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Palaeogeographic development of west Sarawak

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Abstract: Since Carboniferous time, west Sarawak has shown vertical sub-stability to sub-mobility, with intermittent but progressive changes in the distribution of land and sea through geologic times till the present distribution of land and sea is achieved.

The palaeogeographic development of west Sarawak since Carboniferous time is summarised in 4 maps covering 4 different geological intervals, namely Carbo-Permian and older, Triassic, Jurassic-Cretaceous, and Lower Tertiary. Highlands, and marine and mixed (fluvial-deltaic-estuarine-lacustrine-shallow marine) facies are differentiated, and the main areas of volcanic accumulations are plotted.

Present knowledge of the Carbo-Permian rocks is limited but distributions of these rocks indicate the occurrence of warm shallow and deep seas in a few scattered areas.

By Middle to Late Triassic, the older rocks appear to have been uplifted to form land which contributed detritus to the deposition of the Sadong Formation in a mixed continental-shallow marine environment. Widespread subaerial volcanism gave rise to the Serian Volcanics.

An early Jurassic orogeny probably occurred, raising the Triassic rocks to form highlands. Sediments derived from these highlands were deposited in a shallow to deep sea from late Jurassic to Cretaceous, resulting in the Kedadom and Pedawan Formations. The Bau Limestone built up in a shelf environment. Further offshore, deep-sea pelagic sedimentation resulted in the Sejingkat, Serabang and Sebangan Formations.

By Early Tertiary, the major portion of west Sarawak had been uplifted to form highlands. Sedimentation in intermontane basins gave rise to the Silantek Formation, Kayan sandstone and Plateau Sandstone.

At the end of Tertiary and during Quaternary, most of west Sarawak had been raised above sea level. Peneplanation occurred during Pliocene-Pleistocene times. Successive stages of continental and marine conditions, caused mainly by eustatic movement of the sea, resulted in the successive lowering of the sea level after each completed cycle.

INTRODUCTION

M.E. Geiger (1964) described the palaeogeography of the Late Cretaceous—Eocene geosyncline in northwest Borneo. Although Geiger also mentioned the compilation of a set of palaeogeographic maps showing in successive stages the geological development of northwest Borneo in time and space, these maps were never published. A palaeographic map of offshore central-northern Sarawak during the upper Cycle IV, i.e. upper Lower Miocene, was given in Ho (1978, fig. 10). To date, however, nothing has been published on the palaeogeographic development of west Sarawak.

West Sarawak is that part of the state west of Batang Lupar. The present knowledge of the geology of west Sarawak has reached a level whereby an attempt should be made to synthesize the palaeogeographic development of west Sarawak. In this attempt the palaeogeographic development of west Sarawak is presented in 4 maps covering the periods of Carbo-Permian and older, Triassic, Jurassic-Cretaceous, and Lower Tertiary. These maps show the actual outcrops of the different sedimentary formations uncorrected for tectonic compressions or movements that may have taken place after their depositions. The accompanying text is little more than a brief catalogue of the main areas where the different rock formations have been recognised, together with the biased interpretations and generalisation of the writer.

Palaeogeographic maps can be prepared to show the distribution of land and sea, geomorphology of the land, depth of the sea, distribution of bottom sediments, direction of currents in water and air, and climatic belts. However, the accuracy of a palaeogeographic map is dependent on the precision of correlation of the stratigraphic units represented, and evidence is rarely sufficiently complete and unequivocal to permit more than approximations (Kay, 1945).

Harrington (1962) considers that palaeogeographic maps are, at best, subjective synthesis born out of a personal appraisal and interpretation of numerous observational facts. The accuracy and detail of the maps are directly related to the quantity and quality of the data. With the same set of observational facts, two different authors may arrive at two different palaeogeographic pictures, the divergence increasing in reverse relation to the abundance and accuracy of the data, and on the authors' ideas and personal experiences. When a wealth of observational facts is at hand and the map covers a small area, the two interpretations may be closely similar.

Despite these limitations, the concepts presented below are believed to be useful models for illustrating the palaeogeographic evolution of west Sarawak since Carbo-Permian times.

GENERAL GEOLOGY

West Sarawak forms part of the West Borneo Basement which is the exposed part of the Sunda Shield in southwest Borneo. This Basement is built up of Palaeozoic and Mesozoic rocks, but in west Sarawak these rocks are concealed, in places, under a thick cover of Tertiary strata.

The oldest rocks are considered to be the pre-Upper Carboniferous schist and phyllite (Kerait Schist, Tuang Formation) although these have not been actually dated. Succeeding sedimentary formations include the Upper Carboniferous-Lower Permian Terbat Formation, the Triassic Sadong Formation, the Jurassic-Cretaceous Serabang, Sejingkat, Sebangan Formations, the Upper Jurassic Kedadom Formation, the Upper Jurassic-Lower Cretaceous Bau Limestone, the Upper Jurassic-Upper Cretaceous Pedawan Formation, and the Lower Tertiary Kayan sandstone, Silantek Formation and Plateau Sandstone (fig. 1.). Breaks in the sedimentary records are represented by 4 major unconformities which are apparent between the pre-Upper Carboniferous and Carbo-Permian rocks, between the Carbo-Permian and Triassic

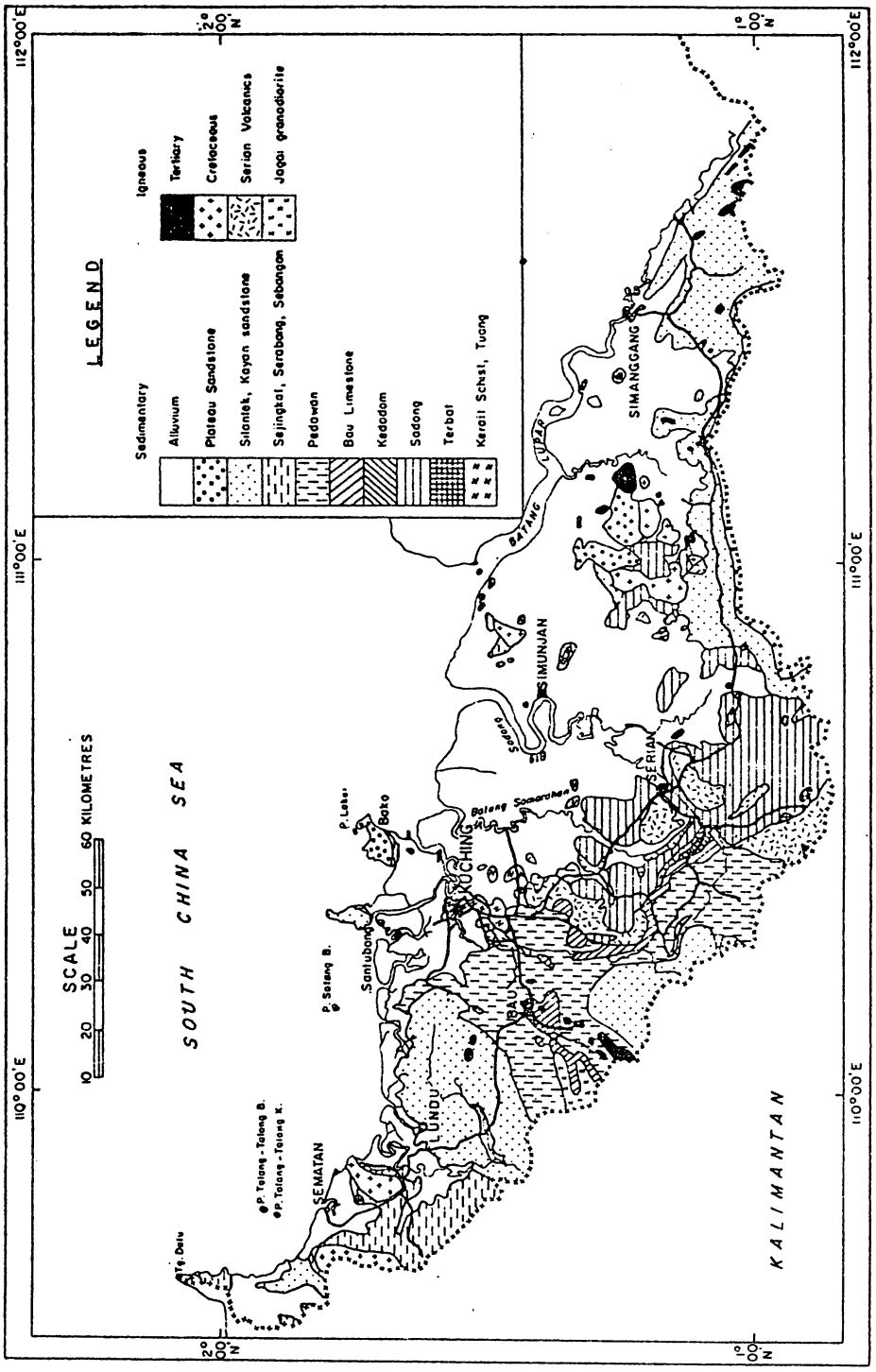

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Fig. 1. Generalised Geological Map of West Sarawak.

rocks, between the Triassic and Upper Jurassic rocks, and between the Upper Cretaceous and Lower Tertiary rocks. The spatial and temporal relationships between the various sedimentary rocks formations are shown in Figure 2.

The oldest granitic rocks are the pre-Triassic granodiorite at Gunung Jagoi and Gunung Kisam. Volcanic activities during the Late Triassic gave rise to thick piles of basaltic and andesitic lavas and pyroclastics (Serian Volcanics), and associated minor dioritic intrusions. The basic volcanic and intrusive rocks in the Serabang and Sejingkat Formations, the minor acid volcanic rocks in the Pedawan Formation, and the extensive feature-forming adamellite at Pueh, Gading, Tanjung Datu, Tinteng Bedil and Buri, the Sebuyau granodiorite, and the Sematan gabbro resulted from igneous activities from the Late Jurassic to Late Cretaceous. Tertiary, probably predominantly mid-Miocene, igneous activities resulted in widespread intrusions of stocks, dikes and sills of high-level, hypabyssal igneous rocks throughout west Sarawak. The latest igneous activity was during the Pliocene-Pleistocene resulting in a small andesite lava flow at Sematan.

PALAEOGEOGRAPHIC DEVELOPMENT

The palaeogeographic development of west Sarawak may be considered in five time-spans, namely:

(i) Carbo-Permian and older
(ii) Triassic
(iii) Jurassic-Cretaceous
(iv) Lower Tertiary, and
(v) Pliocene-Pleistocene and Recent

Carbo-Permian and Older (fig. 3A)

No rocks definitely older than the Carboniferous have been found in west Sarawak. Therefore, the palaeogeogprahic evolution of west Sarawak can only be considered from the Carboniferous.

The oldest rocks in west Sarawak are the phyllite, schist and metagraywacke of the Tuang Formation in the Kuching-Kuap area (Tan, 1980, ms; Hon, in prep.) and the schist of the Kerait Schist in the Serian area (Pimm, 1965). These rocks are considered to be older than the Late Carboniferous although no fossils have been found except for a dubious fossil sample, from Kuching, which was identified as possibly "tentaculatids which means that the strata could be pre-Carboniferous" (Tan, Kho & Hon, 1980). The depositional environment of the original sediments, from which the metamorphic rocks were derived, is uncertain but is considered to be marine. In the Kuching area, the Tuang Formation shows evidence of being deposited in a marine environment, in some places under turbiditic conditions (Tan, 1980, ms).

Fossiliferous Upper Carboniferous (Moscovian) and Lower Permian (Wolfcampian) beds are scarce in west Sarawak. The only known occurrences are in the Gunung Selabor area, about 70 km south-southeast of Kuching, in a sequence, at least 610 m thick, of predominantly massive limestone, chert and subordinate shale

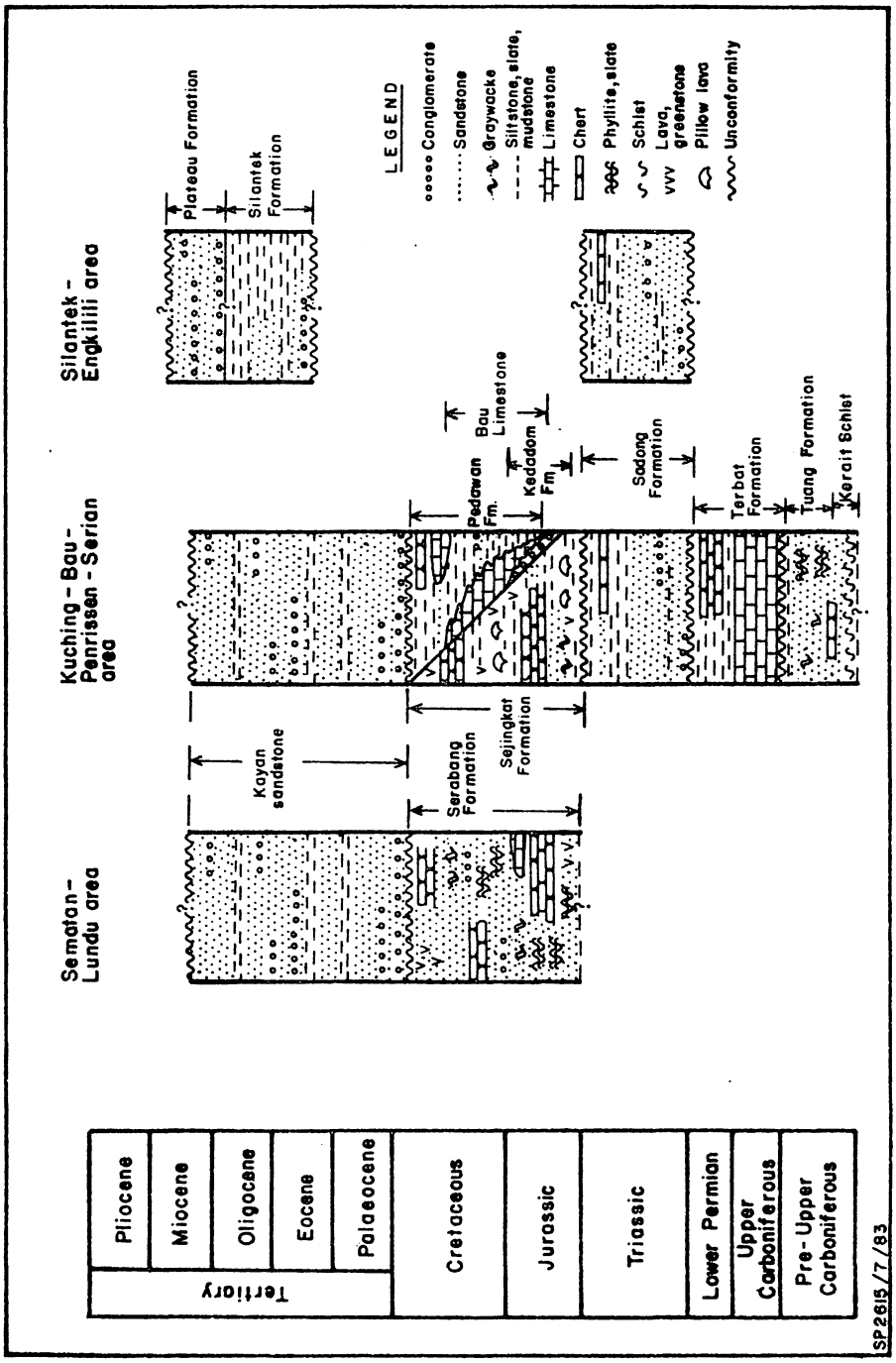

Fig. 2. Generalised stratigraphy of West Sarawak.

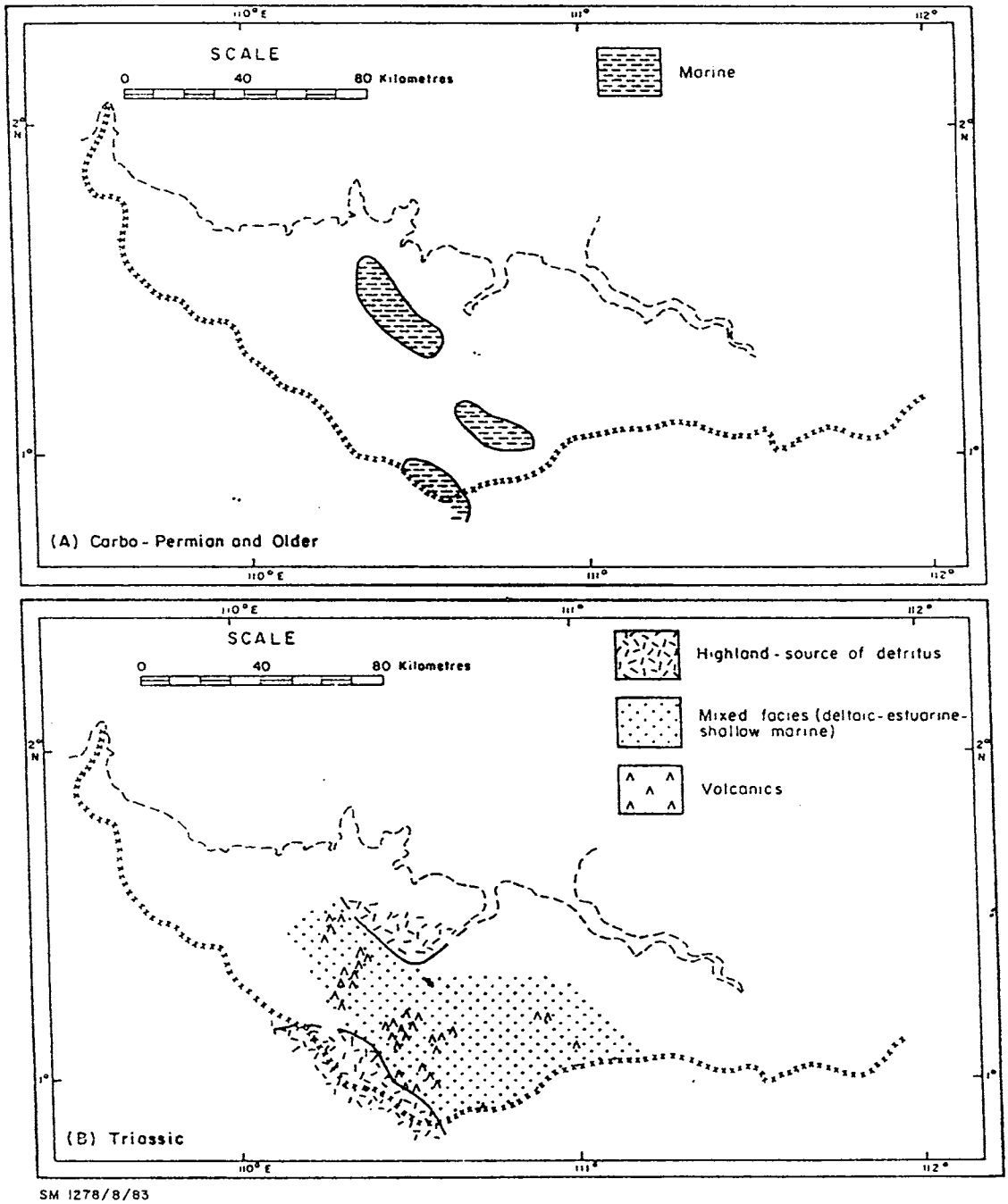

Fig. 3. Palaeogeographic maps of West Sarawak (A) Carbo-Permian and older, (B) Triassic. Present land indicated by dashed line and the Sarawak-Kalimantan boundary by crosses.

(Terbat Formation). These sediments were probably deposited in a warm shallow sea relatively free from terrigenous materials (Pimm, 1965; Wilford, 1965).

Triassic (fig. 3B)

Artinskian to Scythian sedimentary rocks appear to be absent. This is probably due to non-deposition during the Late Permian-Early Triassic period of folding when most of the area may have been uplifted above sea level. In the middle Triassic, slight subsidence occurred in the Kuap-Penrissen-Serian area resulting in an estuarine-deltaic-shallow marine environment for the deposition of the Sadong Formation.

Upper Triassic (Carnian to Norian) fossiliferous beds are found in the Sadong Formation which occupies a large portion of the Kuap-Penrissen-Serian area. This Formation, at least 2,300 m thick, consists of shale, sandstone, conglomerate, arkose, and, in some places, tuff, tuffaceous sandstone and thin beds of coal, chert and limestone. The upper parts of the Formation yielded assemblages of *Halobia* spp. and *Monotis* spp. In one locality, the presence of *Sturia* sp. nov.(?) aff. *S. sansovinii* (Mojsisovics) probably indicates the presence of the Middle Triassic (?Anisian)(Ishibashi, 1975). The lower parts of the formation are devoid of fossils but may possibly extend into the Lower Triassic.

The Formation was deposited in an estuarine to shallow marine environment, with brackish water, non-marine, and paralic swamp conditions in places (Pimm, 1965; Wilford, 1965). Pimm (1965) considered that the probable Late Triassic shoreline was southwest of Serian. Along this shoreline, pebble and coarse sand beach deposits were laid down as the sea transgressed over the older Terbat Formation. The distribution of sandstone types (Pimm, 1965, fig. 6) also supports the idea of a shoreline southwest of Serian because the sandstone becomes progressively finer and better sorted towards the northeast. Pebbles in the conglomerate and grains in the coarse sandstone consist predominantly of chert, in parts derived from the Terbat Formation, and lesser amounts of metamorphic quartz, vein quartz, and granite possibly derived from the south in Kalimantan. However, Hon (in prep.) considered that in the Kuap area, the Sadong Formation appeared to have received most of its detritus from the older schist and phyllite to the north and northeast, and that the Formation became progressively more shallow marine towards the south and southwest. Evidence for these include the distribution of the arkose as northern outcrops of the Formation and the distribution of marine fossils in the southern and southwestern outcrops of the Formation.

Towards the close of the Triassic, probably in late Norian times (Pimm, 1965), widespread volcanic activity occurred, forming the extensive piles of andesitic to basaltic lavas, breccias, and tuffs of the Serian Volcanics. From indirect evidence, Wilford (1965) concluded that the volcanic activity probably occurred mainly in a marine environment, although in some areas it may be subaerial, or in a deltaic to estuarine environment. Hon (in prep.) considered the Serian Volcanics to be predominantly subaerial—deltaic to estuarine—near the top.

Jurassic-Cretaceous (fig. 4A)

No Rhaetian to Bathonian sedimentary rocks are known in west Sarawak. This

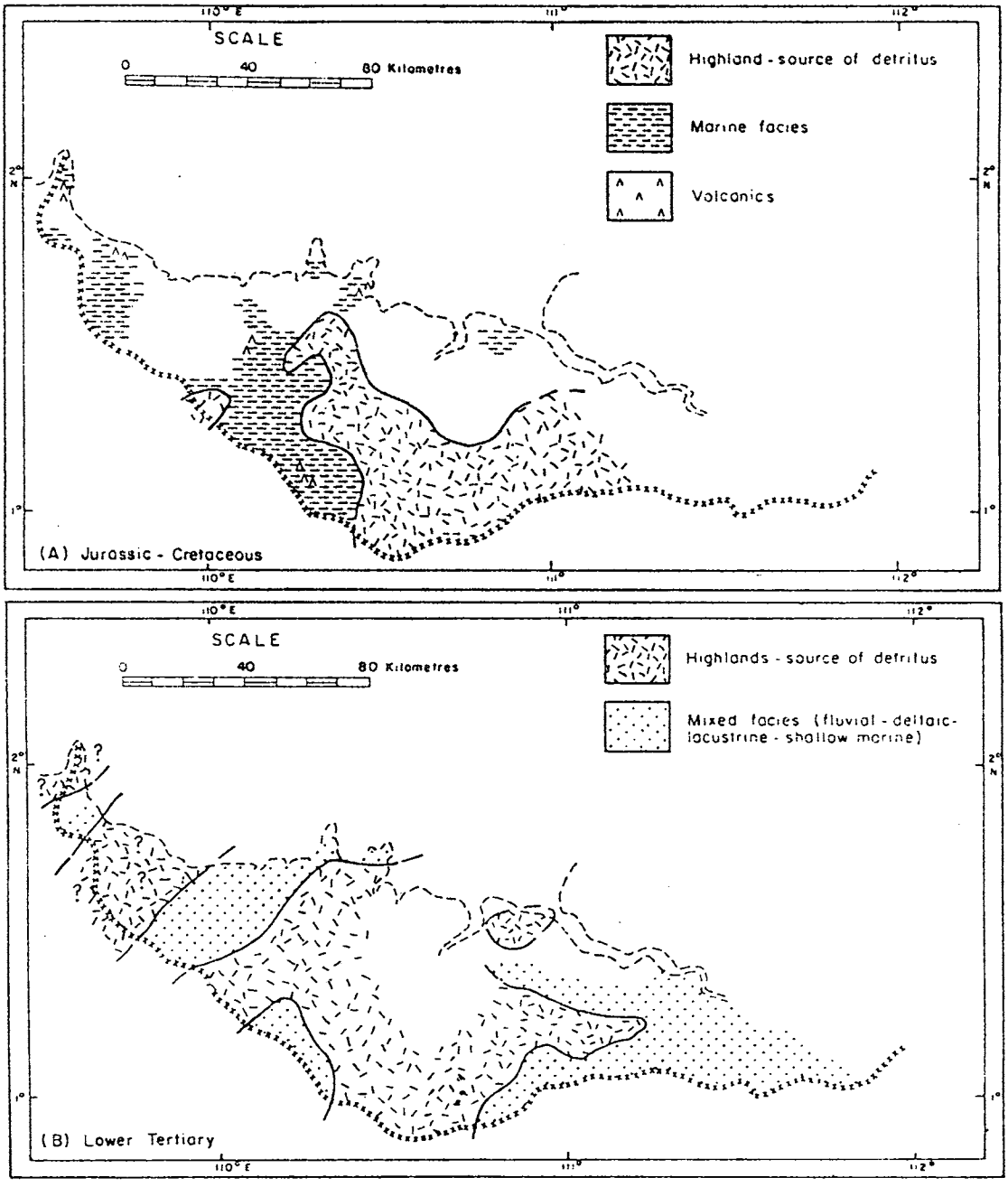

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Fig. 4. Palaeogeographic maps of West Sarawak (A) Jurassic-Cretaceous, (B) Lower Tertiary. Present land indicated by dashed line and the Sarawak-Kalimantan boundary by crosses.

may be the result of an Early Jurassic orogeny that affected the region. However, the sedimentary record from the Late Jurassic to Late Cretaceous is fairly complete.

During the Late Jurassic to Late Cretaceous, in the Kuching-Bau-Penrissen area, the older rock units apparently formed highlands surrounded by a marine sea with coastlines formed by the Jagoi granodiorite, Tuang and Sadong Formations, and Serian Volcanics.

In the late Jurassic (probably Kimmeridgian time), sand and gravel were laid down near the shorelines in a shallow marine environment; the detritus being derived from the Serian Volcanics, Sadong Formation and Jagoi granodiorite. These gave rise to a sequence of massive sandstone, conglomerate, and thin beds of shale, limestone, and tuff (Kedadom Formation) from which the ammonites *Lamellaptychus* sp. and *Lithacoceras* or *Subplanites* sp. have been recovered (Wildford, 1965). The present distributions of the Kedadom Formation bordering the present outcrops of the Serian Volcanics, Sadong Formation, and Jagoi granodiorite further support the interpretation that these latter rock units formed the highland sources from which the Kedadom detritus were derived.

Further offshore, in a clear, warm, shallow sea practically free from terrigeneous debris, reef build-ups gave rise to a thick sequence of carbonates from the Late Jurassic to Early Cretaceous (Bau Limestone). In places, the reef build-ups were drowned by periodic influxes of sand and clay. In the Early Cretaceous, these reef build-ups were brought to an end by the rapid subsidence of the basin which was acocompanied by an increased influx of detritus, thereby drowning and burying the reefs (Wilford, 1965; de Coo & Lau, 1977).

In areas not affected by the reef build-ups, i.e. in the deeper seas and along the contemporary shorelines where the reefs were periodically covered by mud and sand from the land, a thick sequence of mud, sand and gravel with lenses of limestone and chert (Pedawan Formation) was deposited from the Late Jurassic to Late Cretaceous. The Bau Limestone and Pedawan Formation were deposited in a rapidly subsiding shallow marine basin which probably deepened during the Late Cretaceous, as indicated by the assemblages of pelagic foraminifers (Wilford, 1965) and the drowning of the reefs. Subsidence resulted also in an enlargement of the basin of deposition, particularly to the north and the south. During this time, minor volcanism gave rise to the accumulation of beds of dacitic, andesitic and rhyolitic lavas and tuffs.

In the west (Sematan-Lundu area) and north (Bako-Sebuyau area), deep-marine sedimentation occurred probably from the Jurassic to Cretaceous, with pelagic siliceous ooze (indicated by presence of chert) and the intrusion and extrusion of basic magma (indicated by presence of gabbro, serpentinite, basalt, spilite). These sediments are now marked by outcrops of the Serabang, Sejingkat and Sebangan Formations (Wolfenden, 1963; Tan, ms).

Lower Tertiary (fig. 4B)

Marine deposition was probably interrupted in the Late Cretaceous by a period of up-warping, uplift and strong folding. These movements were probably coeval with

the intrusions of adamellite in the Sematan-Lundu area in the west, and the Sebuyau and Tinteng Bedil granodiorites in the east (Kirk, 1963).

Towards the close of the Cretaceous, the Bungo, Kayan, Samunsan and Santubong areas began to subside and the essentially deltaic deposition of the Kayan sandstone in these areas commenced, and continued until at least the early Eocene. Palaeocurrent studies indicate that the Kayan sandstone in the Kayan basin, Santubong peninsula and Bungo basin received its detritus from the older formations forming highlands in the Kuching-Bau-Serian area (Tan, 1984). From pollen studies, Muller (1968) concluded that the Kayan sandstone appears to have a regressive character, the lower and middle parts representing a deltaic facies and the upper parts a fluviatile-lacustrine facies. A fairly high proportion of montane pollen types in the *Rugubivesiculites* zone suggests the nearness of a mountain range, which came into existence during the stratigraphic hiatus at the base of the Kayan sandstone, during the deposition of the older parts of the Kayan sandstone.

There is an eastward shift in the depo-centres during the Lower Tertiary so that by the late Eocene when sedimentation appears to have ceased in the Kayan, Bungo and Samunsan areas, deposition of sediments, in a similar predominantly deltaic-fluviatile-lacustrine environment with limited shallow marine influences, was active in the Silantek-Simanggang area where the Silantek Formation and Plateau Sandstone were deposited from at least the late Eocene to possibly the Miocene times (Tan, 1979). The sources of detritus were probably the highlands in the Tinteng Bedil area and the eastward continuations of the mountain chains in the Kuching-Bau-Serian area.

Pliocene-Pleistocene and Recent

Towards the end of the Tertiary, most of west Sarawak was raised above sea level. A prolonged period of erosion followed in the late Tertiary and early Quarternary times, reducing much of the area to a peneplane. Throughout the Pleistocene with its successive stages of continental and marine conditions caused mainly by eustatic movement of the sea, the sea level was successively lowered after each completed cycle (Andriesse, 1972).

At various times during the Quarternary, the present-day large rivers were able to extend their levees much further into the coastal shelf than at present, and favourable conditions existed for the development of large interfluvial basins in the extended coastal shelf. According to Andriesse (1972), with the end of the last glacial period the sea level rose to above the present level and during the early Holocene marine and deltaic deposits accumulated in the present Sungei Sarawak delta to a level about 3 m above the present level of accumulation. The first ridges in the Santubong-Sematan area were probably formed at this time. Marine deposits were probably also accumulating in the erstwhile interfluvial basins which were subsequently filled by peat deposits.

During the Holocene, the sea level showed minor oscillations with a net fall of probably 3 to 5 m. During this period, the old mudflat and deltaic deposits were partly eroded and redeposited at a lower level. A succession of ridges developed between

Sematan and Santubong, and peat accumulated in the old riverine basins, following the retreating coastline.

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