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Palaeocurrents in the Tertiary sedimentary deposits in western Sarawak

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Abstract: The Tertiary sedimentary deposits in western Sarawak are commonly cross-bedded and, in places, ripple-marked. Palaeocurrent studies have been carried out in 7 widely-distributed locations of these rocks, namely Snibong, Stinggang, Gunung Moi, Gunung Serapi, Santubong peninsula, Bako peninsula, and Sungai Tebia. The results of these studies yield unimodal (to rarely bimodal) palaeocurent patterns consistent with fluvial and deltaic deposition of the sediments. Local mean directions are to the NW, N, NNE, and ESE, and suggest the provenance for the Tertiary sedimentary deposits to be the Palaeozoic and Mesozoic rocks occupying the present Bau-Kuching-Serian area.

INTRODUCTION

Regional palaeocurrent studies have long been recognised as invaluable in the palaeogeographic and palaeo-environmental interpretation of ancient sediments. The Tertiary sedimentary rocks in western Sarawak are commonly cross-bedded and, in places, contain pebble imbrications and ripple marks, and have been the subject of a number of palaeocurrent studies since 1969.

The first such study was made by Stauffer (1969) who measured the foresets of cross-beddings in a number of widely-distributed locations of the Tertiary deposits in western Sarawak. Subsequently, interest in palaeocurrent studies was shown by a number of undergraduates from the University of Malaya who carried out project studies in Sarawak. These projects areas were Gunung Serapi (Kong, 1970), Gunung Moi (Tan, 1971), Snibong (Kloni, 1978), Stinggang (Kijam, 1978), and Santubong (Kasumajaya, 1979). During the course of geological mapping, the palaeocurrents in the Santubong and Bako peninsulas were studied (Tan, manuscript).

The purpose of this paper is to make the results of all these studies more readily available to those interested, because most of these results appear in unpublished theses of limited circulation. The palaeocurrent studies in the Santubong and Bako peninsulas are presented below, and the results of the studies there and in the other areas are discussed.

GENERAL GEOLOGY

The Tertiary sedimentary rocks in western Sarawak had previously been described as the Plateau Sandstone (Liechti, Roe & Haile, 1960; Wolfenden, 1963; Wilford, 1965). However, the so-called Plateau Sandstone in the Bungo Range and Kayan basin have long been recognised to be quite different, both lithologically and biostratigraphically, from the Plateau Sandstone in its type locality in the Klingkang Range (Haile, 1968). Tan (1980) discussed the nomenclature of these Tertiary rocks and proposed that those in the Kayan basin, Bungo Range, and Santubong peninsula

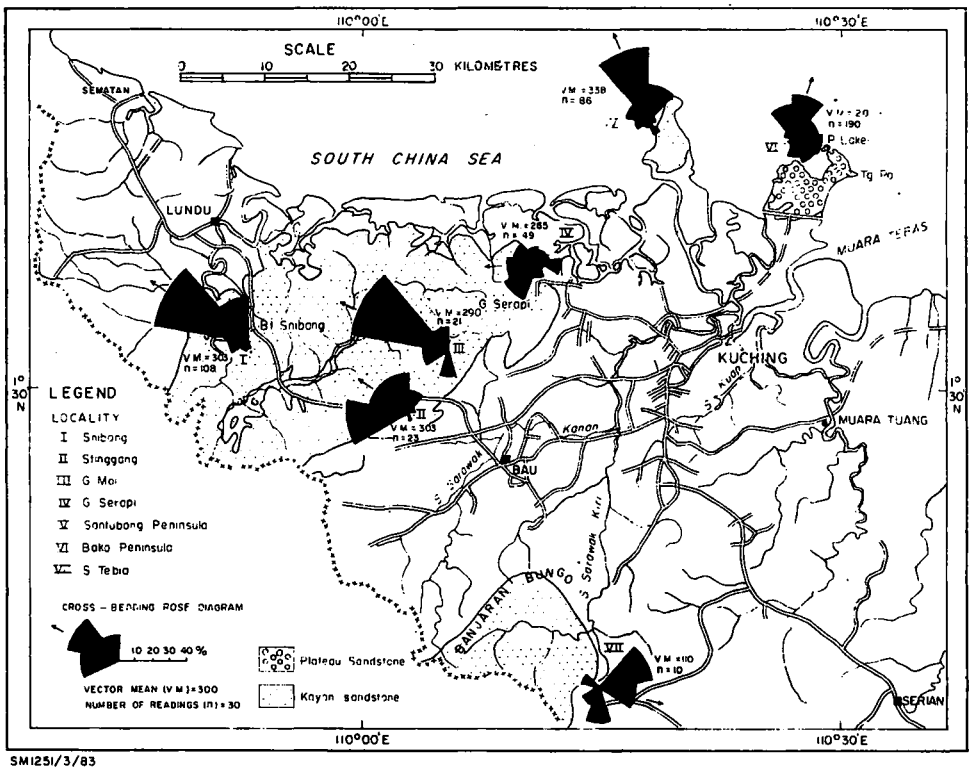

Fig. 1 Cross-bedding measurements in the tertiary sedimentary deposits in western Sarawak.

be termed informally as the "Kayan sandstone". The Bako peninsula is underlain, however, by the Plateau Sandstone. The distributions of the "Kayan sandstone" and the Plateau Sandstone in the area under discussion are shown in Figure 1.

The "Kayan sandstone" is essentially a monotonous succession of feature-forming, thick-bedded, cross-bedded sandstone interbedded with conglomerate, siltstone, and red, green, and grey variegated mudstone. In the Kayan basin, Wolfenden (1963) mapped 3 divisions, namely: a *Lower Division* which is mainly argillaceous and consists of thinly bedded, grey to dark grey, laminated carbonaceous silty shale, and include thin beds to dark grey, laminated carbonaceous silty shale, and include thin beds of siltstone and fine-grained sandstone showing small-scale cross-bedding, and a few thicker beds of light coloured, cross-bedded sandstone, and rare lenses of conglomerate; a *Middle Division* which forms prominent scarps and consists of thick successions of predominantly arenaceous strata, mainly thick-bedded, cross-bedded sandstone but including thin beds and lenses of conglomerate, and a little interbedded shale; and an *Upper Division* consisting of sandstone and conglomerate, and interbedded shale; the sandstone contains cross-bedding, slump bedding, and ripple marks. In the Bungo Range, Lau (1975) recognised 2 distinct units: a *Lower Member* consisting of predominantly massive to thick-bedded sandstone but including

rare thick beds of conglomerate and thin beds of shale and mudstone, and an *Upper Member* consisting of maroon-coloured mudstone but including minor sandstone and conglomerate beds.

The rocks in the Kayan basin and Bungo Range have been dated by pollen to be of Late Cretaceous to early Eocene age (Wolfenden, 1963; Wilford, 1965; Muller, 1968).

The Plateau Sandstone in its type locality in the Klingkang Range consists of a succession of thick-bedded, cross-bedded, polymict sandstone but includes minor intercalations and lenses of conglomerate, and grey and red silty shale, and is practically barren of fossils. However, it is underlain by the Silantek Formation, the base of which has been dated by larger foraminiferas to be late Eocene, but the top contains only undiagnostic wide-ranging molluscs. Due to its thickness, however, the Silantek Formation probably extends into Oligocene, which would imply at least an Oligocene or even Miocene age for the Plateau Sandstone.

PALAEOCURRENT STUDIES IN THE SANTUBONG AND BAKO PENINSULAS

During the course of mapping the Kuching area, the opportunity was taken to study the palaeocurrents of the Tertiary deposits underlying the Santubong and Bako peninsulas. Prior to this study, Stauffer (1969) made palaeocurrent measurements on both peninsulas, and Kasumajaya (1979) studies the Santubong peninsula.

Santubong peninsula: The "Kayan sandstone" here is generally well bedded and, in parts, well laminated. The most common primary structure is cross-bedding, mainly tabular and of medium-scale, although trough cross-bedding and small-sclae cross-bedding are also present. Other primary structures include ripple marks, convolute laminae, slump structures, and animal burrows and tubes.

The orientations of 86 small- and medium-scale cross-beddings were measured at 9 localities, and those of 4 asymmetric ripple marks at 2 localities. Where the bedding dip exceeds 10°, the attitude of the cross-bedding measured in the field was corrected using the method of Potter & Pettijohn (1963). No correction was made if the bedding dip is 10° or less. The mean palaeocurrent directions indicated by the cross-beddings and ripple marks at these localities are shown in Figure 2. The rose diagram for the 86 readings taken over the peninsula gives a unimodal palaeocurrent pattern with a calculated vector mean of 338°, indicating prevalent palaeocurrent direction from the south-southeast. The unimodal palaeocurrent pattern, the distribution of vector means, and variance suggest a deltaic and/or fluvial environment of deposition for the sediments. An estuarine environment is indicated by bimodal palaeocurrent pattern at one locality (Tan, manuscript).

Bako peninsula: The Plateau Sandstone here is generally well bedded, and the most common primary structure is medium-scale tabular cross-bedding. Some of the cross-beddings are deformed and over-stepped, and others appear to be recumbent-folded deformed cross-beddings. At Teluk Pandan Besar, the abundant cross-beddings appear to be a "climbing" variety of tabular cross-bedding (Stauffer, 1969). Other primary structures include convolute bedding, slump bedding, and channels.

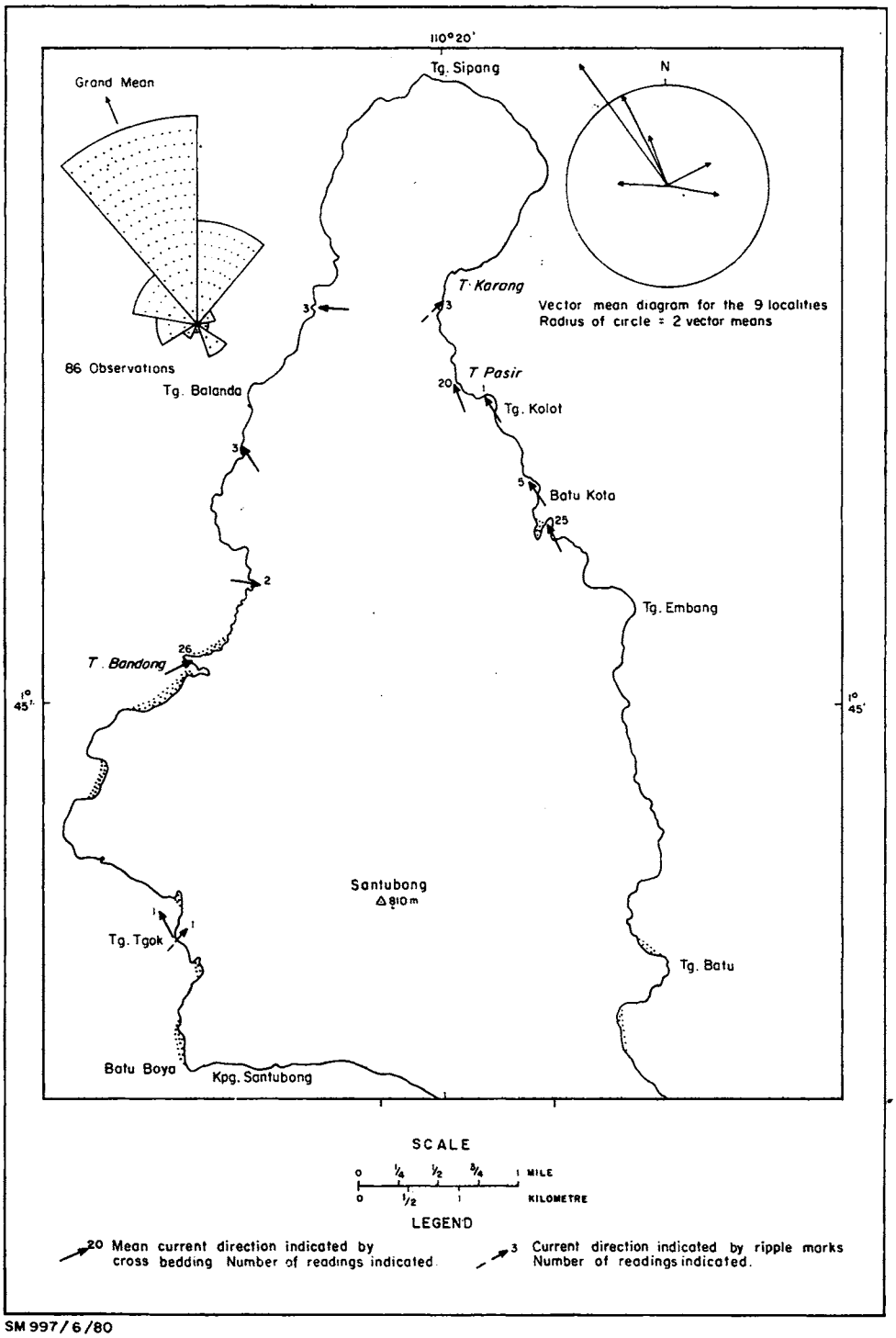

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Fig. 2 Palaeocurrent map of the 'Kayan Sandstone', Santubong Peninsula.

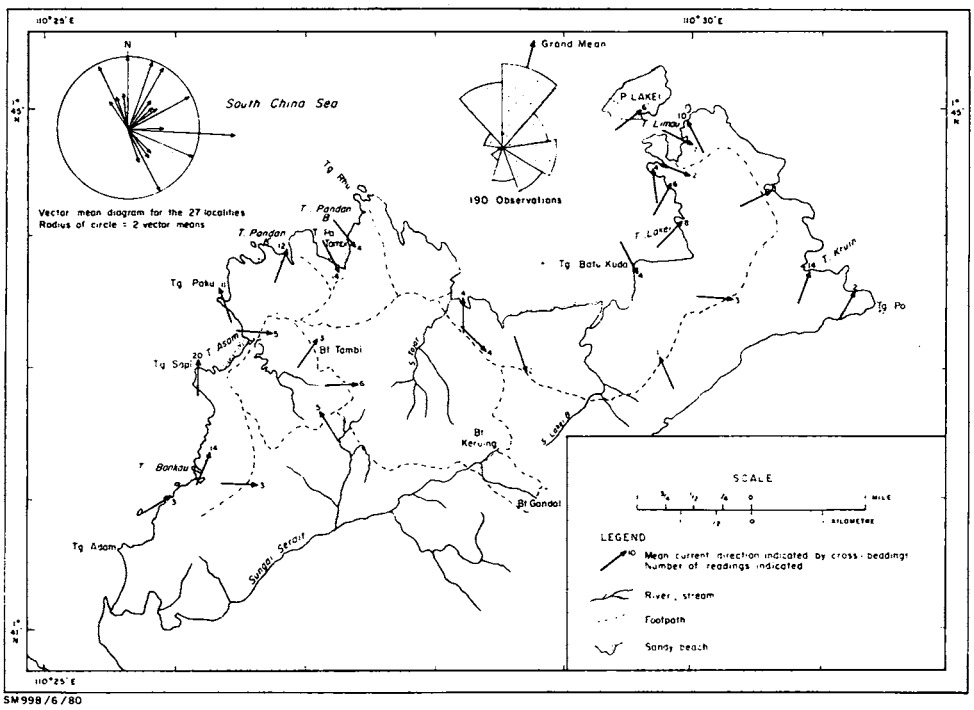

Fig. 2 Palaeocurrent map of the Plateau Sandstone, Bako Peninsula.

A total of 190 measurements of the orientations of cross-beddings were made from 27 localities of the Plateau Sandstone in the Bako peninsula. The measurements made by Stauffer (1969) were incorporated into this study. No corrections of the measurements were made because the structural dips of the beds on which the cross-beddings were measured do not exceed 10°. The mean palaeocurrent directions indicated by the cross-beddings at the 127 localities are shown in Figure 3. The rose diagram for the peninsula, derived from the 190 observations, shows a unimodal palaeocurrent pattern having a calculated vector mean of 020°, thereby suggesting that longtitudinal transport down a palaeoslope to the north-northeast prevailed. The palaeocurrent pattern, the distribution of vector means, and variance suggest a deltaic and/or fluvial depositional environment for the sediments.

REGIONAL PALAEOCURRENT STUDIES

In addition to the 2 peninsulas, palaeocurrent studies have been carried out at 5 locations in the "Kayan sandstone". These locations are: Sungai Tebia (Stauffer, 1969), Gunung Serapi (Kong, 1970), Gunung Moi (Tan, 1971), Snibong (Kloni, 1978), and Stinggang (Kijam, 1978);. The resultant cross-bedding rose diagrams for all these 7 locations are shown in Figure 1; the calculated vector mean (V.M.), the number of readings (n), and the variance for each location are summarised below:

I	Snibong	(V.M. = 303°, n = 108, variance = 1349)
II	Stinggang	(V.M. = 303°, n = 23, variance = 2866)
III	Gunung Moi	(V.M. = 290°, n = 21, variance = 2105)
IV	Gunung Serapi	(V.M. = 265°, n = 49, variance = 7548)
V	Santubong	(V.M. = 338°, n = 86, variance = 3661)
VI	Bako	(V.M. = 020°, n = 190, variance = 7829)
VII	Sungai Tebia	(V.M. = 110°, n = 10, variance = 5636)

Locations I–IV are within the Kayan basin, and the vector means for all 4 locations indicate a prevalent westward palaeocurrent direction, implying a provenance for the sediments to the east of the present outcrops. The variances and standard deviations range from 1349 to 7548 and 36.7° to 86.9° respectively.

Locations V and VI are the peninsulas, and the vector means indicate prevalent north-northwest and north-northeast palaeocurrent directions, thereby implying a provenance for the sediments to the south-southeast and south-southwest of the present outcrops, respectively. The variance and standard deviation at Santubong are 3661 and 60.5°, and at Bako are 7829 and 88.5°, respectively.

Location VII is within the Bungo Range and, although the number of readings is limited, the vector mean indicate a mean palaeocurrent direction towards east-southeast, implying a provenance for the sediments to the west-northwest of the present outcrop. The variance is 5636 and standard deviation is 75°.

The variances of cross-beddings in all 7 locations suggest a fluvial and deltaic environment (cf. Potter & Pettijohn, 1963, table 4–2). Pryor (1960, p. 1490–91) found that variances and standard deviations of regional cross-bedding patterns may be environmentally diagnostic, although these may be controlled by a number of factors like amount of slope, thus making evaluation of the results difficult. However, these statistical treatments provide further evidence of a fluvial–deltaic environment for the deposition of the "Kayan sandstone" and Plateau Sandstone as deduced from the lithologic assemblage, sedimentary structures, and pollen assemblages.

DISCUSSION

The provenance of the Tertiary sedimentary deposits in western Sarawak is uncertain. Zeylmans van Emmichoven (1939) considered the Schwaner Mountains in Kalimantan (Indonesia) to be a possible source, but also considered sources to the north. Liechti and others (1960) considered the Schwaner Mountains to be too far to the south to supply the Sarawak occurrences and favoured sources closer to the present outcrops. Besides the Lupar or Belaga Formations, Liechti and others (1960) suggested that much detritus may have been supplied from the Carbo-Permian and Mesozoic formations of the continental core, including the associated volcanic rocks.

The palaeocurrent patterns derived from the regional study, as shown in Figure 1, support the last hypothesis, suggesting very strongly the provenance for the sediments of the Tertiary deposits to be the Palaeozoic and Mesozoic sedimentary, igneous and metamorphic rocks occupying the present Bau-Kuching-Serian area. Since the end of

Cretaceous, the Bau-Kuching-Serian area was mainly a land area with mountainous regions, which are underlain by the Jagoi granodiorite, Tuan Formation, Serian Volcanics, and Sadong Formation, located in the present Jagoi, Kuching, and Penrissen-Serian areas.

A provenance in the Bau-Kuching-Serian area raises a number of interesting questions and implications, including:

(i) is there sufficient source of quartz for the Teritary? The quartz would appear to have come from the pre-Triassic granodiorite at Gunung Jagoi and the re-working of the Tuang, Sadong, and Pedawan Formations. The bulk of the quartz would apparently be derived from the Jagoi granodiorite and the Tuang Formation. Most of the chert in the Tertiary is probably derived from the Sejingkat Formation;

(ii) What is the source of the agates in the conglomerate of the lower "Kayan sandstone" in the Kayan basin and Santubong peninsula? The agate source could be the Serian Volcanics because agate boulders have been found weathered out of the Serian Volcanics by Hon (in prep.) and

(iii) was the Plateau Sandstone at Bakon derived 'cannibalistically', in parts at least, from the erosion of the Kayan sandstone?

Further work, including studies of heavy minerals, textures, quartz types, and palaeocurrent measurements in the Kayan basin and Bungo range (particularly the western part of the Bungo range where no data are available at the present time) should be carried out in order to test the validity of the above conclusion, and to answer some of the questions raised.

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