Geol. Soc. Malaysia, Bulletin, 10, Dec. 1978; pp. 1–13.

Stratigraphic framework for oil exploration in Sarawak

HO KIAM FUI
Sarawak Shell Berhad, Lutong, Sarawak.

Abstract: The Upper Eocene to Pleistocene sedimentary sequence in Sarawak has been subdivided into eight sedimentary cycles separated by rapid and widespread transgressions. Although cycles are recognised on the basis of depositional environments, it is necessary that they are dated and correlated by biostratigraphic methods for consistent identification.

The recognition of these sedimentary cycles has provided a stratigraphic framework for regional correlation and facies mapping and thus has contributed to the geological evaluation of the Sarawak basin.

INTRODUCTION

The stratigraphic nomenclature of Sarawak (Fig. 1) is complicated. It evolved from a proliferation of local names created during the early stages of geological exploration. Many of the Tertiary "formations" in the absence of distinctive lithological characteristics were defined by palaeontological means. As a result, lithostrati-

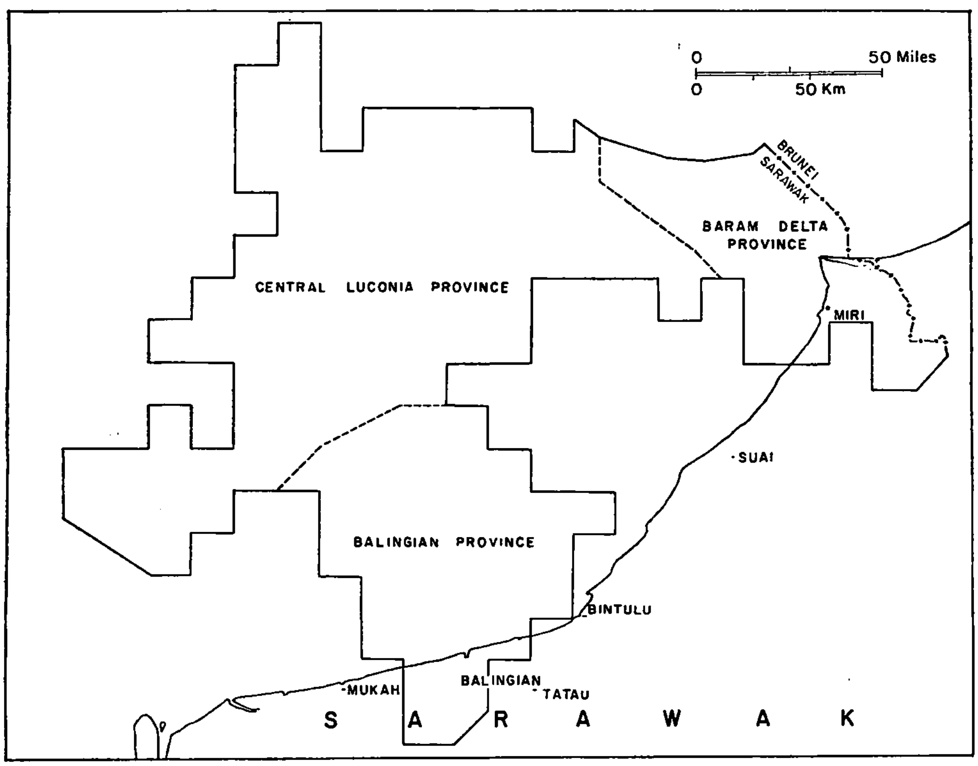

Fig. 1. Situation Map

graphic units were confused with biostratigraphic units. Although Liechti *et al* (1960) in their detailed geological compilation managed to simplify the regional stratigraphy considerably and had properly defined the Palaeogene and older units, the subdivision of the Neogene left much to be desired.

When Shell's exploration activities were extended to offshore Sarawak in the 1950's, drilling proved huge thicknesses of post-Eocene sediments, the younger section of which had not been encountered on land. With the exception of the Central Luconia carbonates, the entire sequence consisted of a rather uniform succession of sand, silt and clay. Therefore, it was not possible to set up a regionally valid formational nomenclature. Strict adherence to lithostratigraphic terminology would only have further confused the existing terminology used for the onshore areas. In view of this, the cyclic development of the sedimentary sequence was used as a stratigraphic subdivision in place of lithostratigraphic nomenclature.

Within the post orogenic (Upper Eocene and younger) sedimentary sequence, eight major sedimentary cycles could be distinguished on the basis of the rapid and widespread transgressions which interrupted the overall regressive sequence.

To establish a practical framework of sedimentary cycles, the pre-requisites are a sound biostratigraphic subdivision and reliable information on depositional environments. These data are essential for the proper identification of the different cycles.

TIME-STRATIGRAPHIC SUBDIVISION

In the Sarawak sedimentary basin where huge thicknesses of Tertiary sediments were deposited, detailed biostratigraphic correlations depend on the ability to subdivide sediments deposited in this rather short geological period into correlatable units.

Biostratigraphic zonation based on planktonic foraminifers, larger benthonic foraminifers and sporomorphs (pollen and spores) provides the best method of measuring geological time in the Sarawak Tertiary sediments. There are, however, many limitations and the usefulness of biostratigraphic zonation is restricted by the distribution of the fossils in the different environments. A planktonic foraminiferal zonation can only be used in deep open marine sediments, while the occurrence of larger benthonic foraminifers is restricted to shallow, warm water marine environments and is generally associated with carbonate sediments. Palynology provides the means of dating shallow fluviomarine and non-marine sediments. In view of the rather uniform climatic conditions since Oligocene time, few changes occur in the overall flora and as a result only a broad palynological zonation can be established for regional correlation. It is, however, possible to subdivide some of the zones into subzones based on quantitative changes of particular sporomorphs, which are valid for local correlation.

None of these stratigraphic methods provides the means for regional correlation across the various facies boundaries. A good correlation between the different biostratigraphic zonation is therefore very important because sediments of the same age might have been deposited in different environments. The comprehensive time-stratigraphic scheme (Fig. 2) used in the Tertiary of Sarawak is a combination of planktonic foraminiferal zonation for open marine sediments, larger foraminiferal biostratigraphy (Letter Classification of van der Vlerk and Umbgrove, 1927) for the carbonates, and palynological zonation for coastal, fluviomarine and terrestrial deposits.

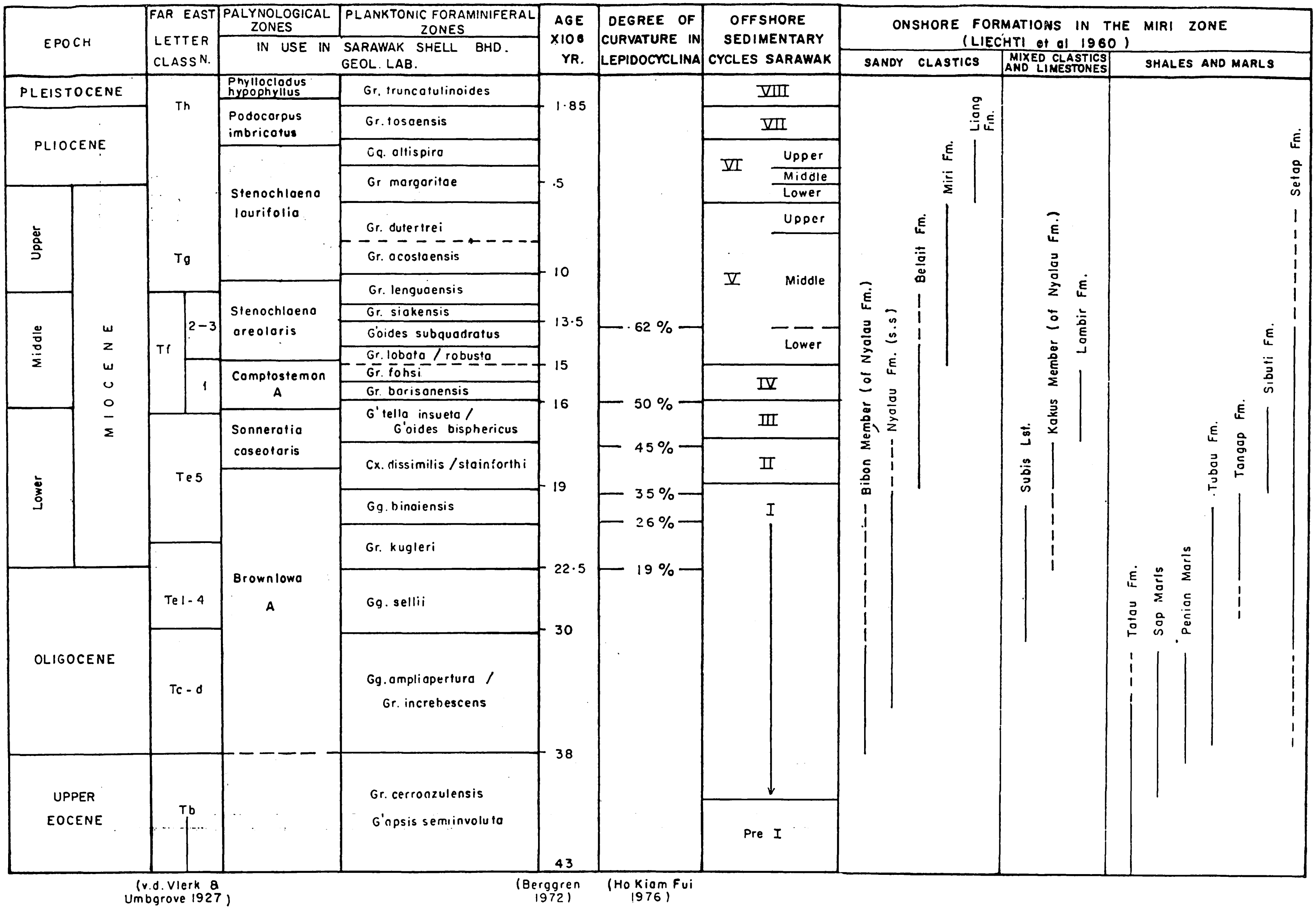

Fig. 2. Stratigraphic subdivisions and palaeontological zonation in the Tertiary of Sarawak.

ENVIRONMENTS OF DEPOSITION

Because the sedimentary sequence reflects the environments of deposition, environmental analysis has become an important tool in any sedimentary basin study. Detailed studies of depositional environments provide the basis for the recognition of regressive or transgressive sequences. Foraminiferal assemblages and, to a lesser degree, lithological descriptions and gamma-ray/spontaneous-potential log shapes

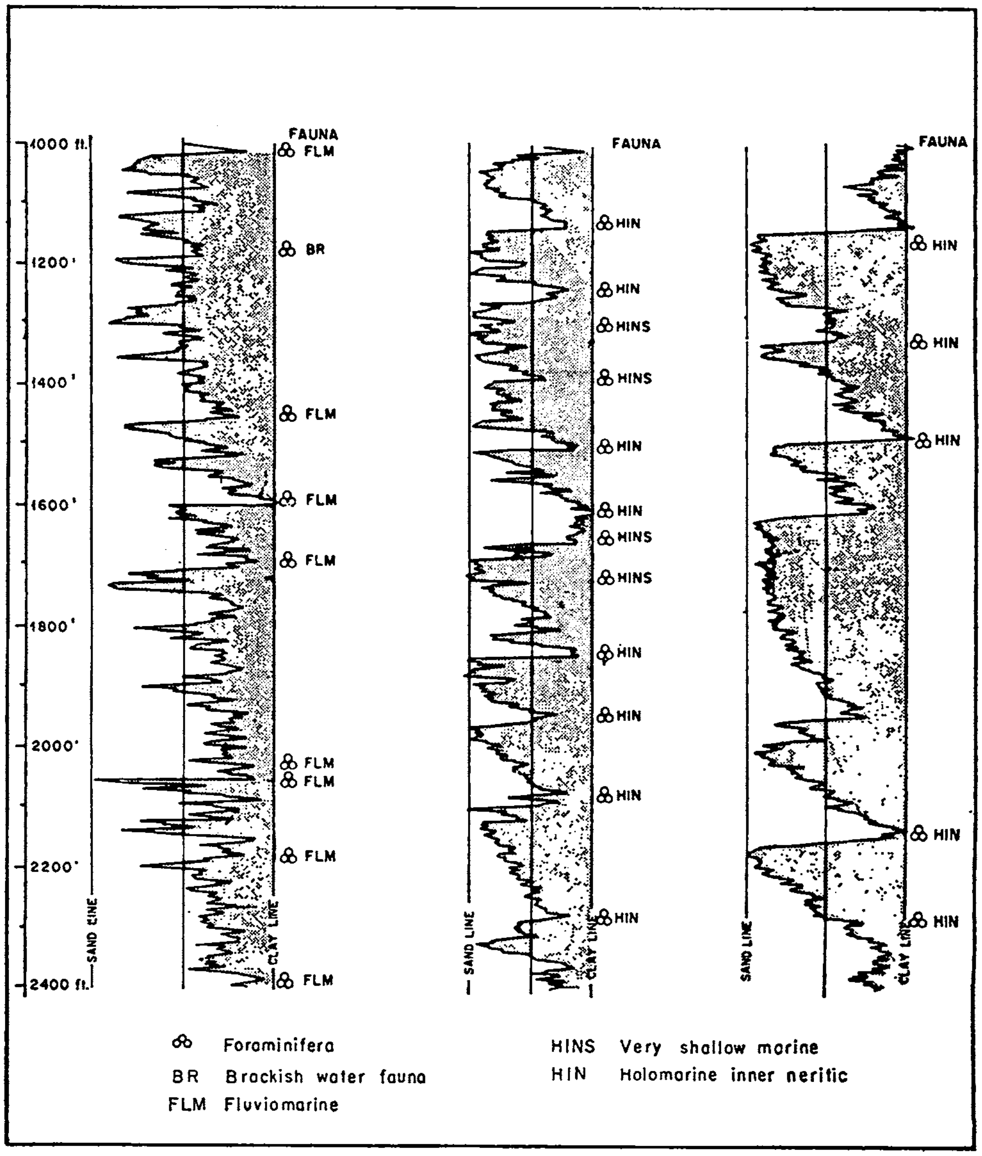

Fig. 3. Gamma-ray log shapes and patterns of coastal sediments.

and patterns (Fig. 3& 4) are used to determine ancient environments. The faunal and sedimentological criteria used have been derived from the study of recent sediments of the Sarawak Shelf. The environmental subdivision is based on the coastal and neritic sedimentation as observed today (Fig. 5).

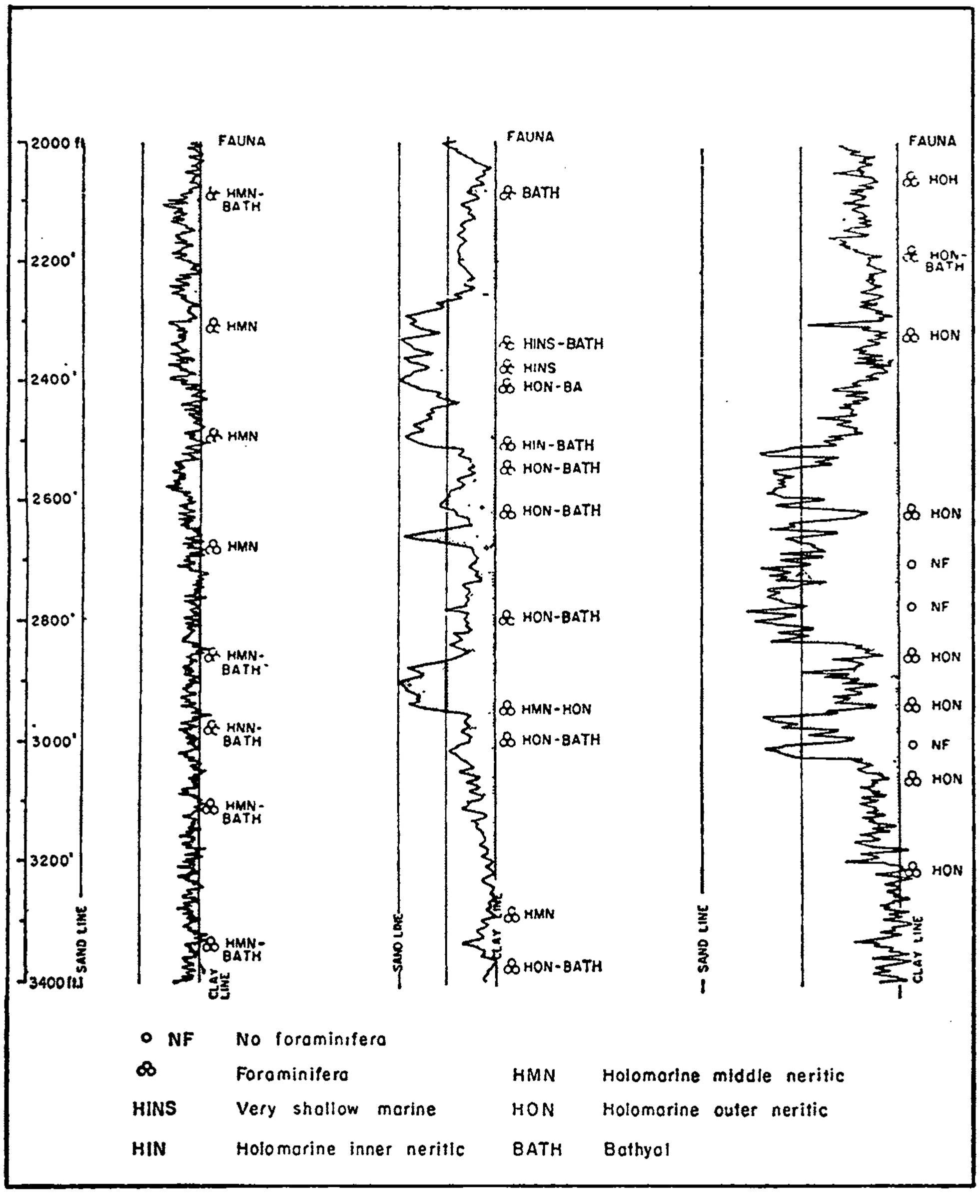

Fig. 4. Gamma-ray log shapes and patterns of neritic-bathyal sediments.

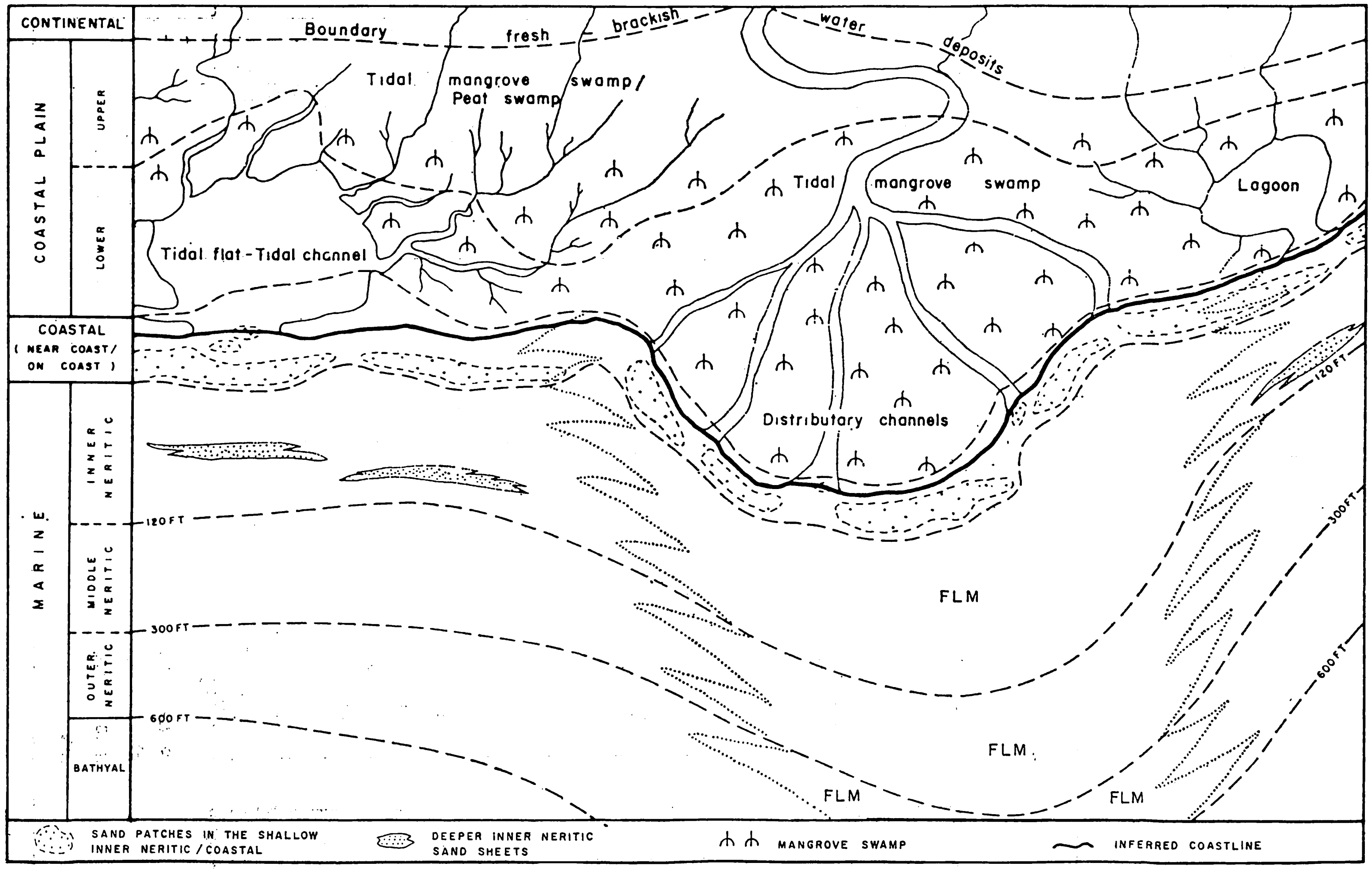

Fig. 5. Schematic outline of Sarawak environmental units.

SEDIMENTARY CYCLES

Eight sedimentary cycles have been recognised and described from the Upper Eocene and younger sequence. Each cycle starts with a transgressive base followed by a regressive sequence which in turn is overlain by the basal transgression of the next cycle. Most of these transgressions have spread over a wide area within a very short time and therefore cycle boundaries closely follow time lines. The cycles thus defined are therefore approximate time units independent of local faunal/floral and lithological developments. They enable correlations across facies boundaries which neither biostratigraphy nor lithostratigraphy alone could provide. Similar sedimentary cycles have been described by Woolands and Haw (1976) from the Gulf of Thailand basin.

Definition

The base of a cycle is taken for practical reasons at the base of the most transgressive interval. An ideal cycle (Fig. 6) displays a gradual transition from marine clay and silt at the base into coastal sand and clay sequences. Thus in principle, cycles and their boundaries are recognised on a sequential environmental subdivision, but in order to check the time validity of the individual cycle boundaries, it is necessary to obtain some palaeontological/palynological age dating at various points in the cyclic sequence.

Examples of sedimentary cycles

Fig. 7 shows the complete stratigraphic cross-section from the Balingian Province through Central Luconia Province to the recent shelf edge. The sedimentary cycles encountered in this area clearly illustrate the general trend of a northward regression. In the south, Cycle I sediments deposited in deep marine environments overlie Eocene sediments of the Belaga Formation of the Rajang Group (Leichti *et al*, 1960). The younger section of Cycle I and Cycle II illustrates the problem of recognising sedimentary cycle boundaries in thick coastal sequences interrupted by only very short-lived transgressive pulses.

The deep marine sediments of Cycle I and II penetrated in Engkabang-1 in the Baram Province (Fig. 8), strongly contrast with the coastal sequence of the same cycles in the south of the Balingian Province (Fig. 7). The problem here is one of continuous sedimentation under deep marine conditions where deepening and shallowing of environments cannot be detected and thus no accurate cycle boundaries can be recognised. But the excellent planktonic foraminiferal zonation established in these sequences allows correlation with the sedimentary cycles in other parts of Sarawak.

In the deltaic environments, as present from Cycle III onwards in the Baram Delta Province (Fig. 8), a lateral migration of the river mouth may result in a local change of environment from fluviomarine to holomarine which may be mistaken for the basal transgression of a cycle. Therefore, utmost care is necessary to ensure that cycle boundaries are picked only where distinct transgressions occur.

In spite of the problems quoted above, the extension of the cycle concept into areas of continuous coastal fluviomarine or deep marine deposition is possible by means of age determinations.

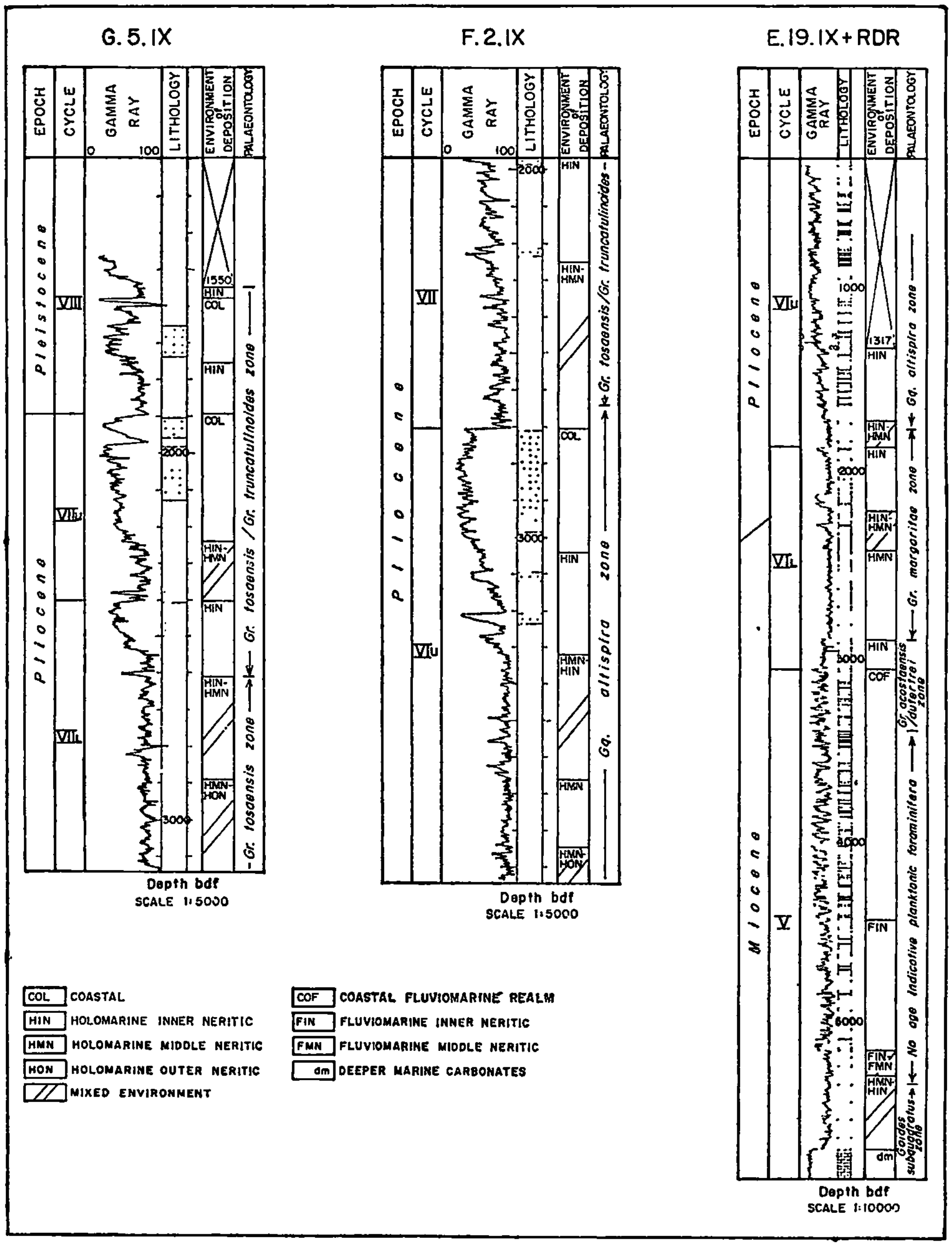

Fig. 6. Lithological and gamma ray logs of some Luconia wells illustrating cyclic deposition in the clastic sequence of cycles V–VIII.

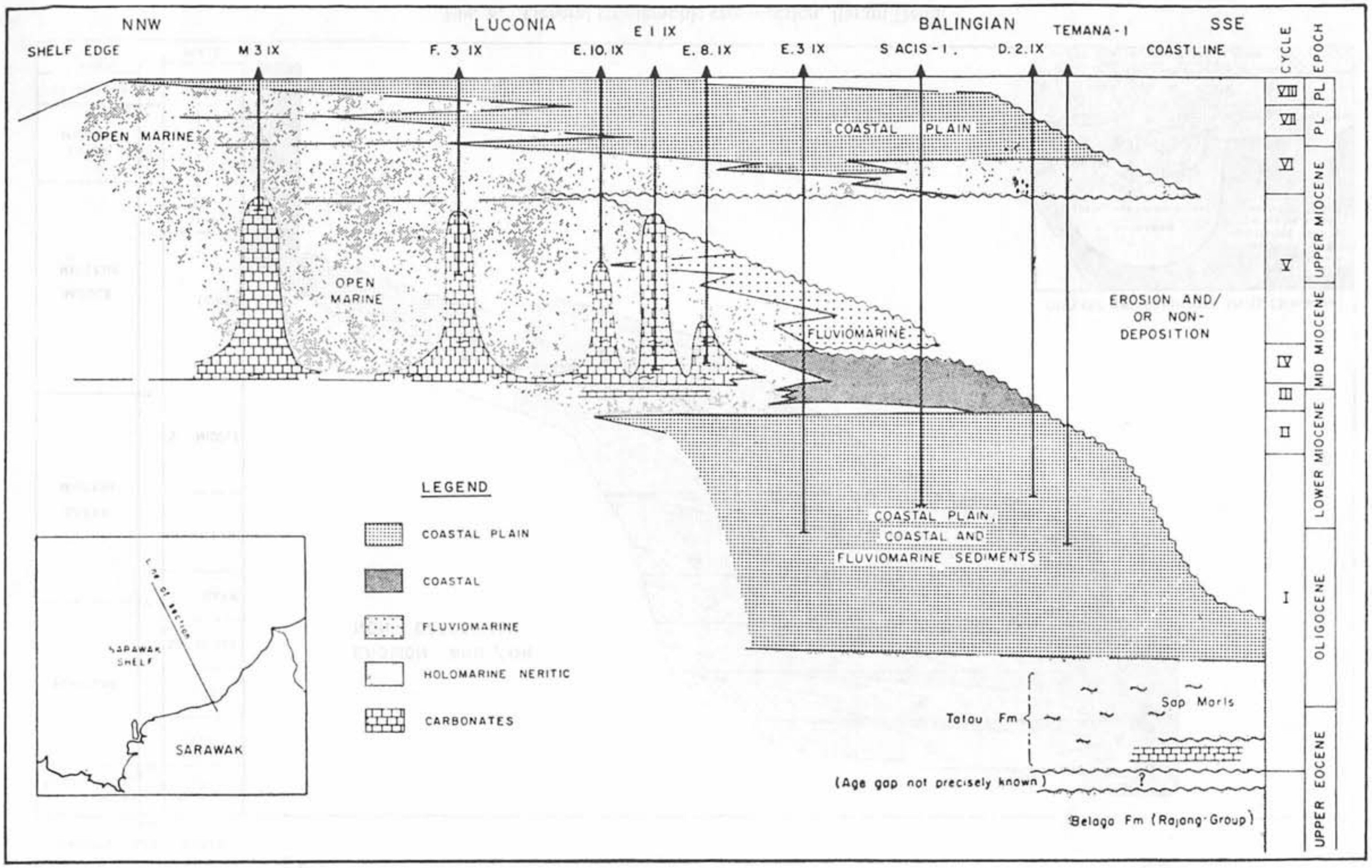

Fig. 7. Stratigraphical section across the Central Sarawak Shelf.

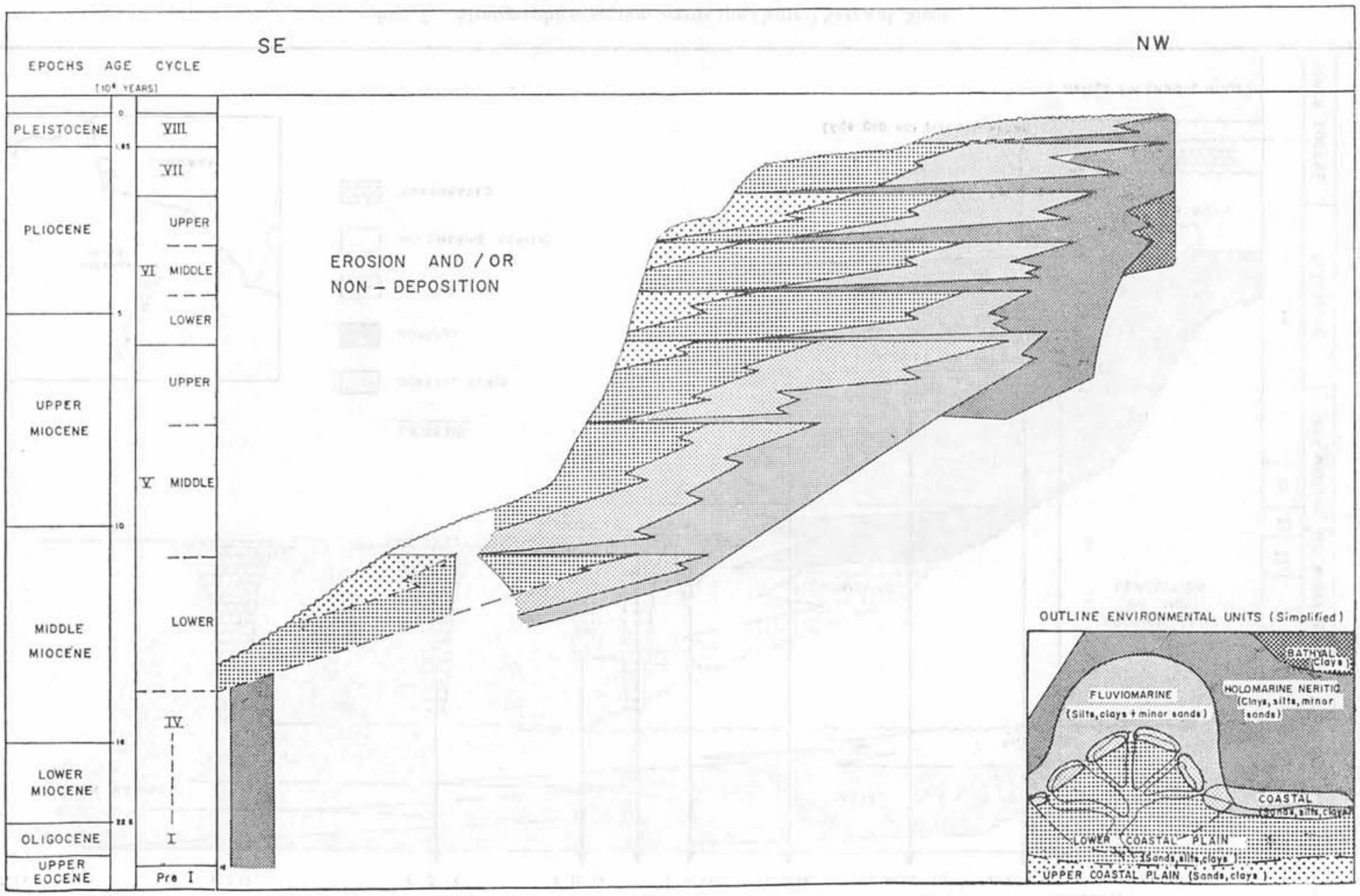

Fig. 8. General stratigraphic cross-section, Baram Delta.

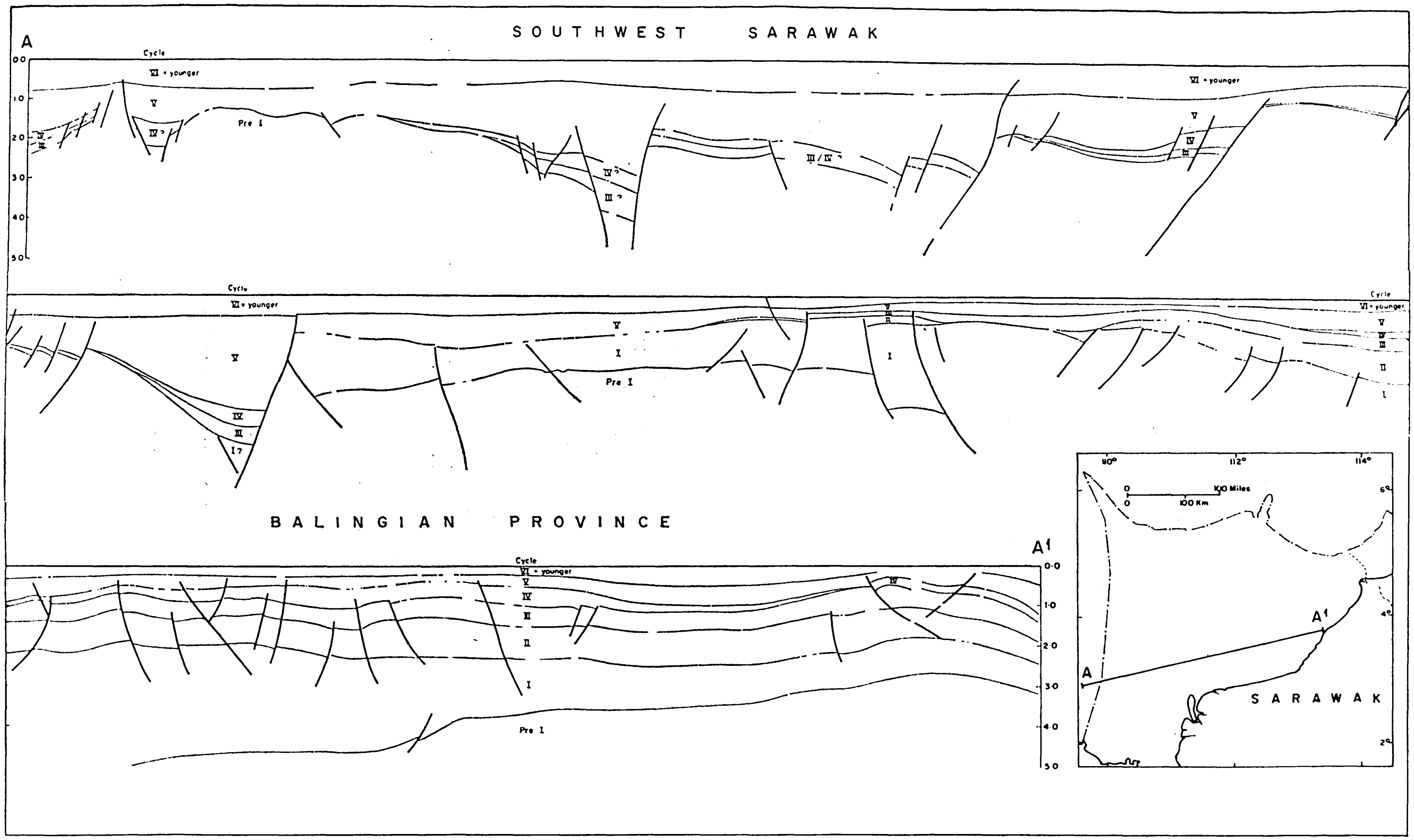

Fig. 9. Seismic section: southwest Sarawak—Bailngian.

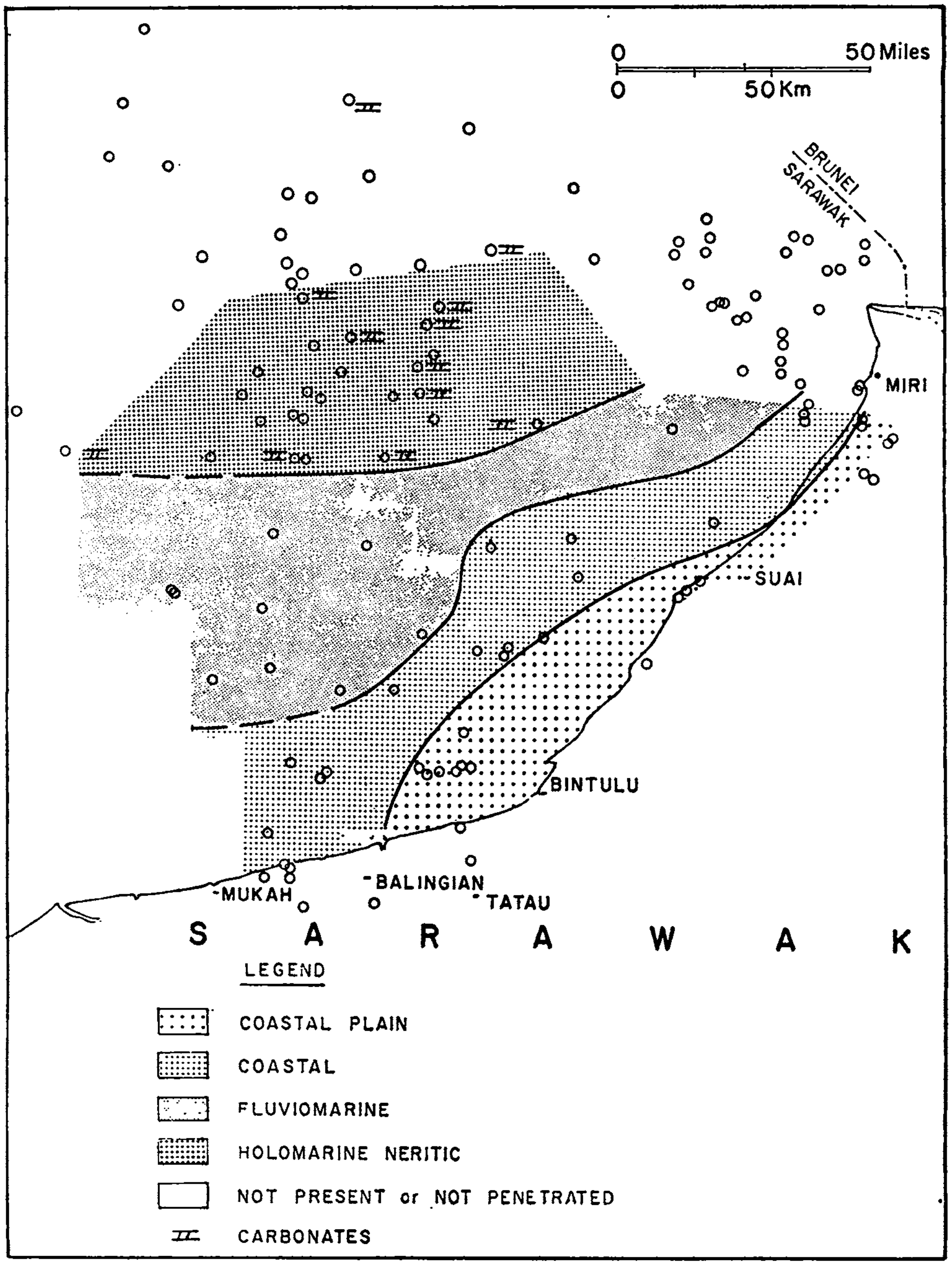

Fig. 10. Facies in upper Cycle III.

On the other hand, age control in the carbonate sequence of the Central Luconia Province (Fig. 1 & 7) is very scanty. Sporomorphs and planktonic foraminifera are virtually absent. The ranges of larger foraminifera do not permit a detailed biostratigraphic zonation and the established subdivision (van der Vlerk, 1927) exceeds by far the duration of the cycles recognised in the siliciclastics. At present, the bases of argillaceous carbonate intervals with a deeper open marine fauna are taken as cyclic transgressions which are tentatively correlated with the cycle boundaries in the surrounding siliciclastics.

Regional mapping

Since cycle boundaries are defined by the contact between the most transgressive and the most regressive sediments, they are generally marked by a change in lithology, e.g. marine clay overlying coastal sand. The lithological contrast frequently gives rise to seismic horizons which can be regionally mapped.

The base of Cycle VI (Fig. 7 & 9), marked by a well developed transgression, provides the best example of regional mapping of a cycle boundary. It has been mapped over some 15,000 sq. miles in the western part of Sarawak and can be followed over 100 miles into the Central Luconia Province.

Palaeogeographic mapping

Because cycles are excellent correlation tools, they can also be used as approximate intervals for the construction of palaeofacies maps. These maps summarise the facies development during the time period covered by a particular cycle (Fig. 10). The maps also indicate the approximate position of the palaeo-coastline and thus assist in the prediction of the best reservoir development and the regional basin evaluation.

CONCLUDING REMARKS

The recognition of the eight sedimentary cycles in the Upper Eocene and younger sedimentary sequence in Sarawak has facilitated the geological evaluation of the Sarawak basin. The cycle concept has provided a geological model for regional correlation and a stratigraphic framework for the mapping of the palaeofacies.

ACKNOWLEDGEMENTS

The author wishes to thank Petronas and Sarawak Shell Berhad for permission to publish this article. Most of the data presented here are the work of colleagues in Sarawak Shell Berhad. The author's role is in the compilation and presentation of this article.

REFERENCES

BERGGREN, W.A., 1972. A Cenozoic time-scale–Some implications for regional geology and palaeobiogeography. *Lethaia,5*, 195–215.

HO KIAM FUI, 1976. Morphogenetic trend of Lepidocyclina and its application in time stratigraphy. *Geol. Mijnb.*, 55, 147–158.

LEICHTI, P., ROE, F.W. and HAILE, N.S., 1960. The geology of Sarawak, Brunei, and the Western part of North Borneo. *Bull. Geol. Survey Dept. Brit. Terr. in Borneo*, 3.

VLERK, I.M. VAN DER and UMBGROVE J.H.F., 1927. Tertiare gidsforaminiferen van Nederlandish Oost–Indie. *Wetensch, Dienst Mijnb. Ned-O-Ind.*, 6, 3–35.

WOOLANDS, M.A. and HAW, H., 1976. Tertiary stratigraphy and sedimentation in the Gulf of Thailand. *SEAPEX Program offshore S.E. Asia Conf.* Paper 7.