

# The Paleogene basins of Sabah, East Malaysia

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**Abstract:** The Paleogene basins of Sabah developed in two stages, represented by early and late Paleogene sediments, in association with NW-SE compressional deformation during the late Mesozoic and Middle Eocene. The earlier deformation produced a wide elongate basin trending NE-SW bordered by a continental block to the NW and an emergent oceanic basement to the SE. The basin became the depositional sites of shallow to deep water early Paleogene sediments. The later deformation divided the earlier basin into two parallel basins (Outer and Inner basins) also trending NE-SW. Both basins were independently filled by shallow to deep water late Paleogene sediments derived axially from the southwest and laterally from the northwest and southeast. These basins were finally closed during the early Miocene resulting in the Paleogene fold-thrust belt of Sabah.

## INTRODUCTION

The Paleogene basins of Sabah here refers to the depositional sites of thick Paleogene sediments forming the mountainous belt of Sabah. Unlike most of the younger basins, the configuration of the Paleogene basins were not preserved but greatly modified by compressional tectonics. The Paleogene sediments are characterised by severe folding and thrusting. In western and southwestern Sabah the sediments were mostly deposited by turbidity currents and mass flows, and a northeast depositional direction has been established (Stauffer, 1967; Tongkul, 1987). The elongate basin so-formed has been, informally referred to as the Rajang Basin or Crocker basin (Hamilton, 1979; Tongkul, 1987; Rangin, 1989; Hutchison, 1989). Detailed sedimentological, paleontological and structural informations on the sediments are still lacking in parts of western, northern, eastern and central Sabah. Therefore the overall nature and extent of the Paleogene basin is still unknown.

This paper presents additional information on the Paleogene sediments and proposes a model on the development of the Paleogene basins.

## REGIONAL GEOLOGICAL SETTING

The Paleogene sediments form part of the NW Borneo subduction complex of Haile (1973) and Hamilton (1979) accreted during the Late Tertiary. These accreted sediments are bounded by the rifted southern continental margin of China presently occupied by the Reed and Dangerous Grounds carbonate platforms in the NW and the Celebes

Sea oceanic crust in the SE (Fig. 1). The sediments covers most of western, northern and central Sabah while in eastern Sabah the sediments are not clearly mapped out due to the presence of extensive mélangé deposits (Fig. 2). The Paleogene sediments continue southward onland into Sarawak and NE Kalimantan (Hamilton, 1979; Hutchison, 1989) and northeastward offshore into Palawan (Rangin, 1989). Paleogene sediments trending NE-SW underlie much of the Neogene basins offshore northwest Sabah (Bol and Hoorn, 1980; Hinz *et al.*, 1989). The continuation eastward offshore Sabah is still uncertain but is also thought to underlie most of the Neogene sediments here.

## STRATIGRAPHY

The stratigraphy of Sabah, based on present age determinations, is at best a general one (Fig. 3). The Paleogene sediments rest unconformably on Mesozoic oceanic crusts and overlain unconformably by Neogene mélangé, pyroclastic and clastic deposits. The precise age determination of most of the Paleogene sediments is still problematic due to lack of good fossil indicators. Therefore the relationship between some formations is still uncertain and the tendency to lump them together is understandable. This, however, is not helpful in understanding the depositional history of the sediments, because it is clear that the sediments were not deposited together as indicated by common facies variations within the sediments.

Based on age differences, the Paleogene sediments can be broadly grouped into early and late Paleogene deposits. The early Paleogene

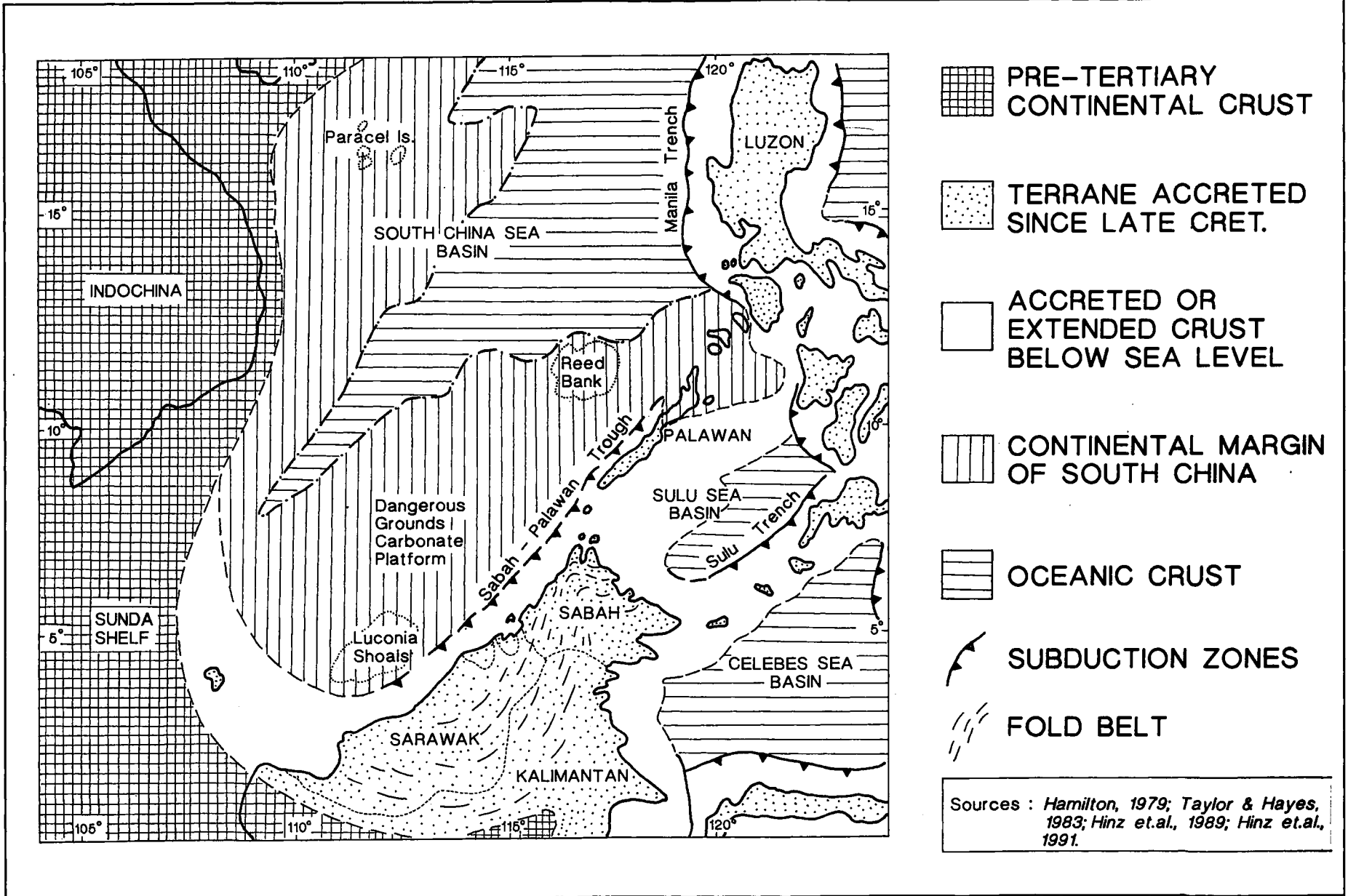


Figure 1. Regional geological setting of Sabah.



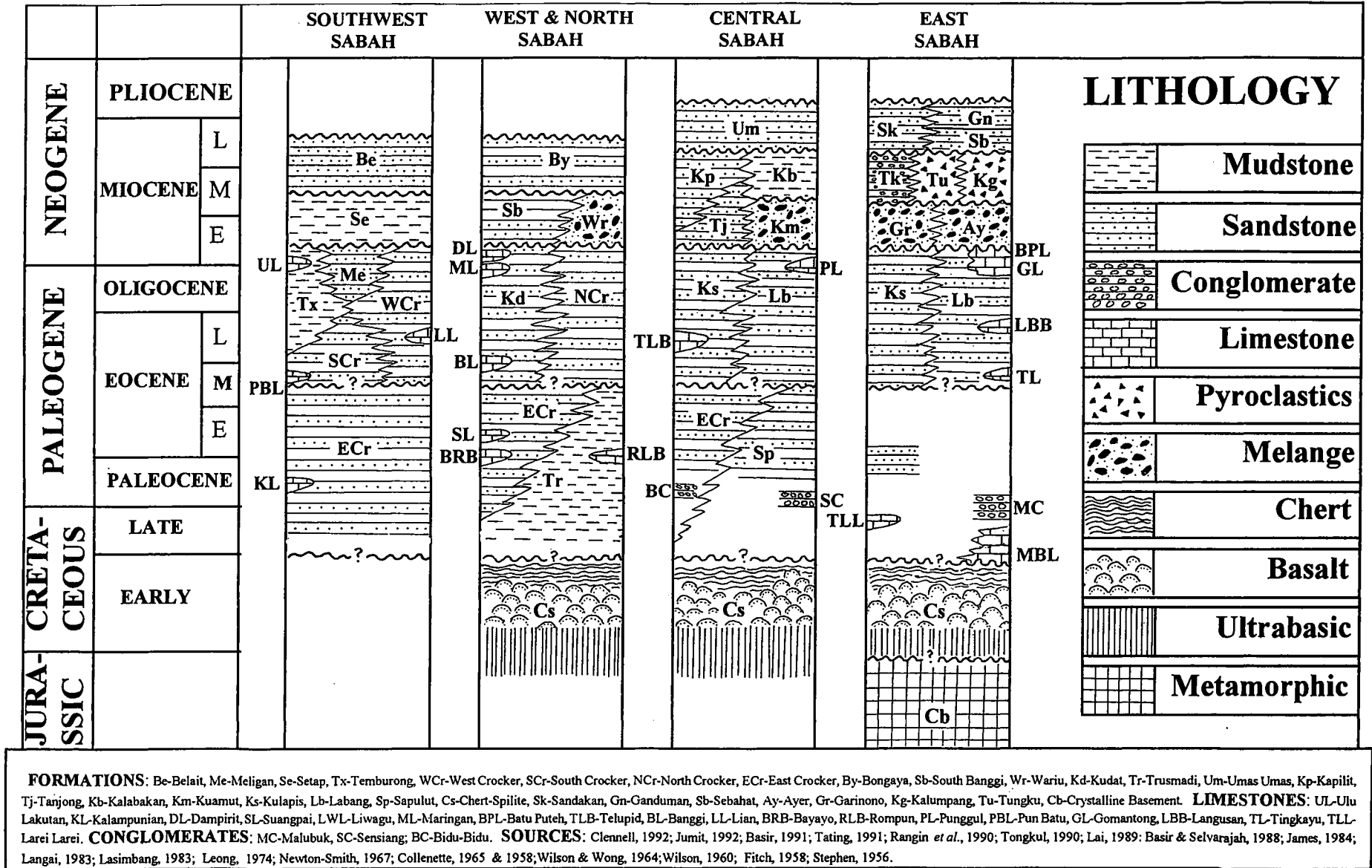


Figure 3. Generalised stratigraphy of Sabah.

sediments ranges in age from Late Cretaceous to Early Eocene and includes formations such as the Sapulut, Trusmadi and East Crocker. The sediments assigned to the upper parts of the Chert-Spilitite Formation has also been included here. The late Paleogene sediments ranges in age from Middle Eocene to Early Miocene and includes formation like the Temburong, Meligan, South Crocker, West Crocker, North Crocker, Kudat, Kulapis and Labang.

## SEDIMENTOLOGY

The early Paleogene sediments consists mostly of interbedded sandstones and mudstones deposited in deep water environments. Local occurrences of limestones (Fitch, 1958; Collenette, 1965) and conglomerates (Newton-Smith, 1967; Leong, 1974) suggests shallow water environments. The overall depositional direction of the sediments is unclear due to the scarcity of paleoflow indicators. The East Crocker sediments were derived from the south and SE (Khor, 1994; Cheing, 1994). The occurrence of conglomerate in the Sapulut Formation (Collenette, 1965) indicates a local source towards the SE. The thickness of the sediments is still uncertain due to its complex structure but is estimated to be not more than 2,000 metres based on measured sections on the East Crocker Formation (Khor, 1994).

The late Paleogene sediments also consist mostly of interbedded sandstones and mudstones deposited by turbidity currents and mass flow in a deep water environments (Wilson and Wong, 1964; Tongkul, 1987). Evidence for shallow water includes the occurrences of limestone lenses within the sediments (Stephen, 1956; Collenette, 1958; Wilson, 1960; Wilson and Wong, 1964; Collenette, 1965; Wilford, 1967; Leong, 1974; Lasimbang, 1983; Yin, 1985; Basir and Selvarajah, 1988; Lai, 1989; Rangin *et al.*, 1990; Basir, 1991; Tating, 1991; Junit, 1992). The depositional direction varies from place to place. In southwestern Sabah, the Temburong, Southwest Crocker and South Crocker sediments shows a consistent paleoflow towards the north (Wilson and Wong, 1964; Stauffer, 1967; Tongkul, 1987; Low, 1992), whereas in northern Sabah, the Kudat and North Crocker Formations show a general paleoflow to the southwest and southeast, respectively (Tongkul, 1994). The red Kulapis sediments were derived mostly from the NW (Tong, 1993), while the Labang sediments were mostly derived from the SE (Lim, 1990). The thickness of the sediment is also uncertain and appears to vary from place to place. Measured sections from the West Crocker and Kulapis Formations show thickness of about 600 metres (Tongkul, 1987; Low, 1992) and 1100 metres (Tong, 1993), respectively.

## STRUCTURE

The Paleogene sediments which are commonly folded and thrust-faulted exhibits complex structural trends as a result of several episodes of deformation (Fig. 2). The major structural trend is shown by the sharp bend from NE-SW to NW-SE near Kota Belud. The exact timing of bending is uncertain, but has been interpreted to have occurred sometimes during the Early Miocene (Tongkul, 1990, 1991, 1994). The bending has been related to the change in opening direction of the South China Sea basin from NE-SW to N-S during this time (Taylor and Hayes, 1983). Prior to the Early Miocene deformation, the sediments were deformed and uplifted. The exact timing of deformation is also uncertain but is interpreted to have occurred sometimes during the Middle Eocene (Tan & Lamy, 1990). This is indicated by the presence of an unconformity between the early and late Paleogene sediments in southwest Sabah. The early Paleogene sediments also experienced more intense deformation — some showing refolded folds and low grade regional metamorphisms (Langai, 1983; James, 1984; Khor, 1994; Chieng, 1994) compared to the late Paleogene sediments. The widespread occurrence of Middle-Late Eocene limestone also suggests such uplift.

## DEPOSITIONAL MODEL

A depositional model is proposed based on the stratigraphy, sedimentology and structure of the Paleogene sediments. It appears that instead of being deposited wholly in a single basin, the sediments were deposited in two stages on more than one basin.

The deposition of the early Paleogene sediments probably occurred in a large open basin. This basin trends approximately NE-SW due to the subduction-collision of an oceanic lithosphere in front of a rifted continental block of China with the Celebes Sea oceanic crust during the late Mesozoic (Fig. 4a). The NW and SE part of the basin was bounded by the continental block and an emergent basement, respectively. The emergent basement in SE Sabah allowed the development of shallow water limestones. The NE-SW geometry of the basin is based on the assumption that the major structural bending occurred much later. This large basin continues southward and northeastward into Sarawak and Palawan, respectively. The elongate geometry of the basin allowed sediments to fill axially from the SW and laterally from the NE and SE from the continental block and emergent basement, respectively. The huge size of the basin enabled the development of several depositional

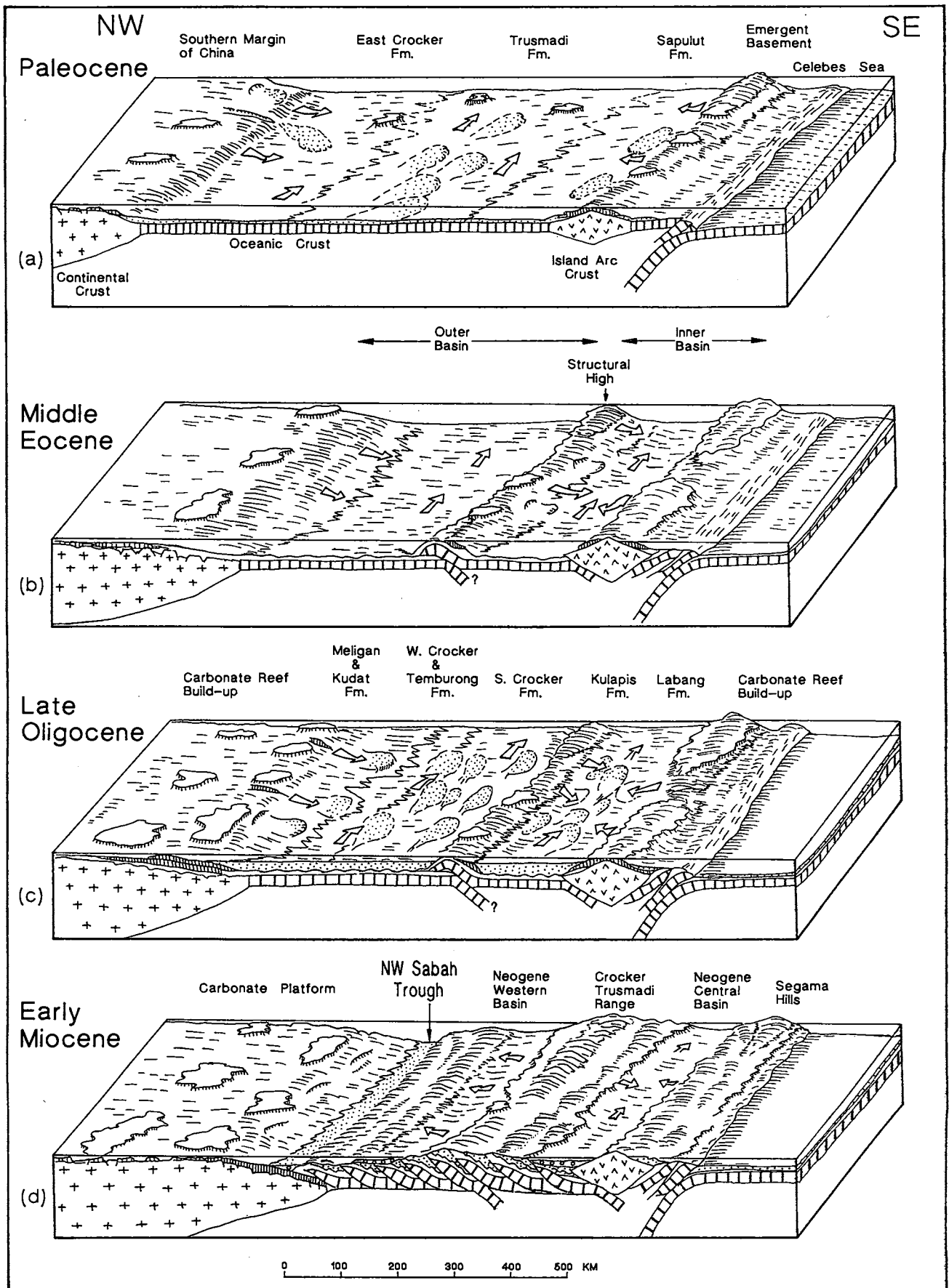


Figure 4. Depositional model of Paleogene sediments. See text for further explanation.

environments.

The deposition of the late Paleogene sediments by contrast, occurred in two parallel basins, an Outer and Inner basins trending NE-SW separated by a structural high. The basins developed as a result of continued NW-SE compression in this region causing southward subduction-imbrication of the oceanic basement and overlying early Paleogene sediments (Fig. 4b). The geometry of the basin is also based on the assumption that the major structural bending in the Paleogene sediments occurred later. The structural high allowed the development of shallow water limestones. The elongate geometry of the Outer and Inner basins enabled sediments to fill axially from the SW and laterally from NW and SE, independently. The huge size of both basins also allowed the development of different internal depositional environments (Fig. 4c). By the end of Oligocene both basins were nearly filled and carbonate reefs developed widely. The basins were finally closed during the early Miocene resulting in the Paleogene fold-thrust belt of Sabah (Fig. 4d). Subsequent deformation caused the major bending of this fold-thrust belt to its present configuration.

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