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Regional seismostratigraphic study of the Tembungo area, offshore West Sabah

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Abstract: The Seismo-stratigraphic study of the Tembungo area, offshore West Sabah provided a depositional model for the hydrocarbon-bearing Stage IVD turbidite sequence in the Tembungo field. The model suggests that the turbidite sequence, characterised by an oblique seismic reflection pattern was deposited in a sedimentary bypass system tract as a result of wrench-related uplift of the Bunbury–St. Joseph area. The uplifted and subsequent removal of Stage IVC–IVA coastal fluviomarine and lower coastal plain sediments during the Shallow Regional Unconformity followed by active Stage IVD deltaic progradation provided a huge volume of sediment input to the confined Tembungo depression beyond the contemporaneous shelf edge. The deltaic sediments with good reservoir and source rock properties have contributed to the hydrocarbon potential of Stage IVD turbidites in the Tembungo field.

INTRODUCTION

The Tembungo field which was discovered by Esso Production Malaysia Inc. in 1971, is located offshore West Sabah, 75.6 km to the NE of Kota Kinabalu, EPMI produced hydrocarbons from this field from 1974 to 1986 and was then relinquished to PETRONAS which in turn appointed PETRONAS Carigali as the operator. Carigali is now doing the work-over and field appraisal studies.

The Tembungo production block is bordered by the SB 1 Exploration Block to the south and by the SB 2 Exploration Block to the north (Fig. 1). PETRONAS Carigali is the partner in both SB 1 and SB 2 exploration blocks.

OBJECTIVES

This report intends:

1. To illustrate the established correlation between the oil producing turbidite sequence in the Tembungo field and its provinance,
2. To discuss the sedimentation and tectonic history of the study area,
3. To discuss the depositional model of the Tembungo turbidite sequence and the hydrocarbon charging scenario of the field.

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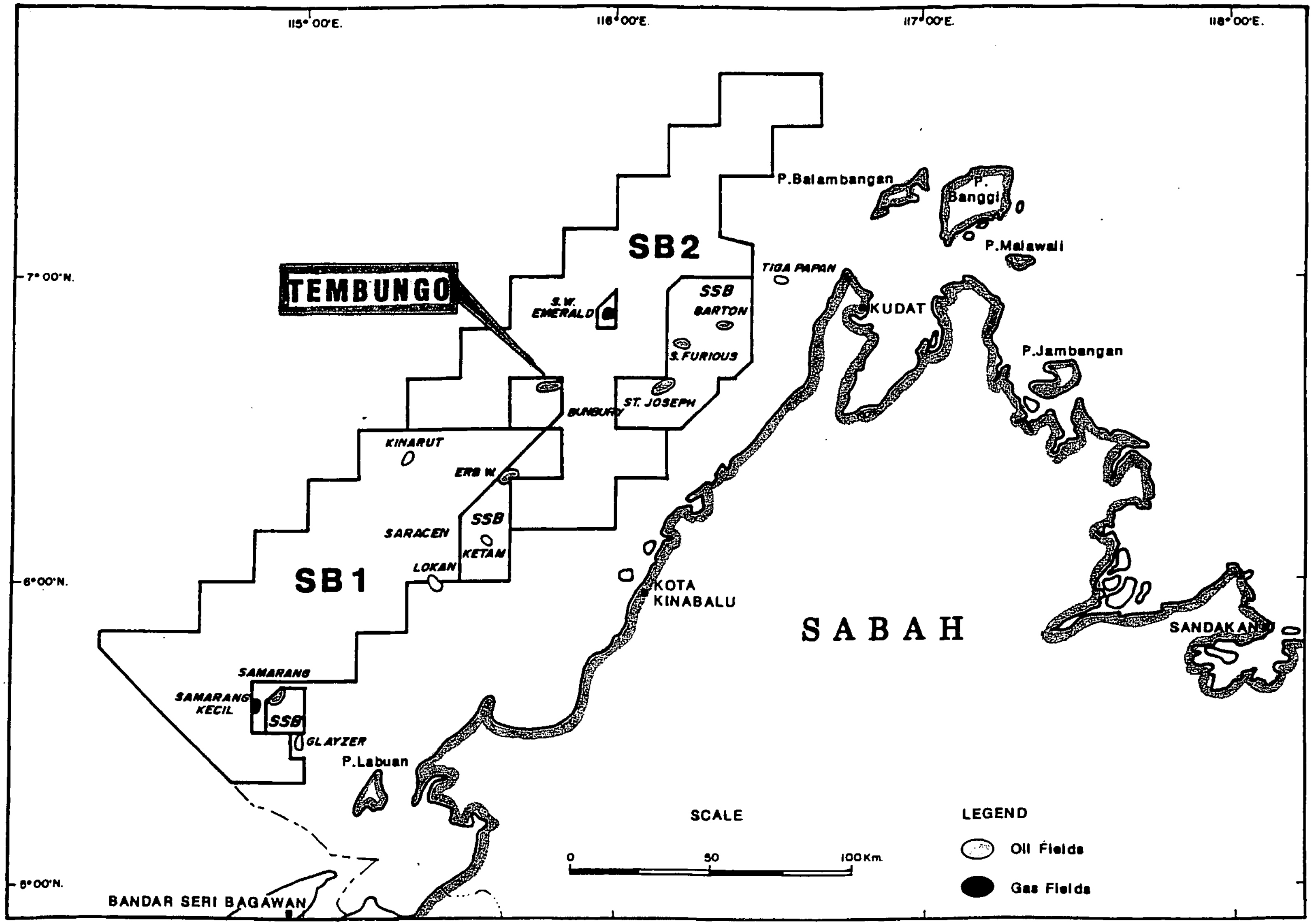

Figure 1: Location map of the Tembungo oil field.

STUDY TECHNIQUE

Regional seismic lines covering the Tembungo field area were selected and interpreted. The following seismo-stratigraphic techniques were applied in the seismic interpretation.

Sequence boundaries and age determination

The sequence boundaries were obtained from the well data drilled in the study area (Table 1). By transferring these sequence boundaries to seismic sections, the mappable reflectors representing the sequence boundaries were picked.

The picked boundaries were further checked by correlating them to the uplifted area where they normally became erosional unconformities. Once the sequence boundaries were confidently picked, the correlation were made throughout the study area. The age of the sedimentary sequences could then be inferred from the SSB stratigraphic scheme (Fig. 2).

Seismic facies and depositional environment interpretation

The distinction of the various seismic facies based on the reflection configuration was calibrated with the interpreted depositional environments and litho facies at the well location. The depositional interpretations made in this report were based on these calibrations and other regional data from offshore west Sabah.

SEISMO-STRATIGRAPHIC INTERPRETATION

Structuration History

The Tembungo–Bunbury area has undergone intervening phases of tectonic uplift and wrenching. Two major uplifts of regional significance have resulted in the formation of the Deep Regional Unconformity (Base Stage IVA) and Shallow Regional Unconformity (Base Stage IVD) in early Middle Miocene and early Late Miocene times respectively.

Table 1: Stage boundaries, in depth and two-way time obtained from the well results in the study area.

WELL NAME	BASE STAGE IVA	BASE STAGE IVB	BASE STAGE IVC	BASE STAGE IVD	BASE STAGE IVE
Bunbury–2	6,605' (1.6)	875' (0.55)	—	—	—
S. Furious–1	—	6,524' (1.9)	4,659' (1.4)	2,689' (0.85)	499' (0.25)
Tembungo–2	—	—	—	7,044' (1.75)	2,681' (0.85)
Erb West–3	—	—	—	8,040' (1.85)	3,511' (0.95)

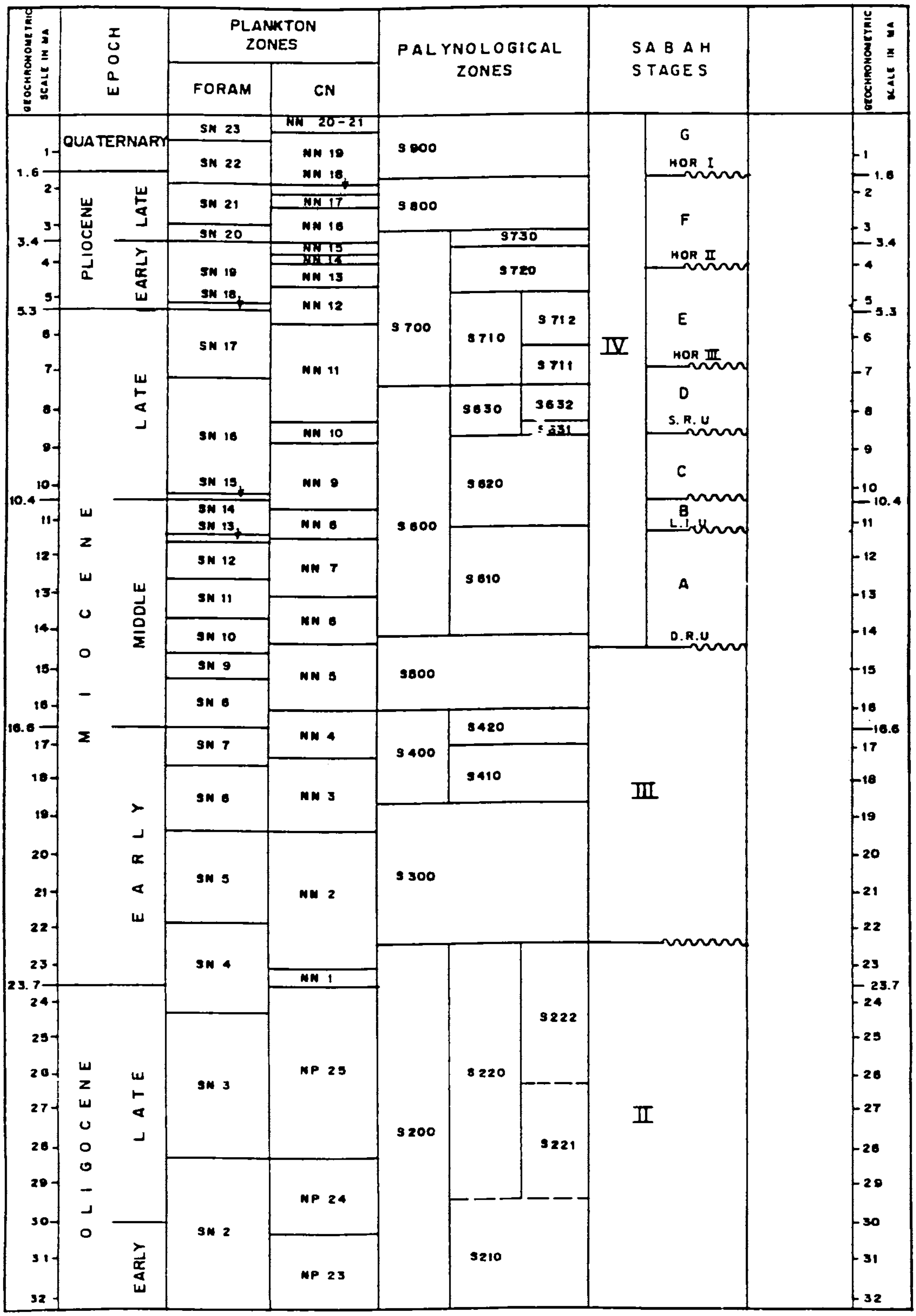

Figure 2: West Sabah stratigraphic scheme.

Erosions during these two unconformities and other intermediate unconformities resulted in the depositions of the Stages IVA–IVC sedimentary sequences in the Tembungo–Bunbury area (Fig. 2). It is inferred that the shelf-edge during Stages IVA–C times was located to north of the Bunbury area.

Wrenching and block rotation in the Bunbury–St. Joseph area occurred in the Stage IVD times (Fig. 3). Erosion in the uplifted area provided a tremendous amount of sediments deposited in the Tembungo depocentre. Compression and wrenching in the Stage IVD time formed the Tembungo structure.

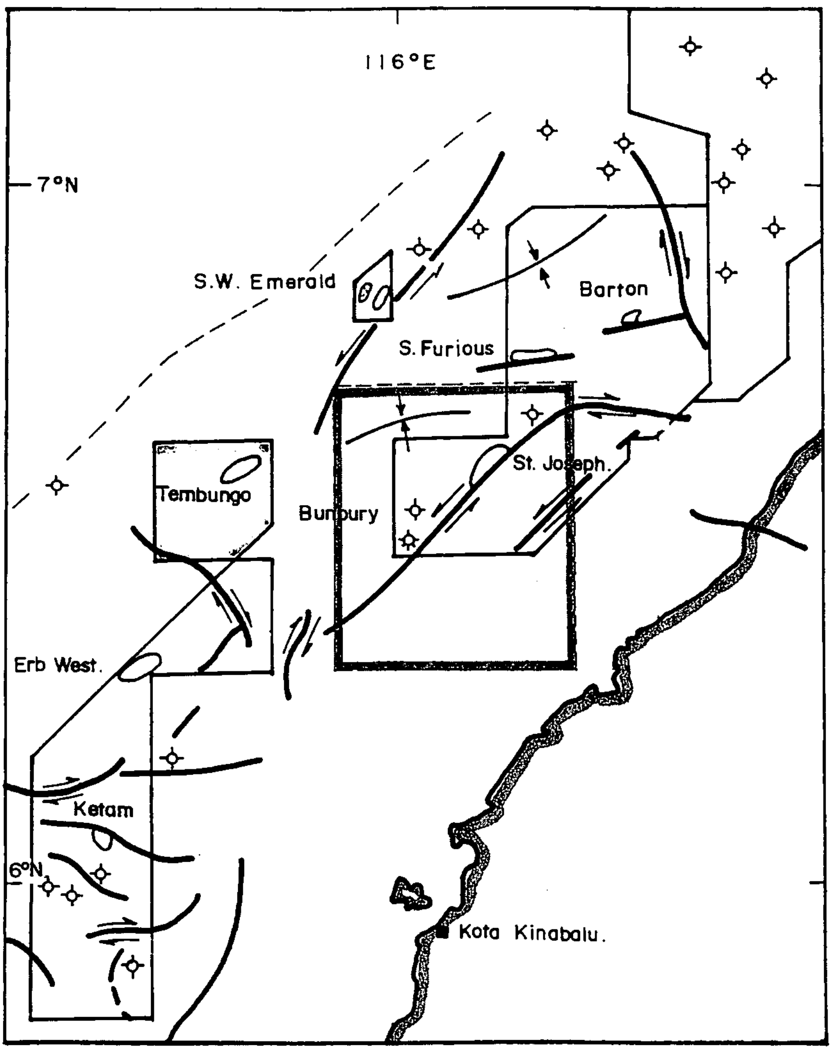

Figure 3: Tectonic map showing the lateral extent of post SRU sinistral wrench faulting in the Banbury – St. Joseph area.

Sedimentation History

The depositional history of this area could be divided into three episodes;

(1) Deposition prior to the formation of Shallow Regional Unconformity (SRU).

(2) Deposition in topographic low during the SRU times.

(3) Deposition after the structuration of Tembungo.

Pre Stage IVD Sequences

The nature of the Stage IVA, B and C sediments in the St. Joseph–Bunbury area could not be conclusively analysed since the area was severely wrenched and rotated. However, their nature could be observed in the south Furious area and other inboard areas including Saracen Bank (Figs. 4 & 5).

In the Saracen Bank and South Furious areas, Stage IVA sequence is characterized by thick topset packages of Lower Coastal Plain and Coastal/Coastal Fluviomarine environments grading into a clinoform sequence of slope what environment towards the northwest. These packages are overlain by low angle clinoform packages illustrating the rapid transgressive event at the end of the Stage IVA time.

Stage IVB represents the maximum transgressive period in offshore West Sabah (Bol & van Hoorn, 1980). In the Saracen Bank area, this sequence is characterized by bottomset packages of Hollomarine to Bathyal environments.

Stage IVC clinoform packages overlying the Stage IVB bottomset, represents the start of overall regressive period in this area. The clinoform packages are overlain by a massive northwest topset outbuilding (Fig. 6).

A similar nature of sedimentation for the Stage IVA, B and C sequences was observed in the South Furious Area and within the preserved wrenched block in the Bunbury Area. The apparent thickness of the three sequences is in excess of three seconds. This represented mainly by topset packages grading to clinoforms in the downdip position. The proximal potions of these sedimentary sequences were eroded.

Depositions of the Stage IVD Sequence

a) Lower Stage IVD sequence

Uplift and erosion in the Erb West area and the area to the west of Bunbury resulted in peneplenation of these areas. This provided sediments for deposition of the basal Stage IVD sediments directly into the Tembungo–Bunbury basin.

This basin was wrenched (left lateral movement) and rotated in the early stage of SRU. Massive erosion of the wrenched and uplifted Bunbury area, cutting into topsets of the Stages IVA, IVB and IVC provided a large amount of sand-rich sediments feeding the turbidite system on the flank of the emerged area (Fig. 7). These sand bodies were blanketed by the Middle-Outer Neritic shales.

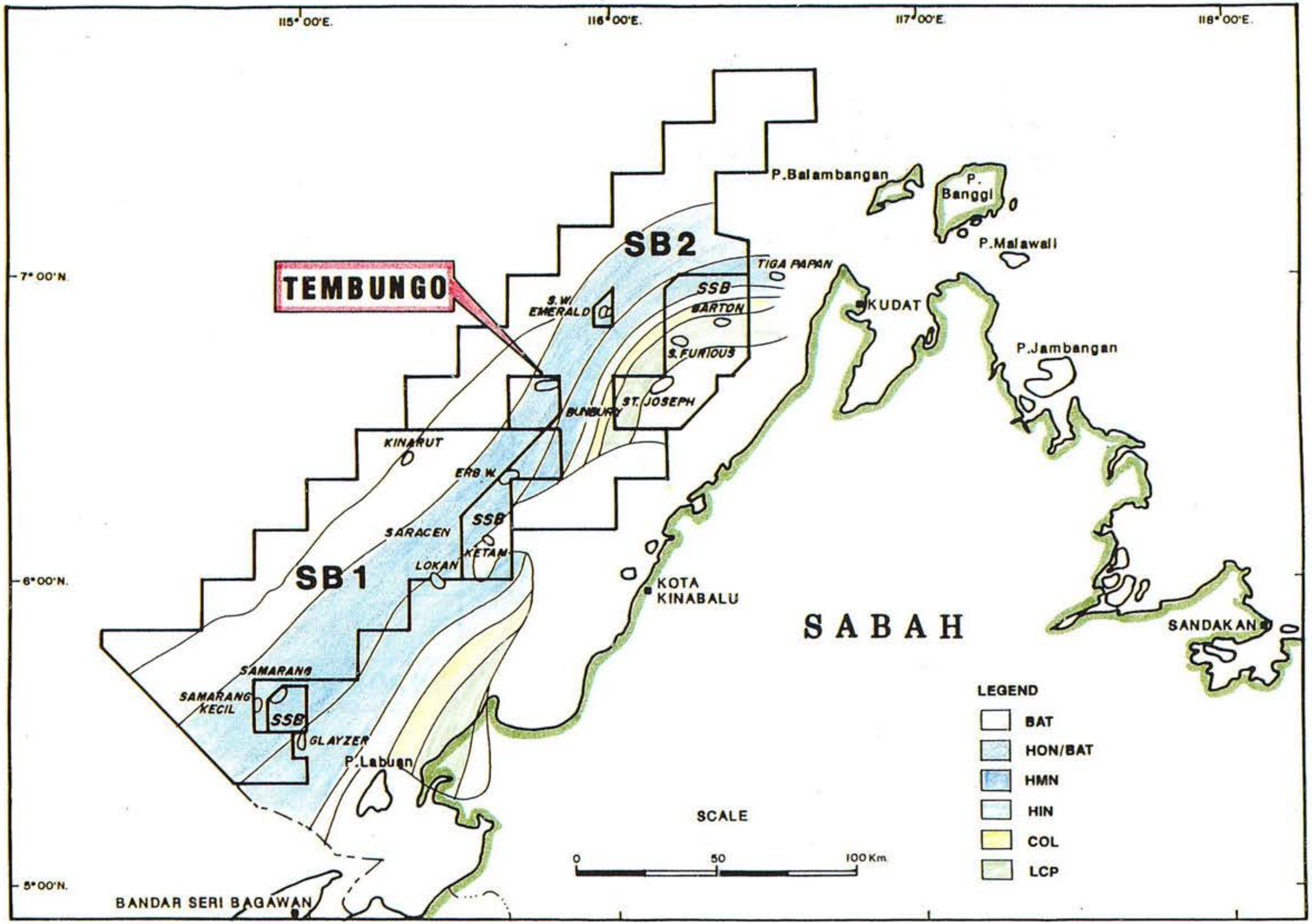

Figure 4: Paleofacies development of the Stage IVA Sequence.

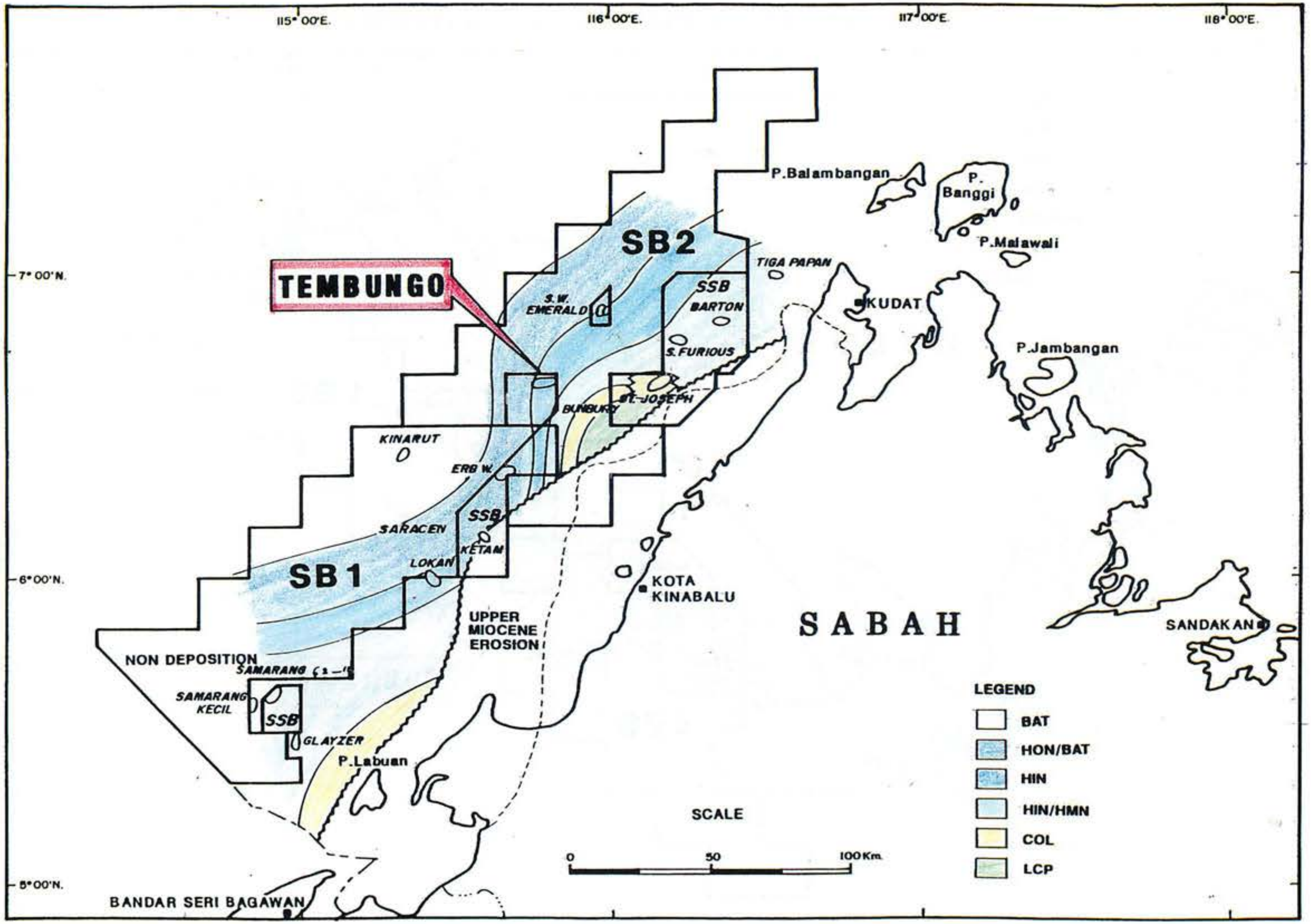

Figure 5: Paleofacies development of Stage IVC Sequence.

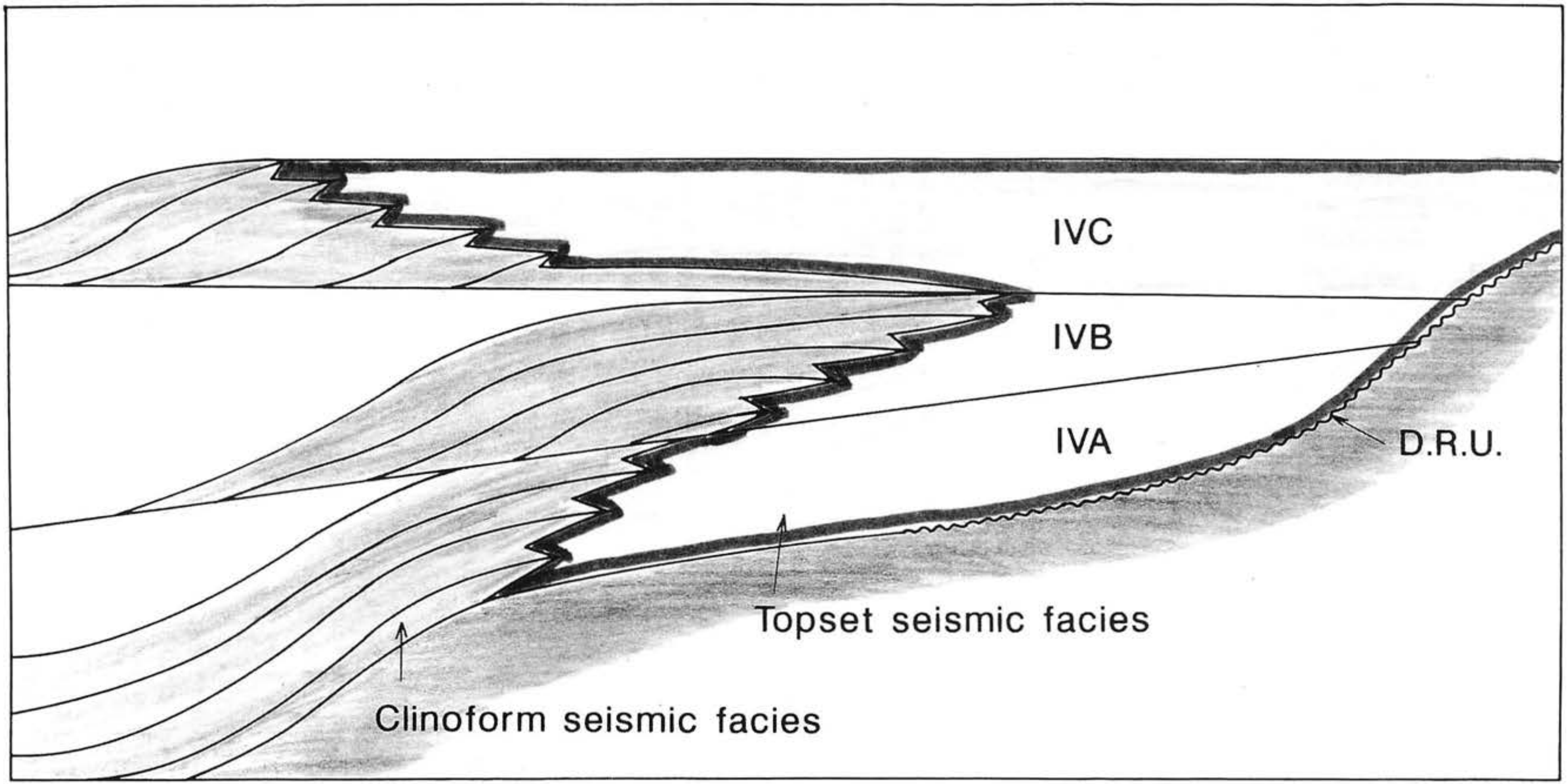

Figure 6: Deposition of the Stage IVA, IVB and IVC Sequences.

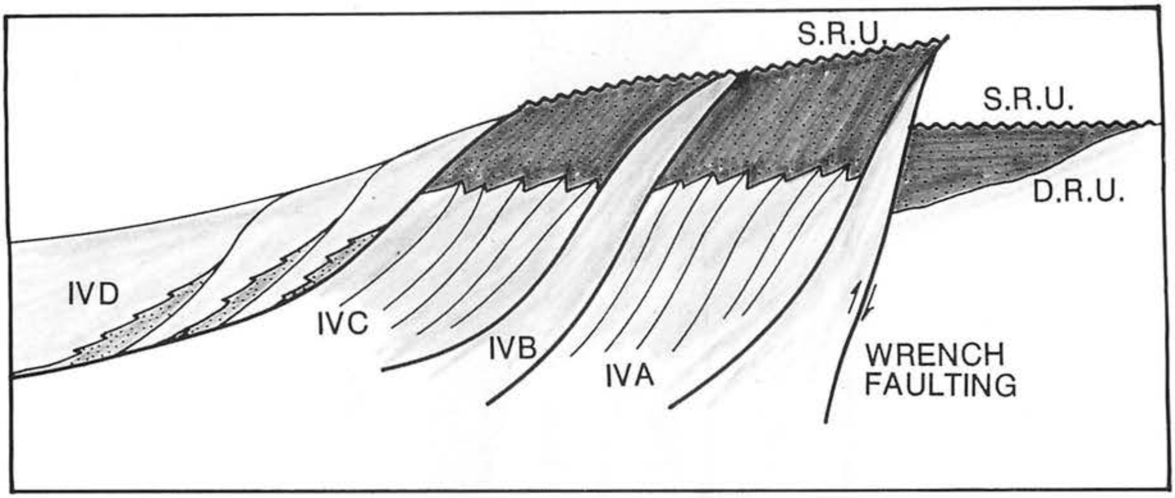

Figure 7: Wrench faulting post S.R.U. formation.

Seismically, the lower Stage IVD sequence is characterized by low angle oblique clinoforms (Figs. 8 and 9). The topset unit of this package is not preserved. This suggests that the topset packages were not developed and/or was eroded and redeposited beyond the contemporaneous shelf-edge.

Calibration with Tembungo 2 and 4 wells indicate that the lower Stage IVD reservoir package occurring within the basal clinoform (fondoform) facies. This clinoform package consist of mainly marine shales.

Theoretically the oblique clinoform configuration represents a progradational sedimentation with high terrigeneous supply within a high energy environment during still stand or slow rising sea level. The fondoform part of oblique facies unit may contain turbidite deposit (Sangree, 1977).

Observation of both well results and seismic facies suggest that the Lower Stage IVD reservoir sequence in the Tembungo field were deposited as a turbidite sequence in a relatively shallow water environment by the still stand sedimentary-by-pass processes within a semi-confined basin. The basin is bounded by a local high to the north and by a synsedimentary growth fault to the west (Fig. 10).

This produced a north-westward prograding lateral discontinuous sand sheets of the Lower Stage IVD sequence. Therefore, the reservoir correlation between the Tembungo 2 and 4 wells should be correlated as shown in Figure 13 instead of Figure 12.

b) Upper Stage IVD Sequence

The upper Stage IVD sequence is characterized by a prograding shallow marine sequence (Fig. 14). The topset package prograded over the Tembungo area and gradually graded into shingles and clinoforms, several kilometres north of the structure. Wireline logs from the Tembungo 2 and 4 wells indicate that the upper

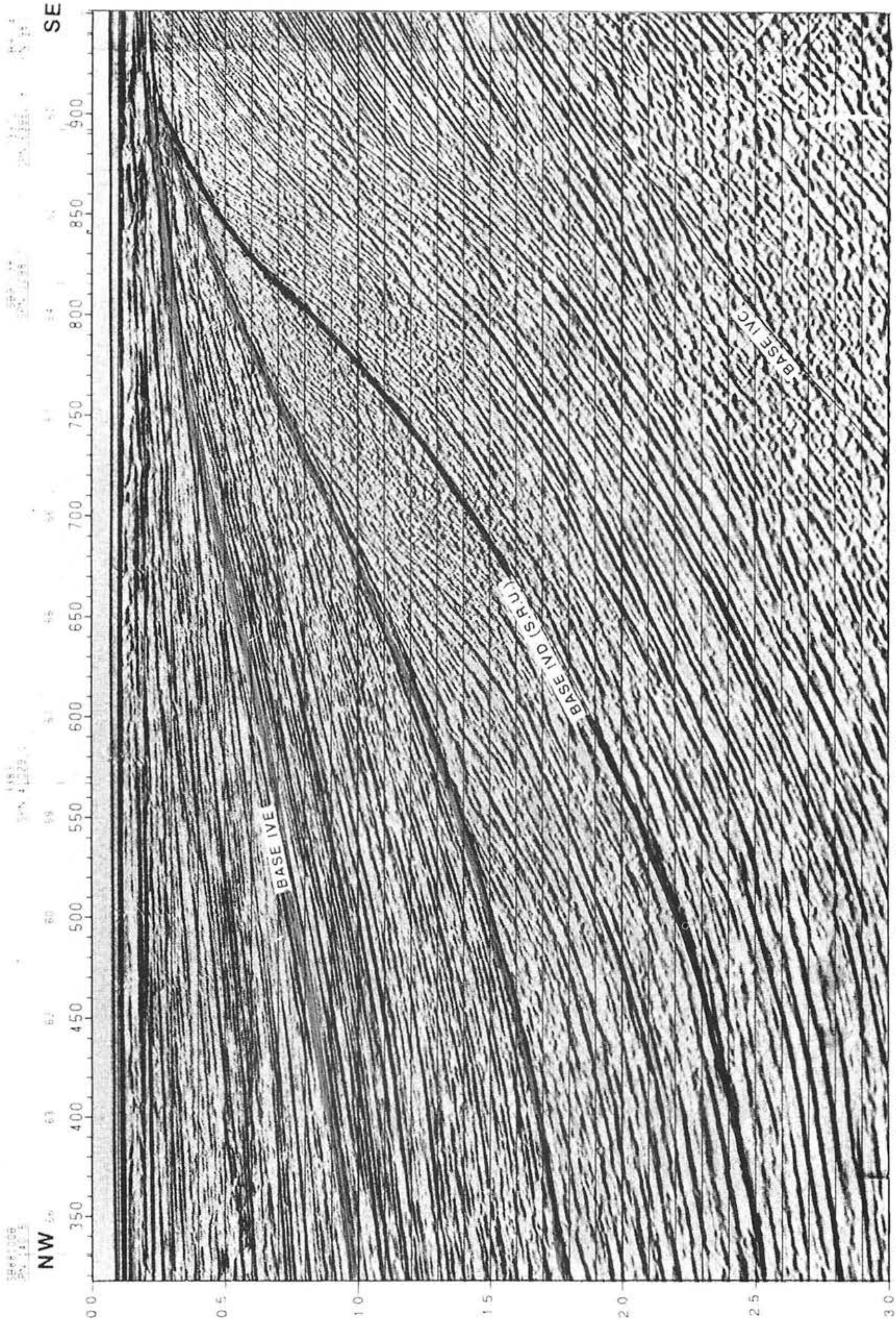

Figure 8: 2D seismic section showing the oblique clinoform nature of the basal Stage IVD Sequence in the Banbury – Tembungo area.

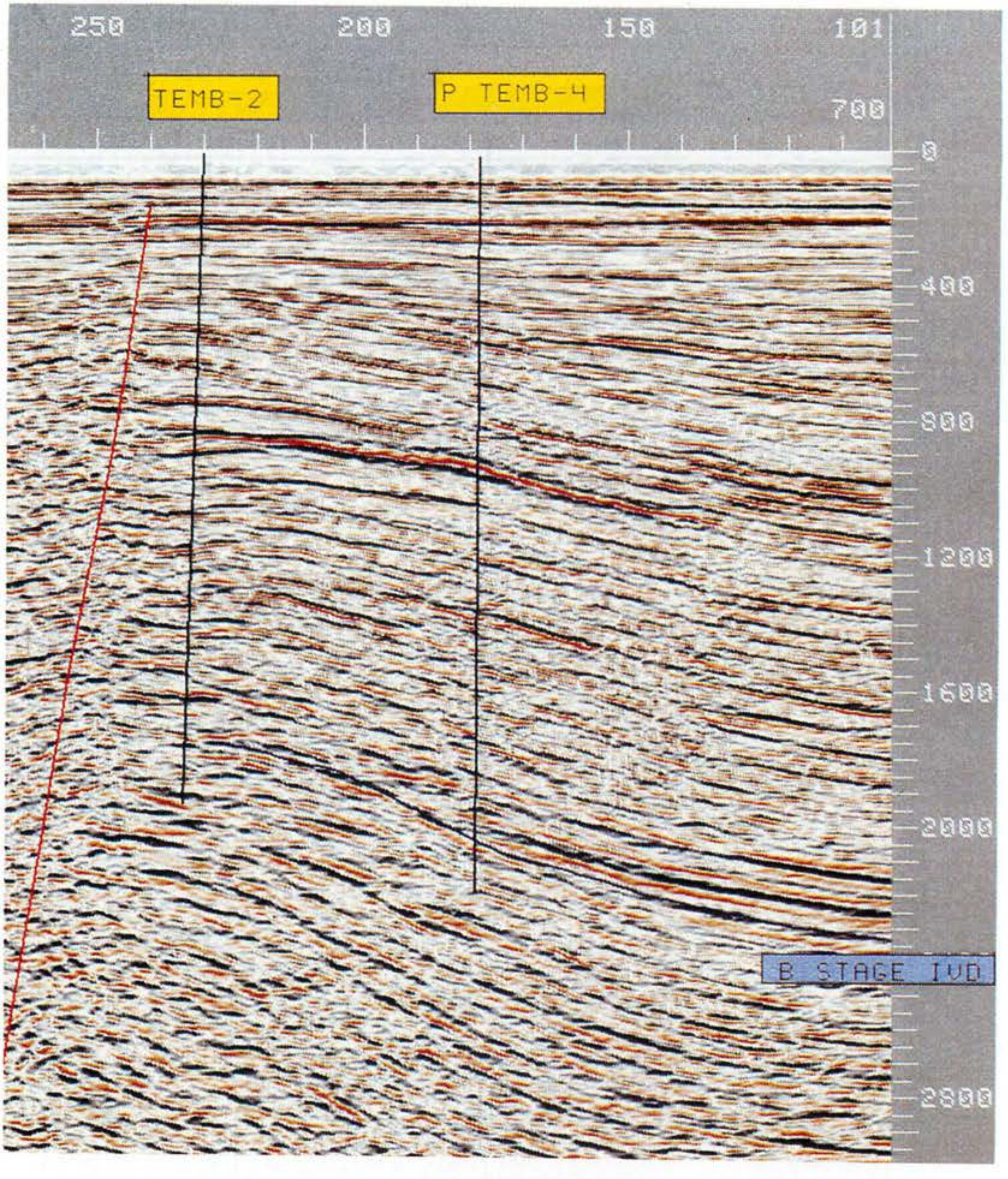

Figure 9: 3D seismic section showing the down lap reflector terminations of Stage IVD Sequence onto SRU in the Tembungo field.

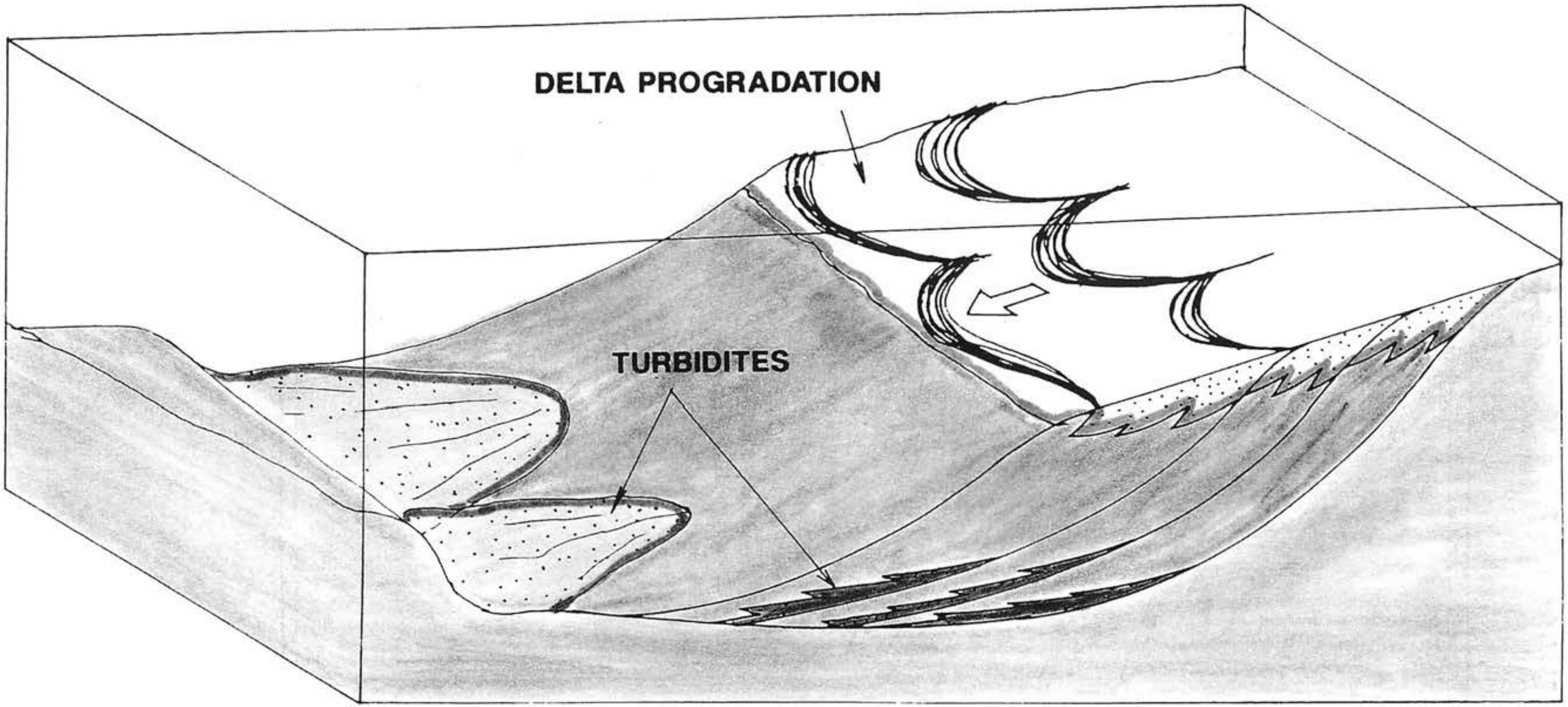

Figure 10: Depositional model of the Tembungo turbidite.

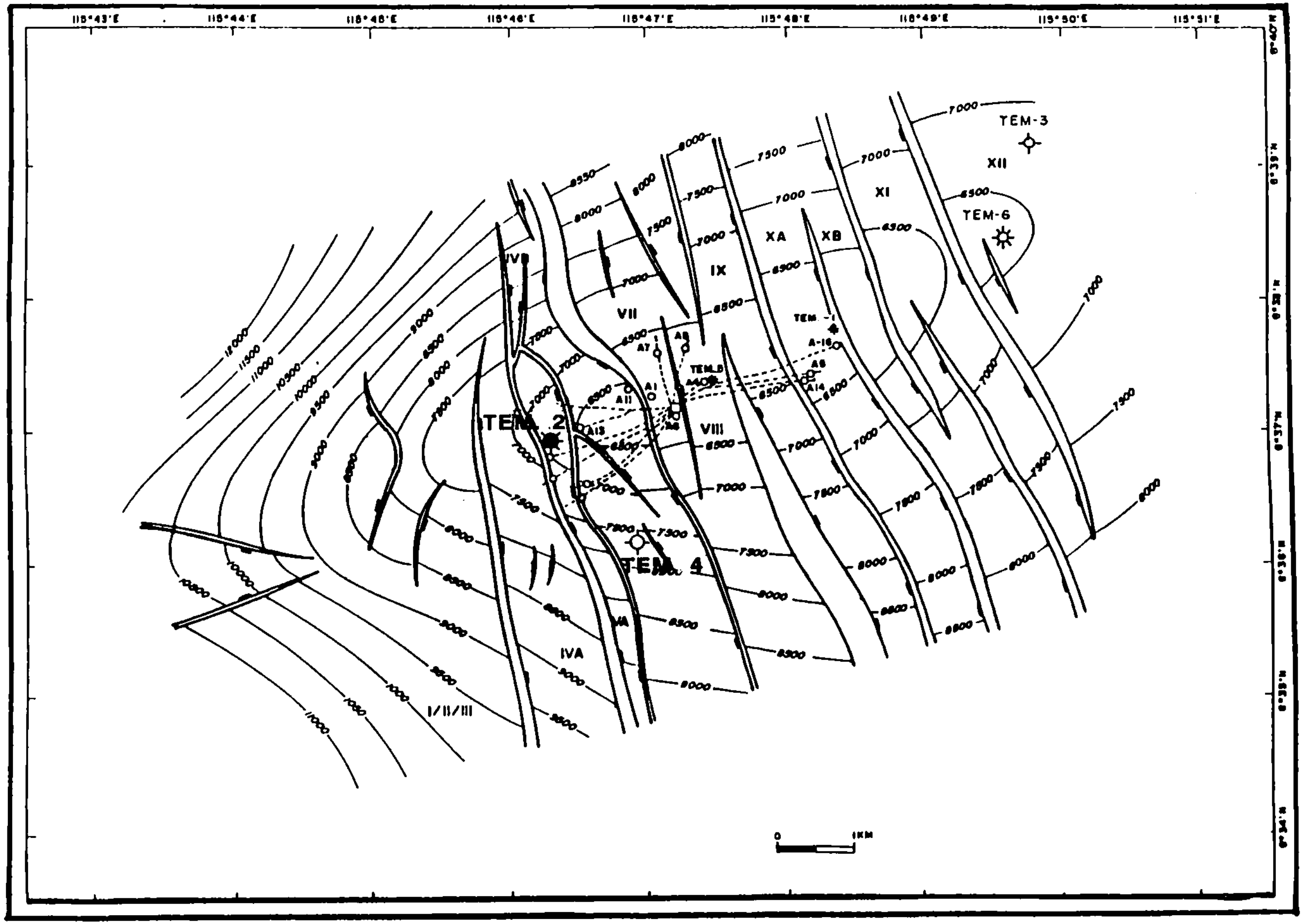

Figure 11: Well location of the Tembungo 2 and 4 in the Tembungo field.

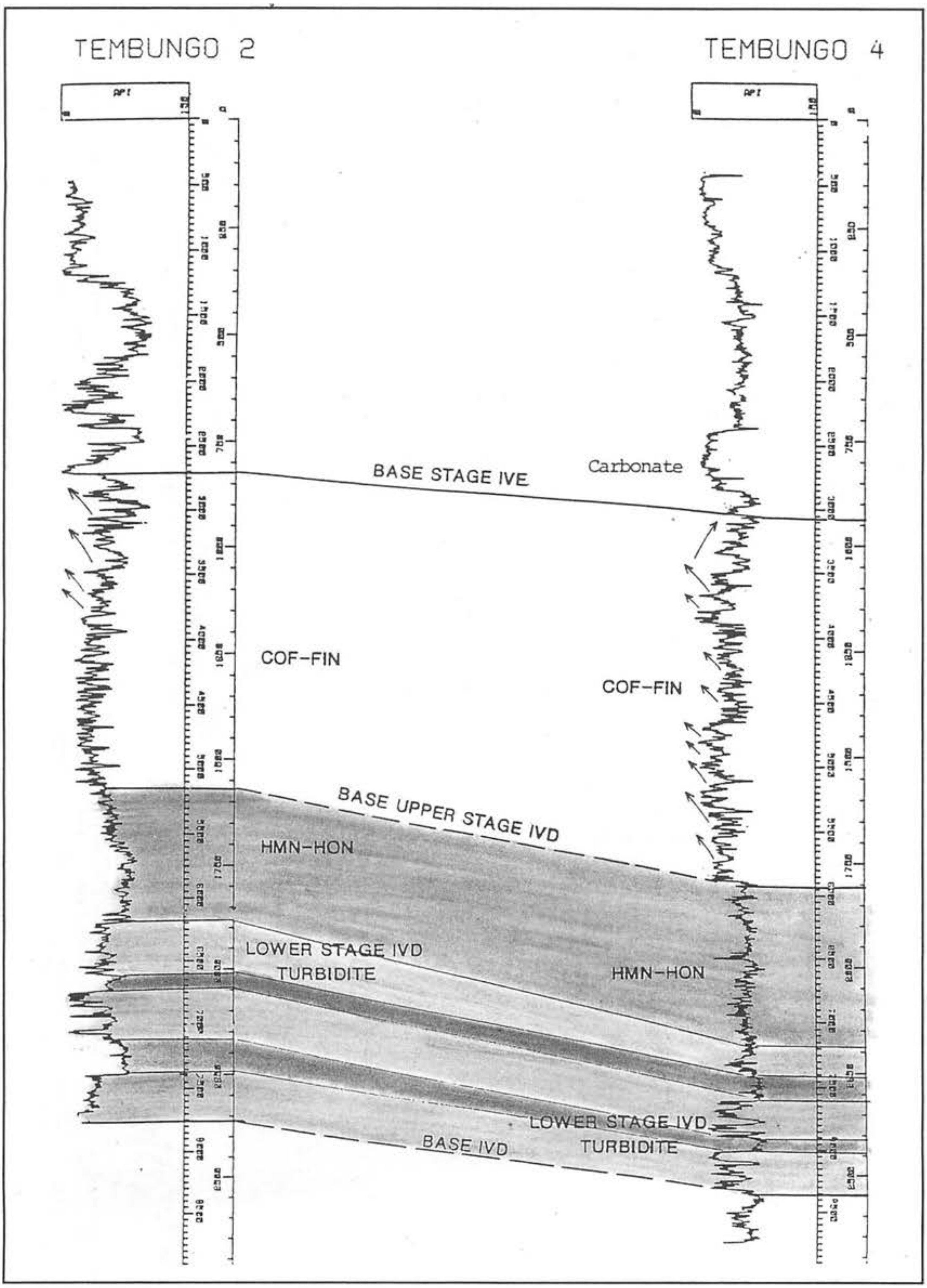

Figure 12: Lithostratigraphic correlation of Tembungo 2 and 4.

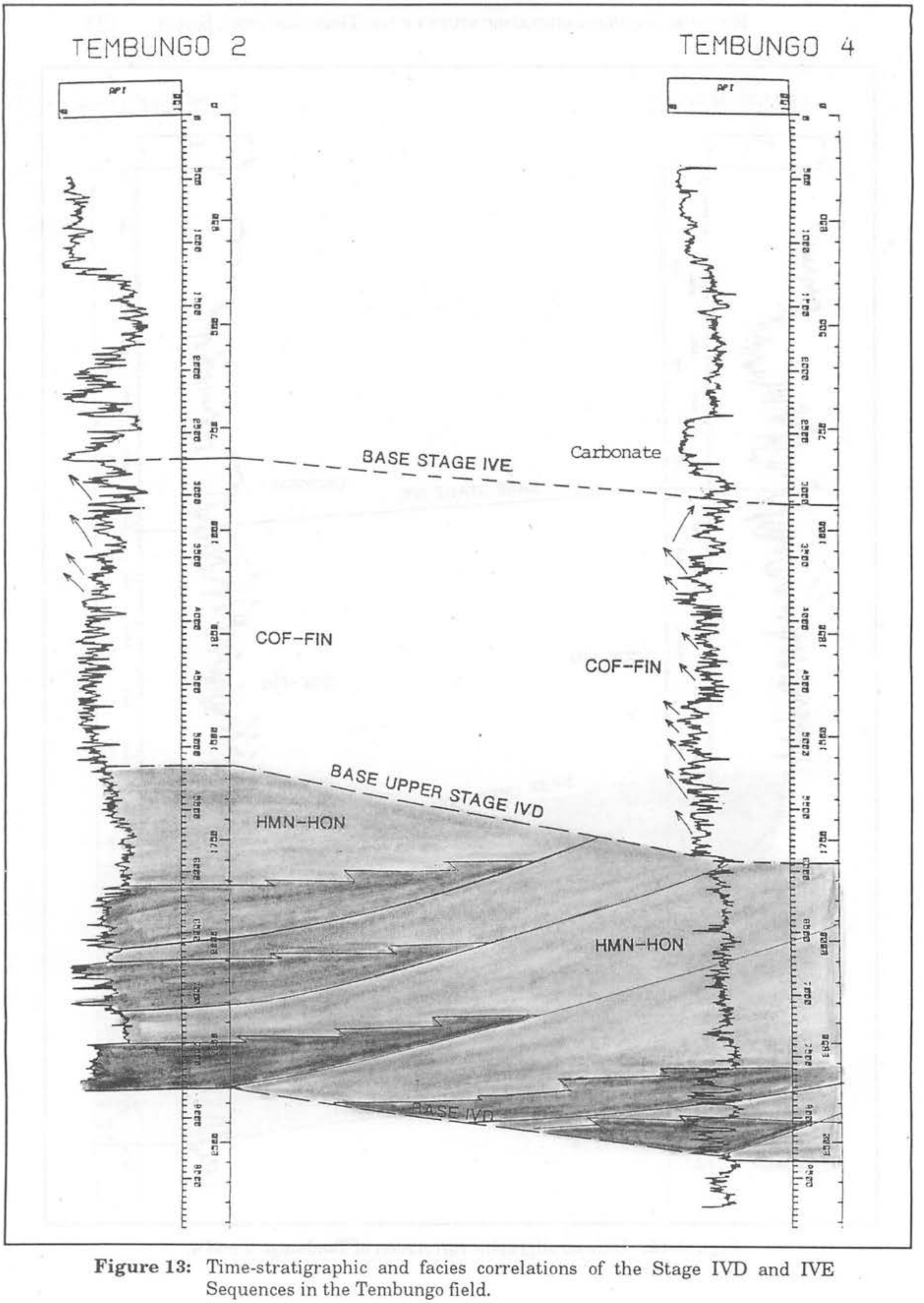

Figure 13: Time-stratigraphic and facies correlations of the Stage IVD and IVE Sequences in the Tembungo field.

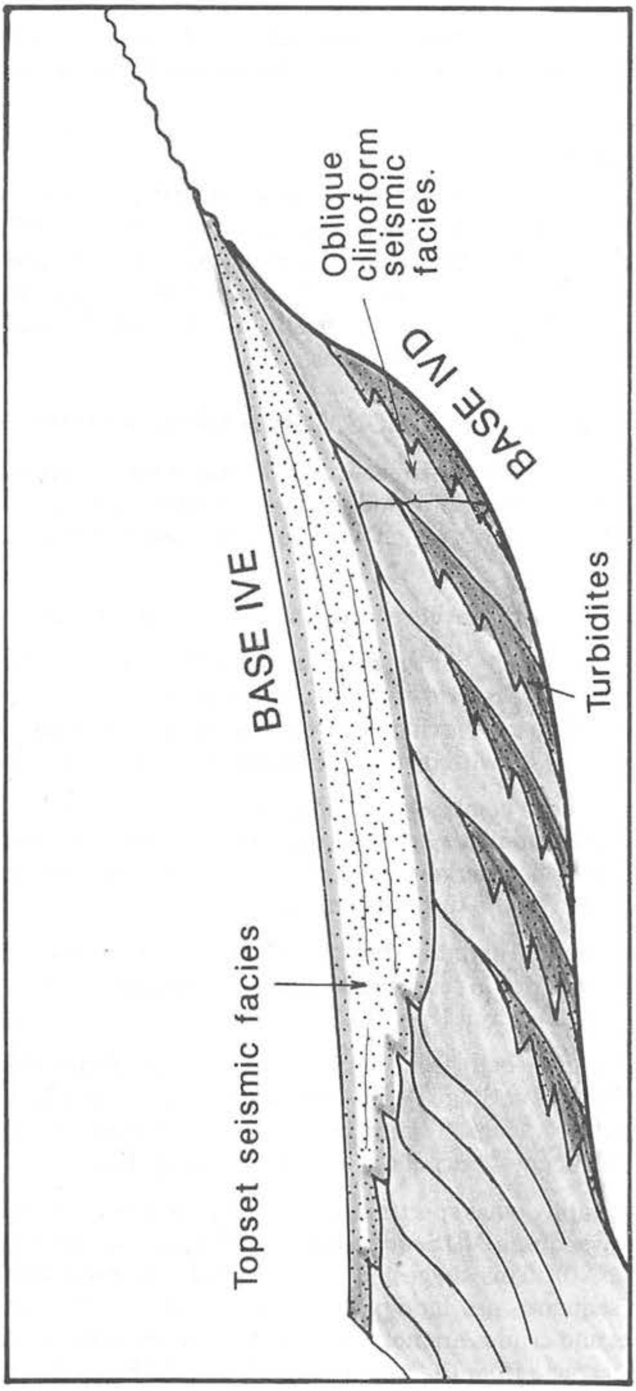

Figure 14: Deposition of Stage IVD Sequence.

Stage IVD package comprises a coarsening upward sequence which inturn similarly suggest a progradational deposition.

Biostratigraphic studies indicated that this unit was deposited in a shallow environment (COL-HIN). This occurred after the basin was filled by the lower Stage IVD sequence.

Post Stage IVD Sequences

The Stage IVE represents a shallow marine basin infills deposit between the two highs, Tembungo and Bunbury. The shelf-edge during this depositional period prograded further northward, beyond the Tembungo structure. Stage IVE carbonates unit was penetrated by most of the wells in the Tembungo fields, suggesting that the Tembungo area was a high, away from clastic influx, and favourable for carbonate deposition during the Stage IVE times.

GEOCHEMISTRY AND HYDROCARBON GENERATION

Geochemical studies conducted on the source rocks and crudes from the Sabah and Sarawak basins by several workers including Awang Sapawi (1990), suggested that most of the hydrocarbons in this region were derived mainly from land-plant source rocks.

No major contribution from marine source has so far been reported.

These studies also concluded that the most prolific area for the development of land-plant source materials is restricted to proximal depositional areas such as Lower Coastal Plain and Coastal Fluviomarine environments. The source rock quality and quantity deteriorate with distance from paleo-coastline (Fig. 15).

Based on this concept, the Tembungo turbidite sequence which derived from the proximal depositional sediments, can be expected to contain substantial amounts of good source and reservoir properties brought down beyond the contemporaneous shelf-edge by the turbidity current.

Source rock data from the Tembungo field, i.e. from A-6 well, showed that the Lower Stage IVD Sequence is rich in source rock. The Total Organic Carbon in this interval ranges from 1.0 to 5 percent (Fig. 16).

Maturity profile studies, both from Vitrinite Reflectance Equivalent and Lopatin indicated that the Lower Stage IVD Reservoir Sequence on the Tembungo structure is in early maturity (Figs. 17 and 18). This sequence attained the oil generation window in the deepest part of the Tembungo basin (Fig. 19).

The gas chromatography mass spectrometry (GCMS) results for both crudes and extracts from the Lower Stage IVD Sequence showed the presence of tetracyclic, resin and oleonane (Fig. 20). This suggested that the crudes and extracts of the Tembungo producing sequence are land-plant origin. Although the available GCMS data on extracts and crudes are not identical, they seem to be of a similar origin. Furthermore, extracts from the underlying Stage IVC Sequence showed that this stage is of marine sediments (Fig. 21).

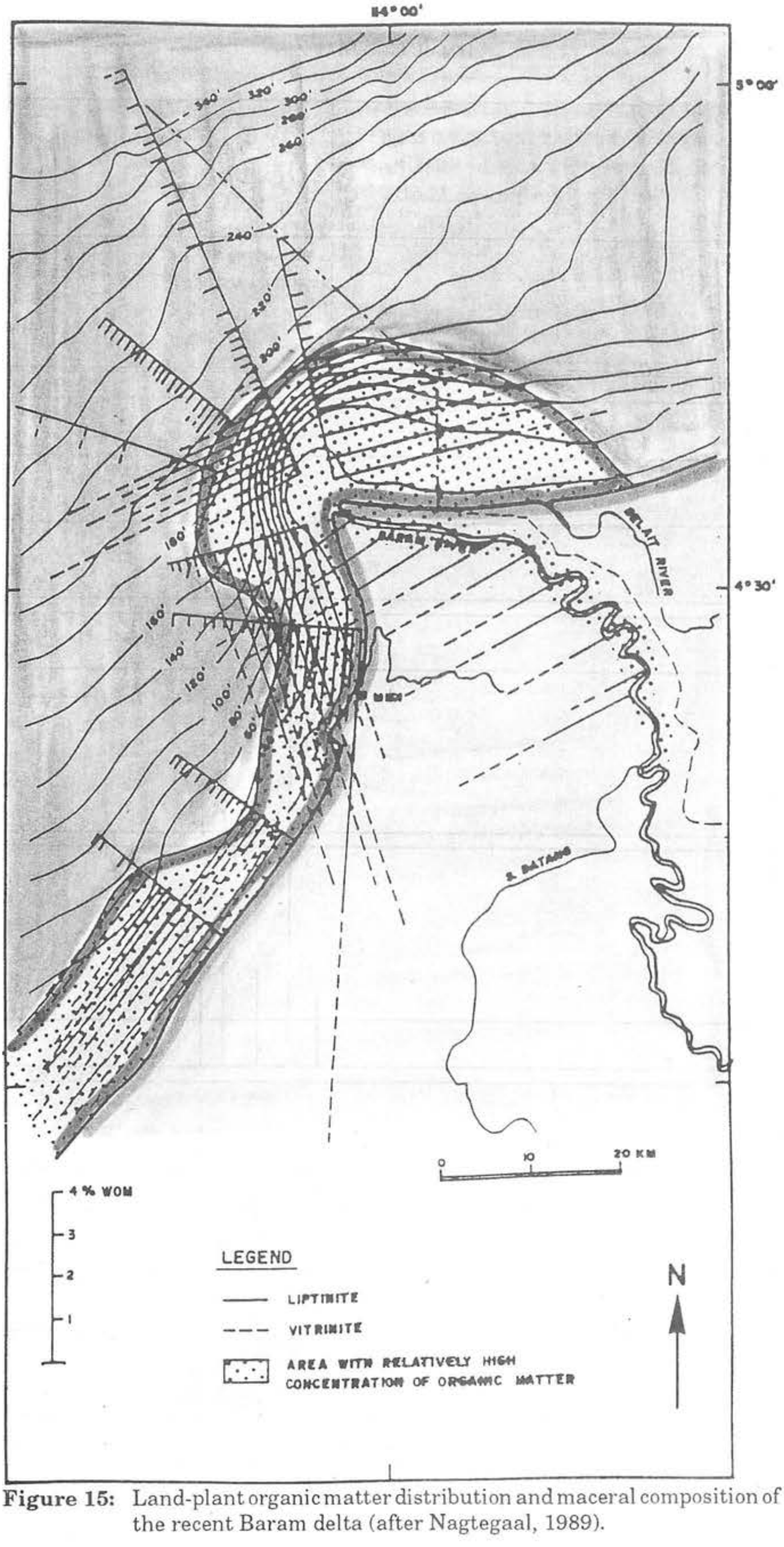

Figure 15: Land-plant organic matter distribution and maceral composition of the recent Baram delta (after Nagtegaal, 1989).

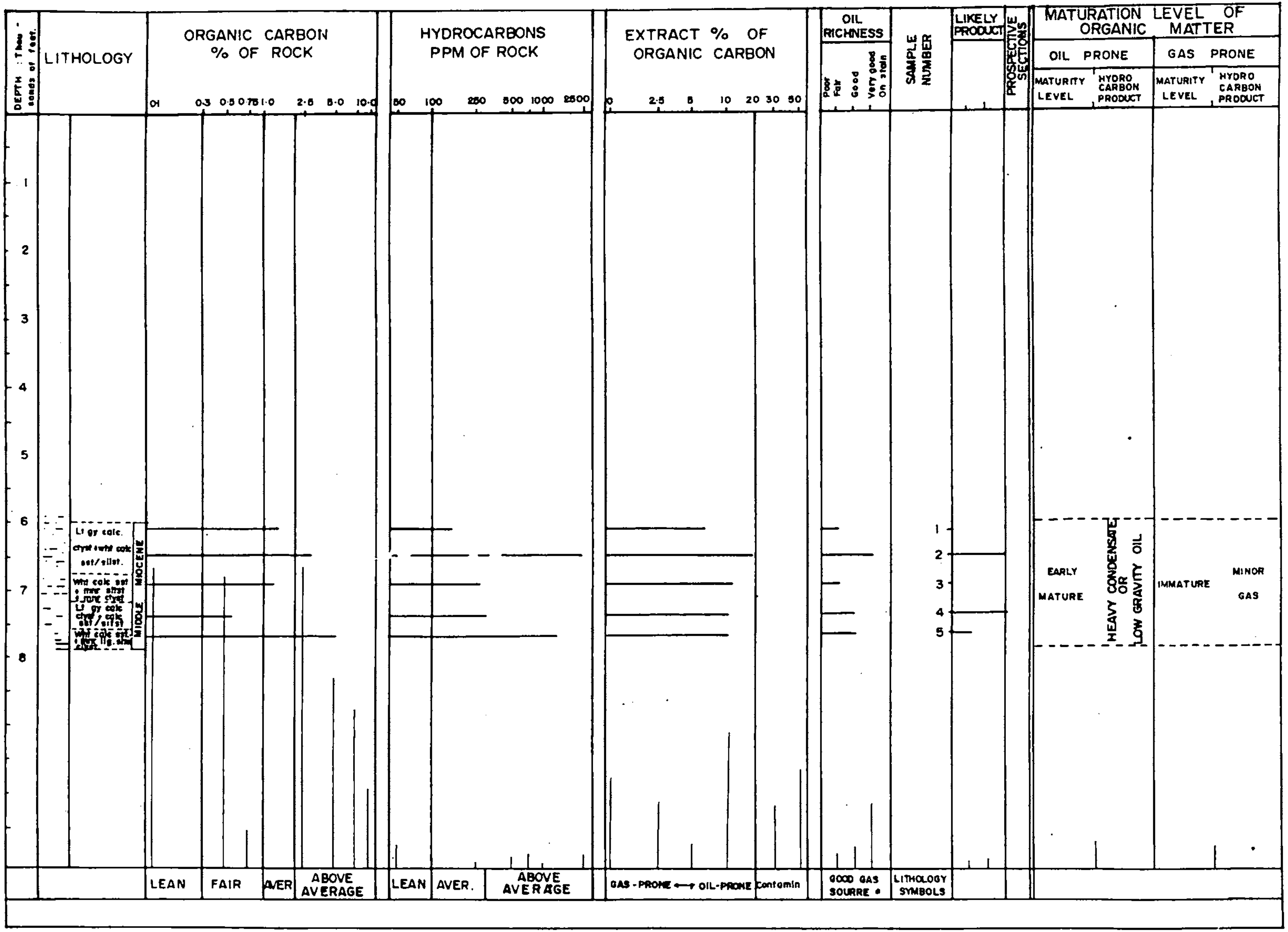

Figure 16: Source rock data of Tembungo A–6.

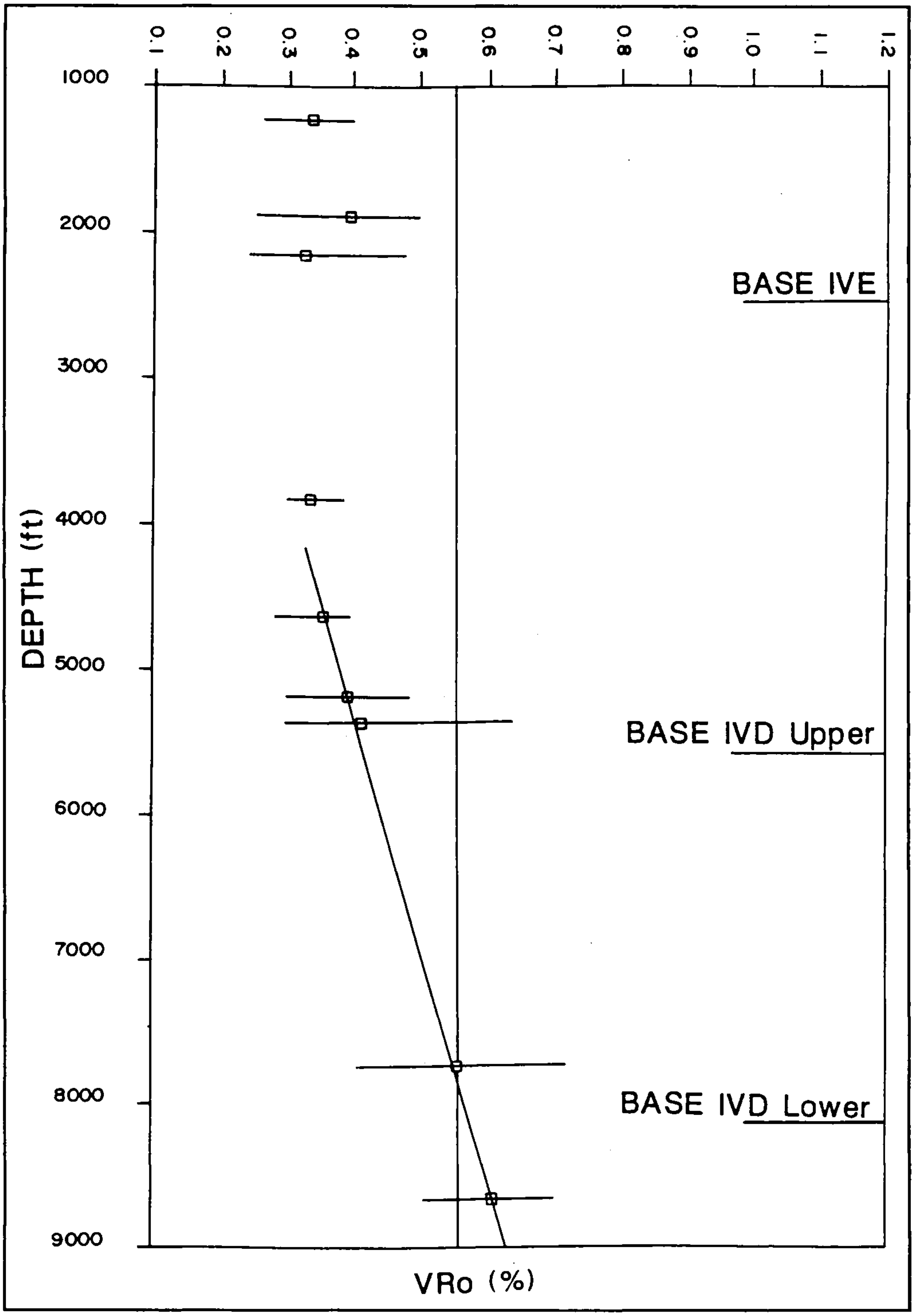

Figure 17: Depth vs VRo of Tembungo–4.

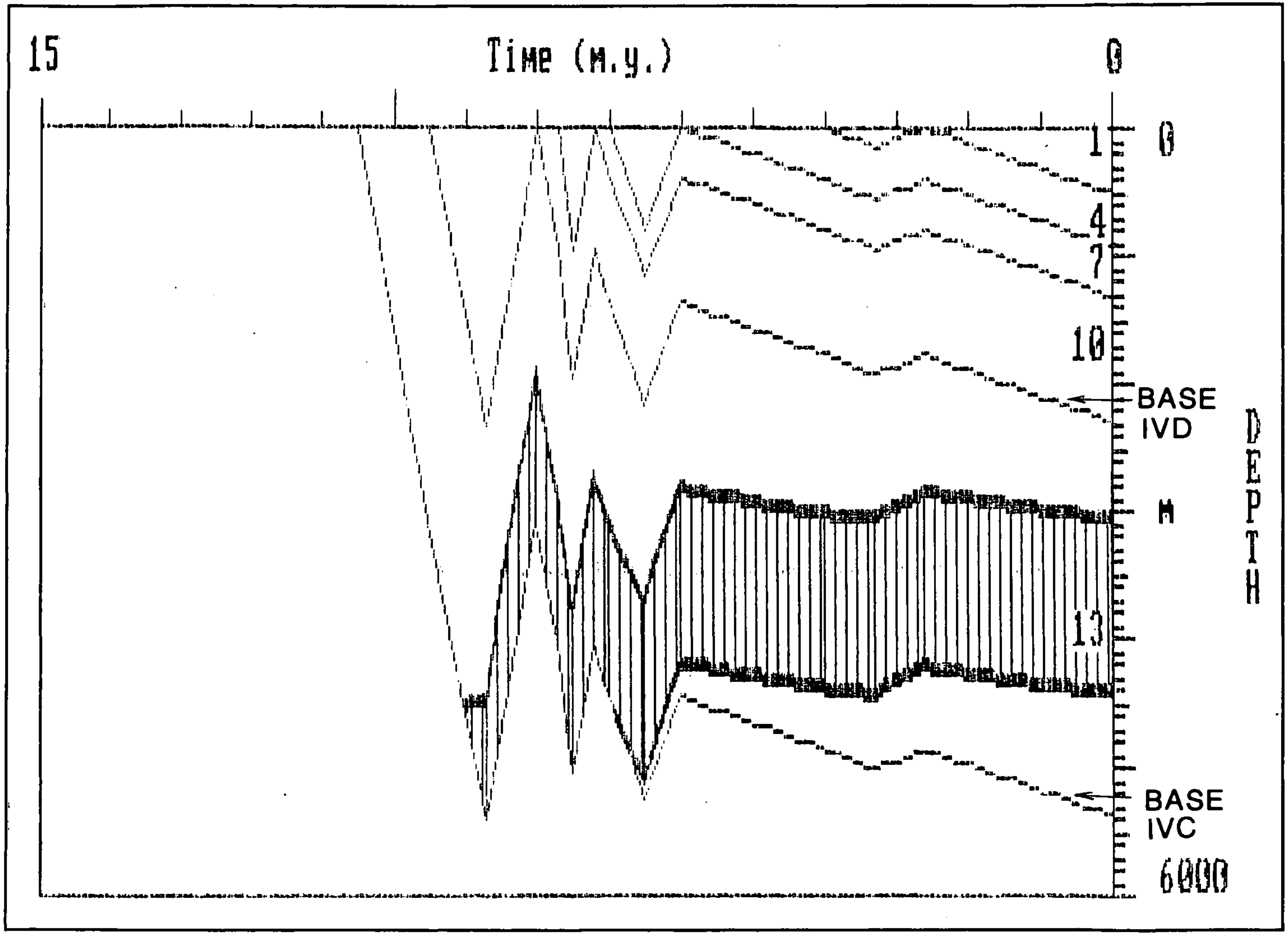

Figure 18: Maturity modelling at the Tembungo–2 location.

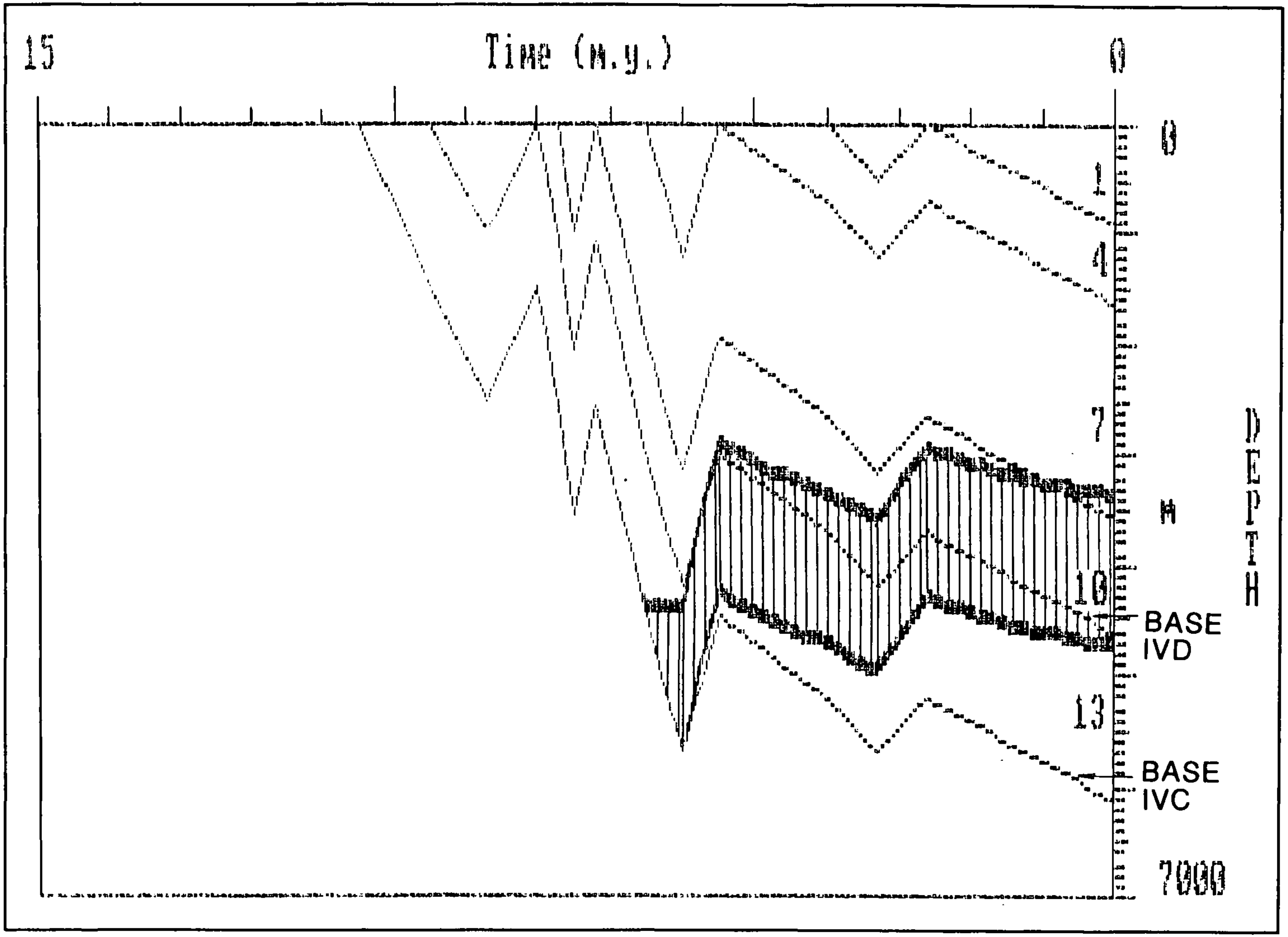

Figure 19: Maturity modelling at the northern flank of the Tembungo structure.

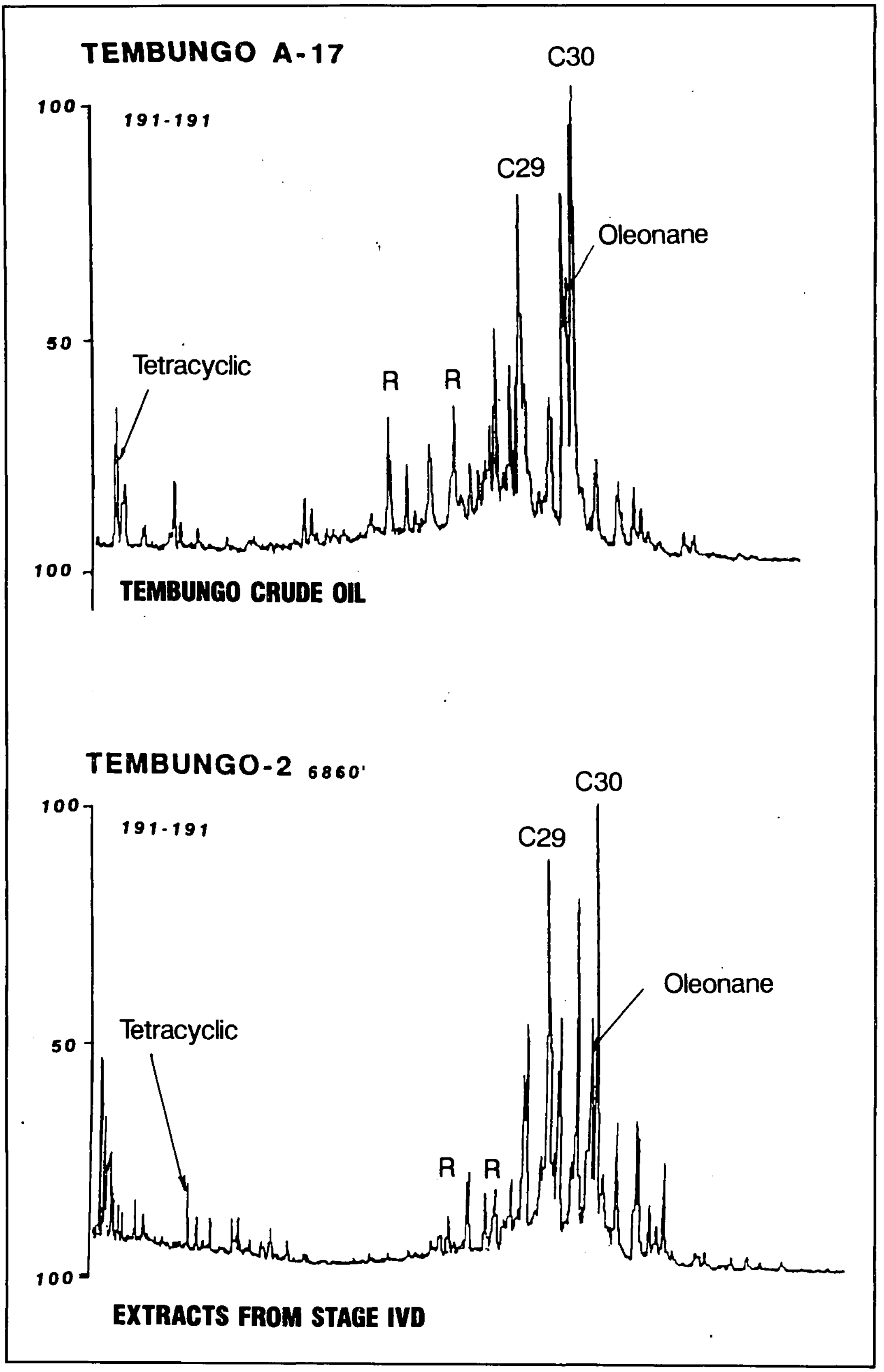

Figure 20: GCMS chromatographs of Tembungo crude and extracts from Stage IVD Sequence.

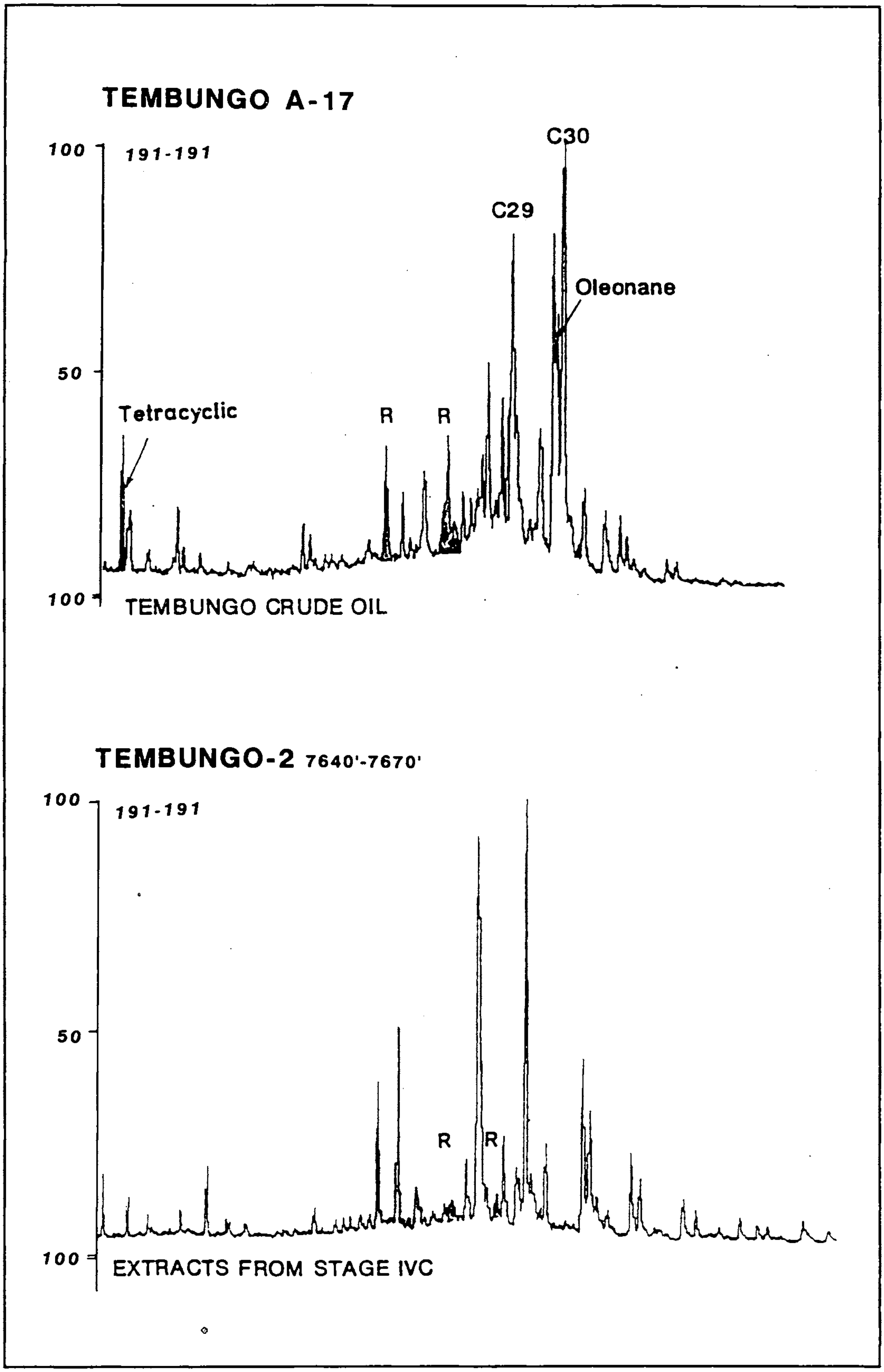

Figure 21: GCMS chromatographs of Tembungo crude and extracts from Stage IVC Sequence.

Therefore, it is strongly believed that the oil in the Tembungo field were derived from the intraformational source of the same sequence in the Tembungo down-flank area.

CONCLUSIONS

Seismo-stratigraphic techniques were successfully applied, in delineating the sequence boundaries of SSPC stratigraphic scheme to the Tembungo and the adjacent areas, and in establishing the depositional model for the Miocene Turbidite sequence in the Tembungo field.

The Tembungo oil producing turbidite sequence is characterized by an oblique clinoform seismic reflection pattern. This suggests that the turbidites were deposited in a sedimentary bypass system tract. So far, no turbidite prospect seen in this region seems to be of a similar nature to that of the Tembungo stage IVD turbidites.

The Tembungo turbidite sequence is unique with respect to its favourable hydrocarbon habitat in that the erosional products of stage IVA–IVC lower coastal plain/coastal fluviomarine sediments transported down-slope and deposited as turbidites contained good source and reservoir properties. These turbidites were buried to depths with the oil generation window in the flank areas of the Tembungo structure.

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