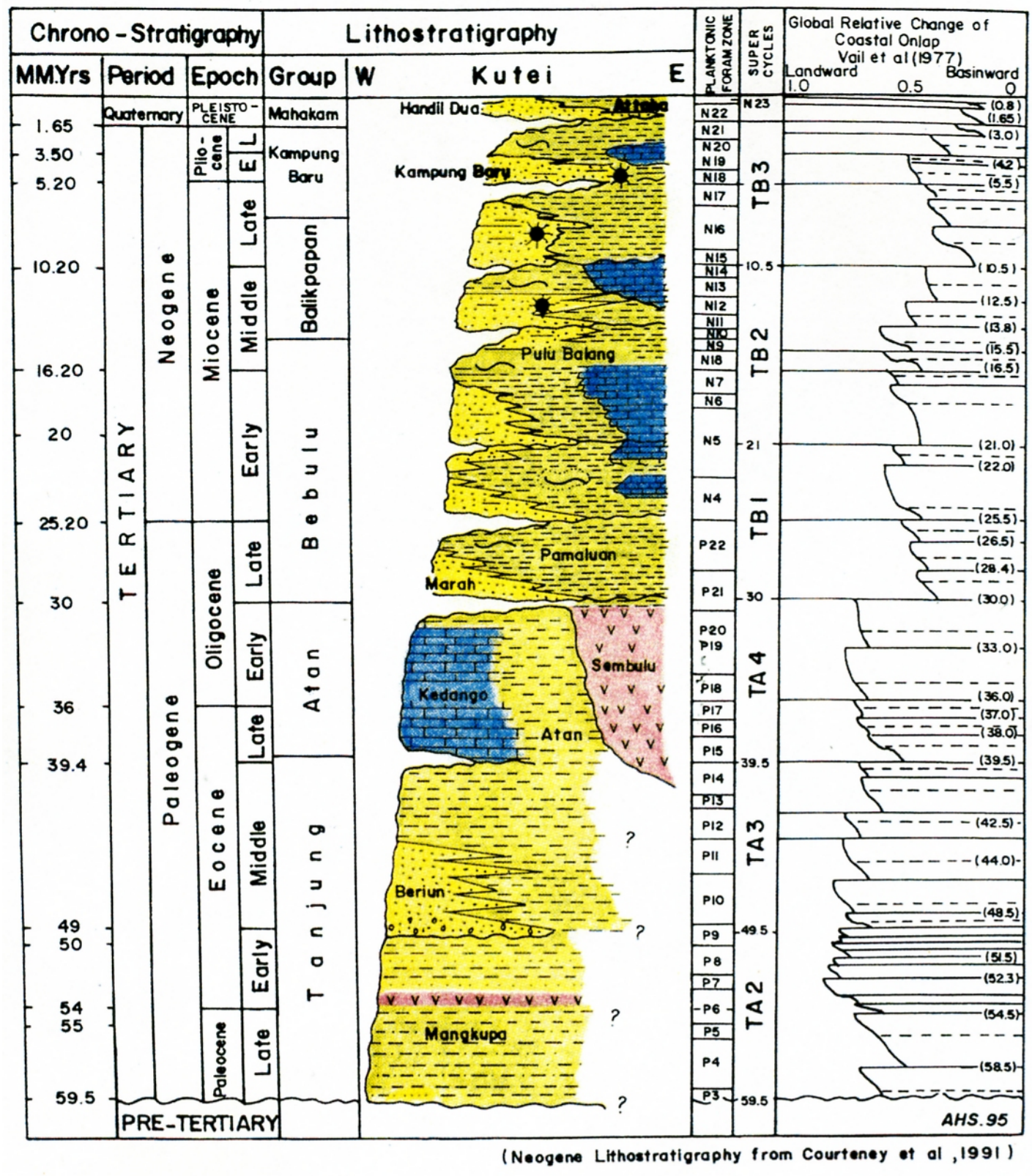

FIGURE 2 - Stratigraphy of the Kutei Basin, recorded hydrocarbon occurrences, and coeval coastal onlap configuration during the Tertiary.

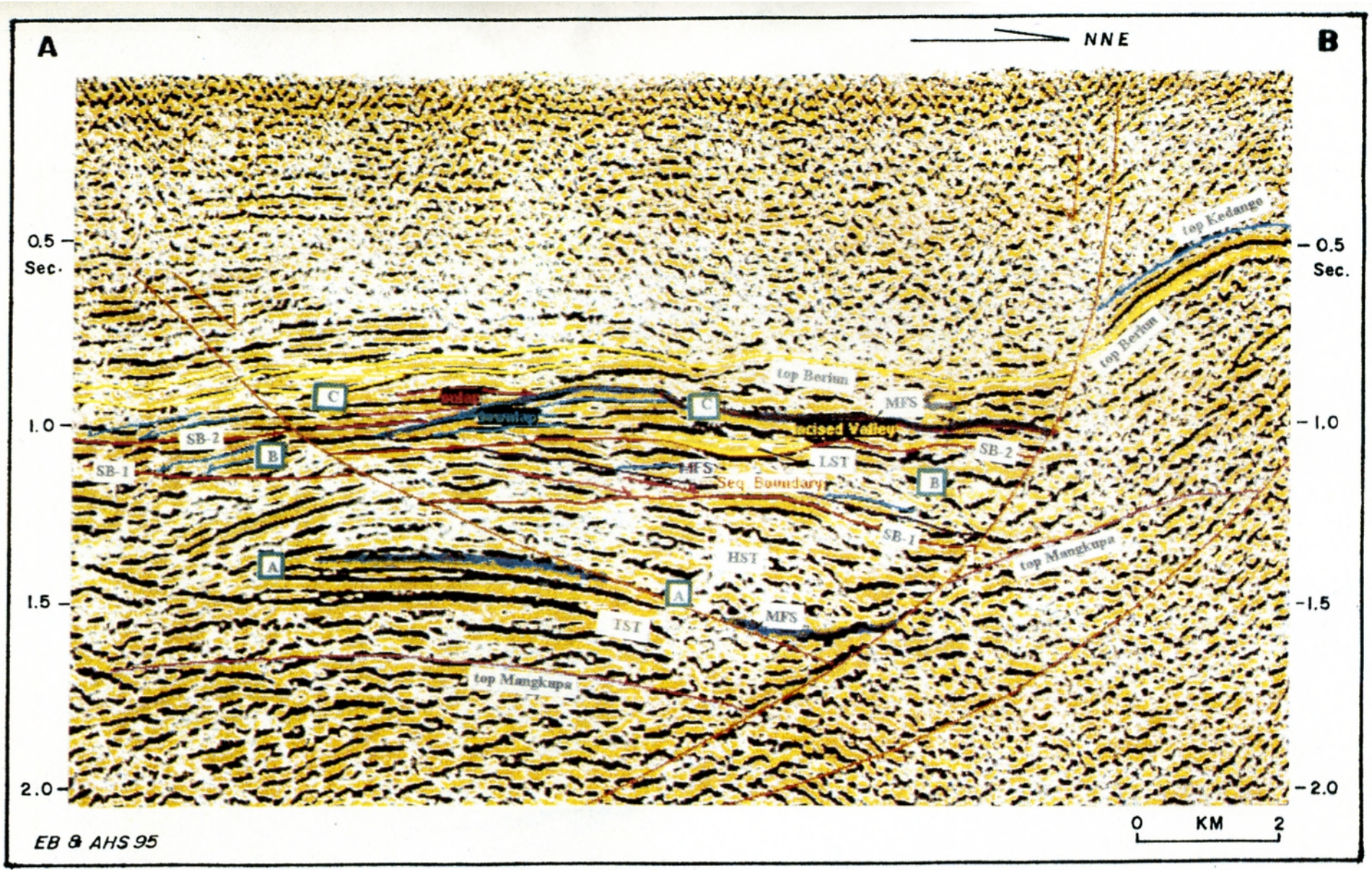

FIGURE 3 - Seismic section A - B showing that the Beriun Formation consists of three seismic stratigraphic sequences (A, B, C) Beriun sands are characterized by anomalous strong amplitudes. Formation thickness is strongly controlled by the main extensional fault. Location of the section is illustrated in Figure 5.

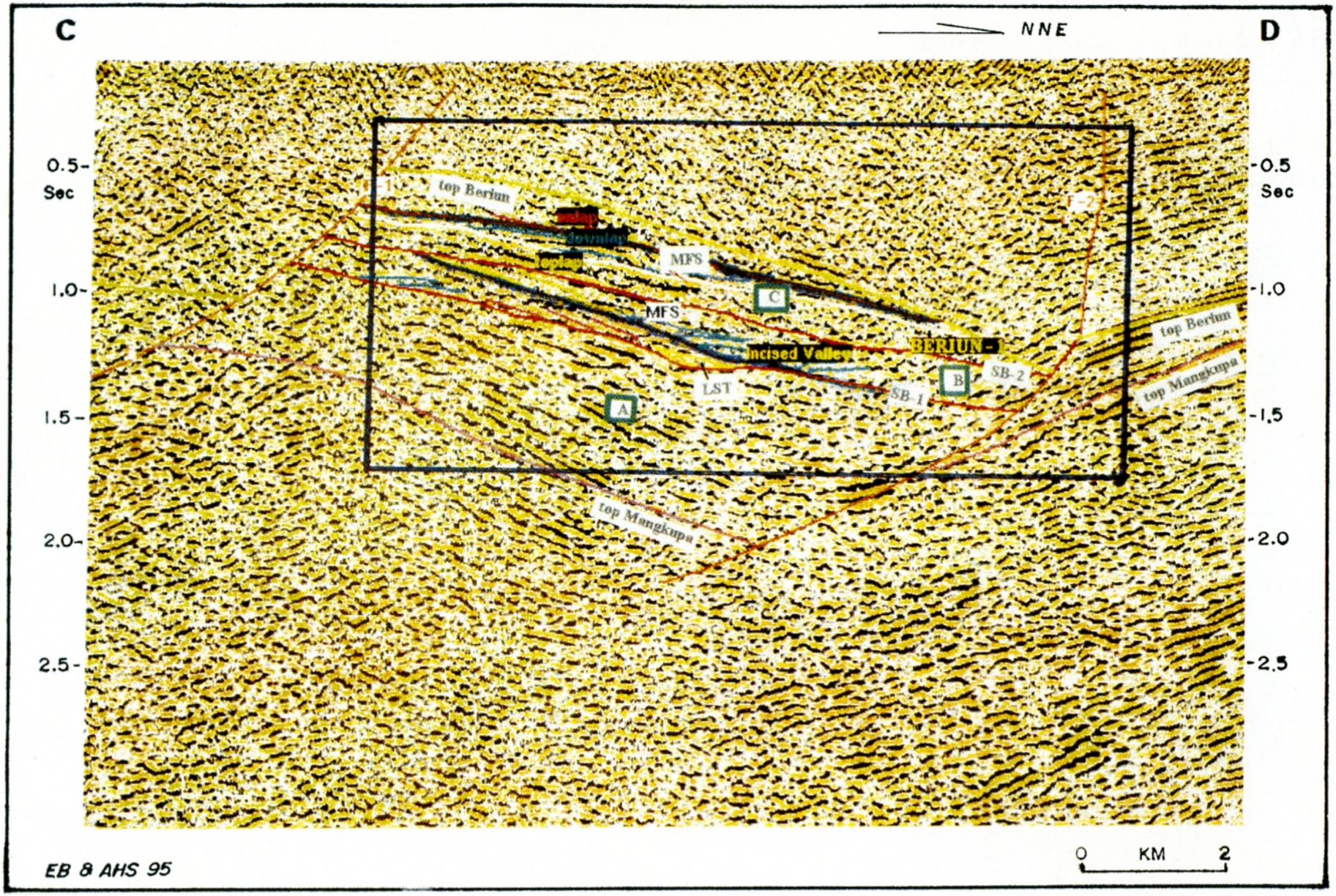

FIGURE 4 - Seismic section C - D showing three seismic stratigraphic sequences (A, B, C) of Berium Formation. Location of the section is illustrated in Figure 5.

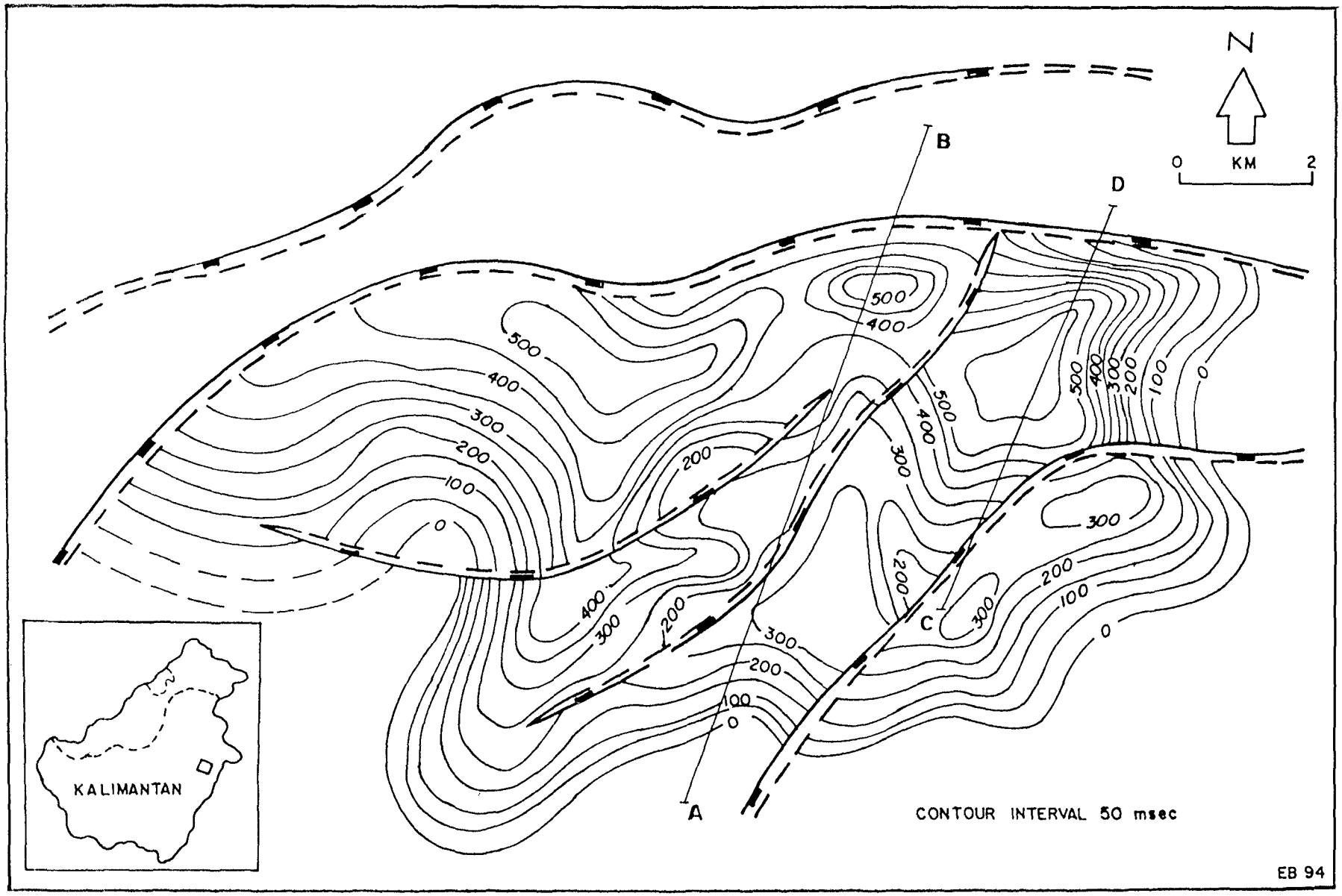

FIGURE 5 - Time-isopach map of Berium clastics showing fan-shaped distribution and decreasing thicknesses away from the main faults.

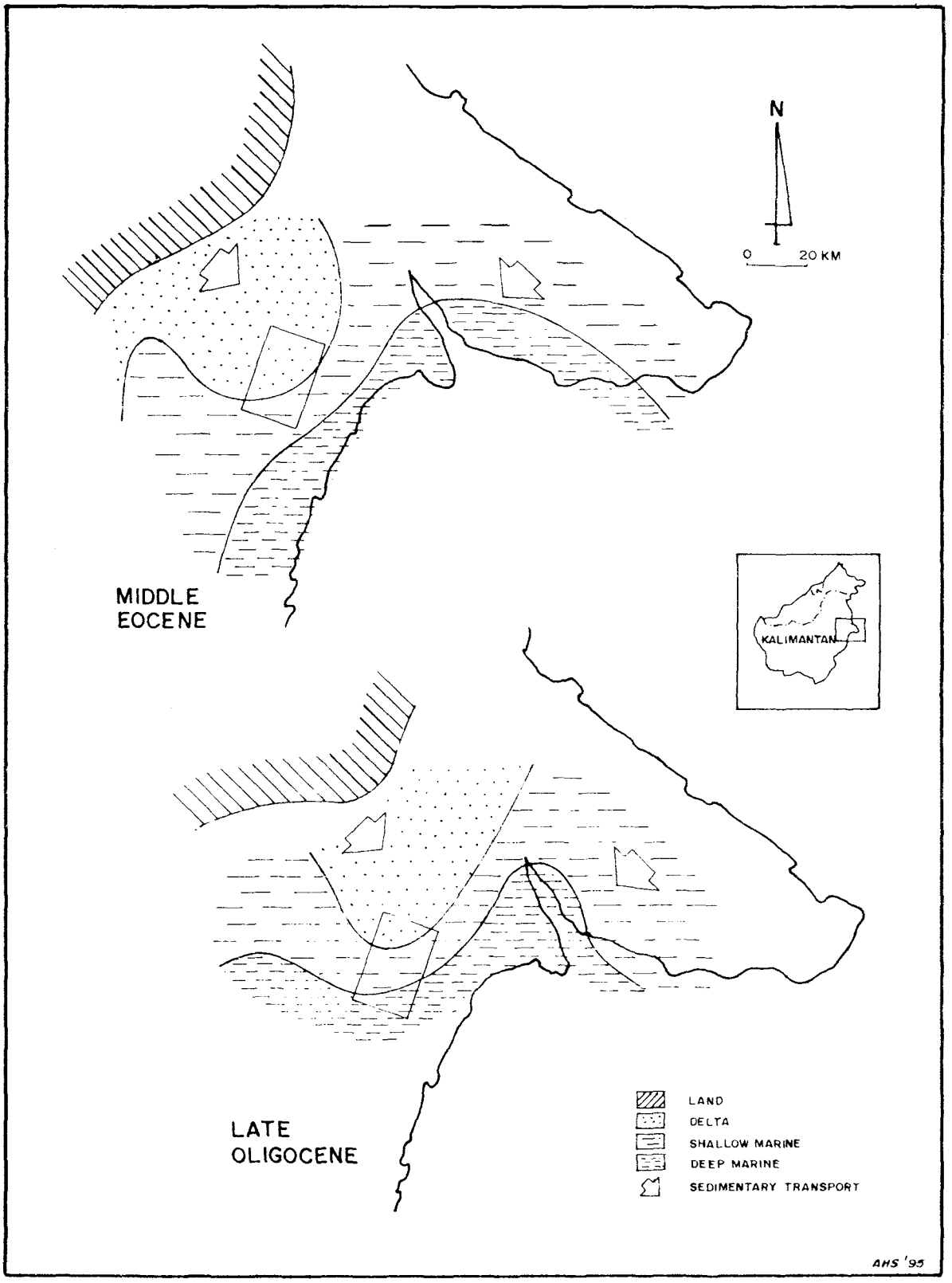

FIGURE 6 - Evolution of paleo-environments in study area (box) from middle Eocene to late Oligocene, indicating marine incursion. Note middle Eocene Beriun sediments were dominantly deposited in deltaic environments.

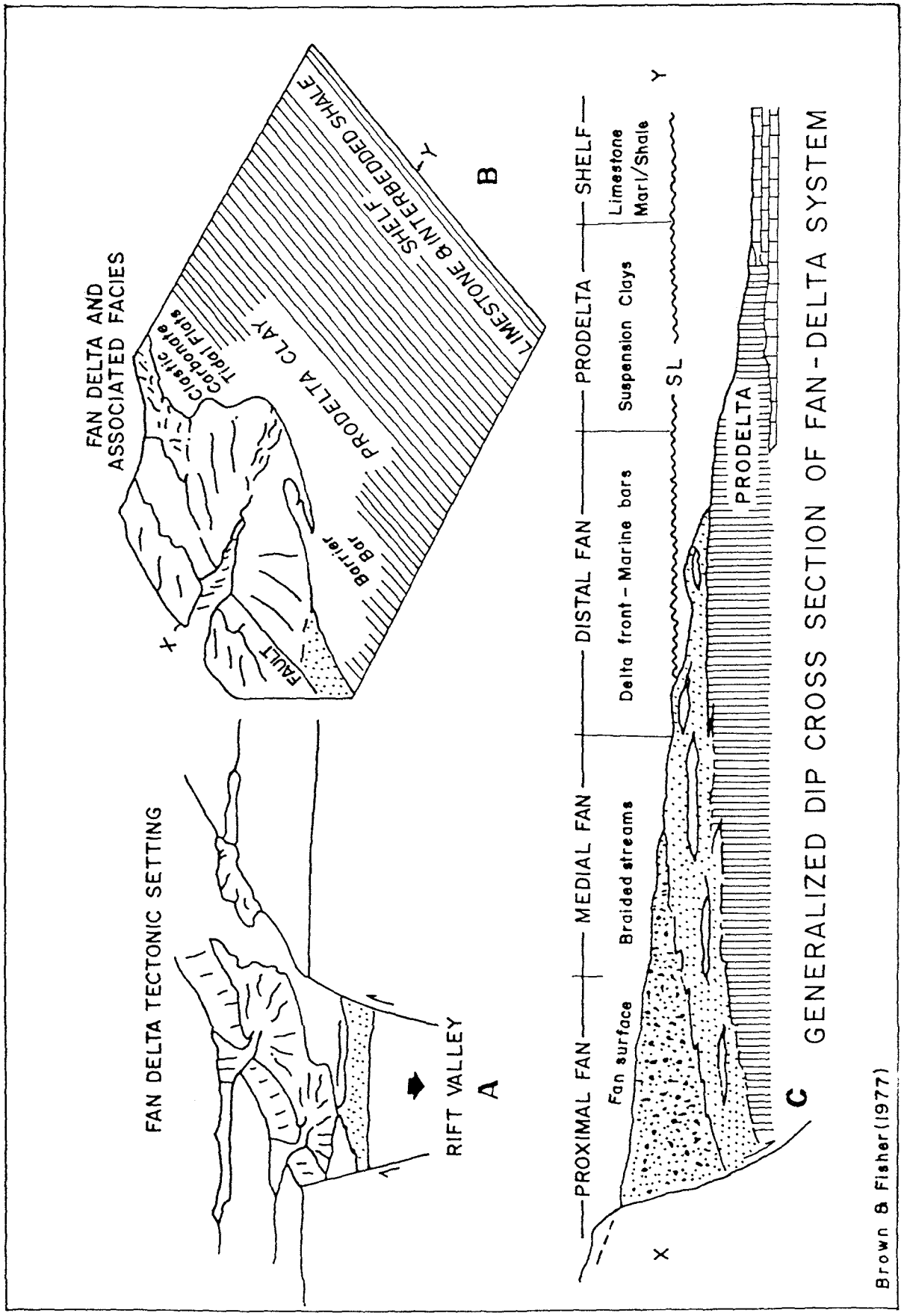

FIGURE 7 - Fan delta tectonic and environmental setting proposed by Brown and Fisher (1977) based on their study in Brazilian rift basins. The Beriun deposits accumulated during similar conditions during Paleogene rifting in Kutei Basin.