

## HOLOCENE SHORELINES OF TIOMAN ISLAND IN THE SOUTH CHINA SEA<sup>1</sup>

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### ABSTRACT

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Ten new radiocarbon ages of biogenic shoreline indicators from tectonically stable Tioman island, Malaysia, demonstrate that regional sea level was between 1.4 m and 3.7 m above present mean sea level during the period 6000 BP to 1900 BP, and that the sea level fluctuated several times in the order of 1 to 2 metres. The dates also suggest that sea level rose twice at rates of 1 m in 300 years but dropped at least twice at slower rates of about 1 to 2 m in 1400 years. In general, a very good correspondence is shown between the eustatic sea level curve constructed on the basis of about 40 dated shorelines from Peninsular Malaysia and that of Tioman island.

### INTRODUCTION

Biogenic fossil shoreline indicators abound on the coasts of Tioman, an island 30 km off the east coast of Peninsular Malaysia (Fig. 1). The fossil shores are indicated by oyster clusters and calcareous algal crusts that are still attached to non-calcareous Mesozoic rocks and also by reef limestone which forms abraded platforms. The oysters and algal crusts are only preserved in the protected cavities and hollows of rocky coasts. On the more exposed parts of the coasts these indicators are absent; a situation that had probably been caused by weathering and solution by seawater. At a score of localities dead oysters, algal crust, and coral from abrasion platforms were collected. The ages of ten samples have been determined at Gakushuin University in Tokyo. This paper presents the ten radiocarbon ages and an interpretation of former sea levels.

Tioman island lies in the tectonically stable Sunda Shelf region. By the beginning of the Tertiary, orogenesis and widespread igneous intrusions had turned the region into a stable tectonic platform. Various lines of evidence in support

of the recent stable tectonic character of the Sunda Shelf were summarized in TJIA (1980). Results of systematic investigations on Quaternary shorelines have been summarized earlier by TJIA ET AL. (1977). GEYH ET AL. (1979) published newer data, especially from the Strait of Malacca area. For selected areas along the same strait the Geological Survey of Malaysia has now a number of data, as yet unpublished on higher Holocene sea levels.

GEYH ET AL. (1979) determined 33 reliable radiocarbon dates of shoreline indicators collected from shallow holes in the Strait of Malacca and from the adjacent coast of Peninsular Malaysia. Both regions belong to the tectonically stable Sunda platform. The material used by GEYH ET AL. consist of *in situ* roots and peat deposits. The dates indicate that sea level, very probably of eustatic character considering the tectonic stability of the region, was at least 40 to 60 m lower during the period 36000 to 10000 BP. Further, from 8000 to 4000 BP sea level rose from -13 m to about +5 m with respect to present sea level and then subsided to its present position. The Holocene shorelines interpreted by this study are consistent with those determined from oyster clusters and other biogenic material from other localities in Peninsular Malaysia by TJIA ET AL. (1977). However, GEYH ET AL. (1979) were unable to conclude whether Holocene sea level fluctuated about present datum or that it rose above it only once and then subsided.

An other recent study of Holocene sea levels in Southeast

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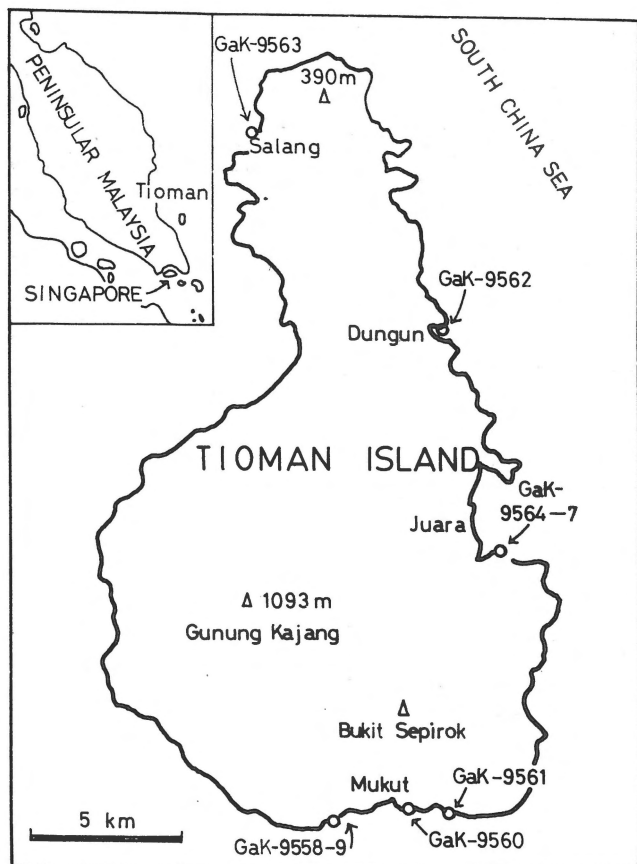


Fig. 1  
Tioman island in the South China Sea. The localities of the ten new shoreline indicators are indicated. GaK = code for Gakushuin Radiocarbon Laboratory.

Asia was published by THOMMERET & THOMMERET (1978) and concerns a 2.5-2.7 m high sea cliff at Jepera on the north coast of Java. The cliff is made up of clastic sediments in which are concentrations of datable material like molluscs (*Cardidae* and *Cerithium* sp. which indicate a shore environment) and corals (*Madreporia*). These sediments rest upon a flat-topped coral head at +1.27 m above mean sea level. The eight samples extracted from certain levels in the cliff indicate that sea level progressively rose from +1.27 m at  $4950 \pm 90$  BP to +2.47 m at  $3650 \pm 80$  BP. The authors interpreted the rise of 0.86 mm per year during that period as possibly eustatic but conceded that it may also be the result of a combination of vertical crustal movements and actual sea level rise. The second interpretation is more likely in view of the fact that Java lies outside the stable Sunda platform and the island is characterized by active volcanism and by frequent earthquakes.

#### RAISED SHORELINES ON TIOMAN

Detailed observations on ancient shorelines were carried out in three coastal regions, i.e. in the vicinity of Juara, Mukut, and Salang (Figs. 1 and 2), while in addition three smaller areas were also investigated.

#### Juara

Juara village lies along a bay on the east side of the island. Most of the bayhead is covered by a sand terrace that slopes from 1.5 m to about 2 m above high tide level. Mean sea level at Tioman island is approximately one metre lower than the high tide mark. The terrace reaches a width of 650 m and near its upper end coral limestone containing *Tridacna* sp. in living position was collected a few years earlier and also dated at Gakushuin. The limestone lies at 3.7 m above mean sea level and is dated  $5930 \pm 115$  BP (its position was erroneously plotted at 5.5 m above high tide mark in TJIA ET AL., 1977, p. 31).

The baysides are formed by rocky headlands while a few smaller rocky projections also occur in the bayhead area. Abrasion terraces that may be 10 m wide are found on the rocks at 1.2 m, 2 m, 2.5-3 m, and 4-4.5 m above high tide level. In protected cavities among the rocks are clusters of dead oysters at 0.4 m, 0.9 m, and 1.6-1.7 m above the high tide mark or above the top limit of living oyster groups. Along the tropical coasts of Southeast Asia the majority of oysters prefer the upper half of the tidal zone and the top limit of these oyster concentrations coincides with the high tide mark. Above this mark a few oysters (usually juvenile specimens) do occur, especially where spray action is important. Among the rocks we also found a slab of calcareous material, 0.7 m above high tide, that is probably a remnant of an algal crust. In our experience, green calcareous algae form crusts in the intertidal zone and reach a top limit of about 30 cm below the high tide mark. Raised and dead algal crusts and living algae forming similar crusts are common on the rocky south coast of Belitung (Billiton) island, Indonesia.

On the sea front of the sand terrace there is a 30 m wide (usually less than 30 m) sand berm that represents a storm berm less than one metre above the high tide mark. Patches of beach conglomerate may occur in the upper 60 cm of the present tidal zone.

A composite profile of the Juara coast is shown in Fig. 2. The following samples were radiometrically dated from this coast (see also Table I):

- (1) GaK-9566, dead oysters, 1.6 m above top limit of living oysters, clinging to huge boulders of metavolcanic rock at the southern promontory; age  $2370 \pm 120$  BP.
- (2) GaK-9567, dead oysters of an other cluster at the same locality at 0.4 m above high tide; age  $2640 \pm 120$  BP.
- (3) GaK-9565, dead oysters at the same locality, 0.9 m above high tide; age  $3160 \pm 170$  BP.
- (4) GaK-9564, dead oysters at the same locality, but from a different cluster at 1.7 m above high tide; age  $4160 \pm 150$  BP.

#### Mukut

Mukut is a village on the south coast of the island (Fig. 1). Sand and coral shingle beaches alternate with rocky stretches

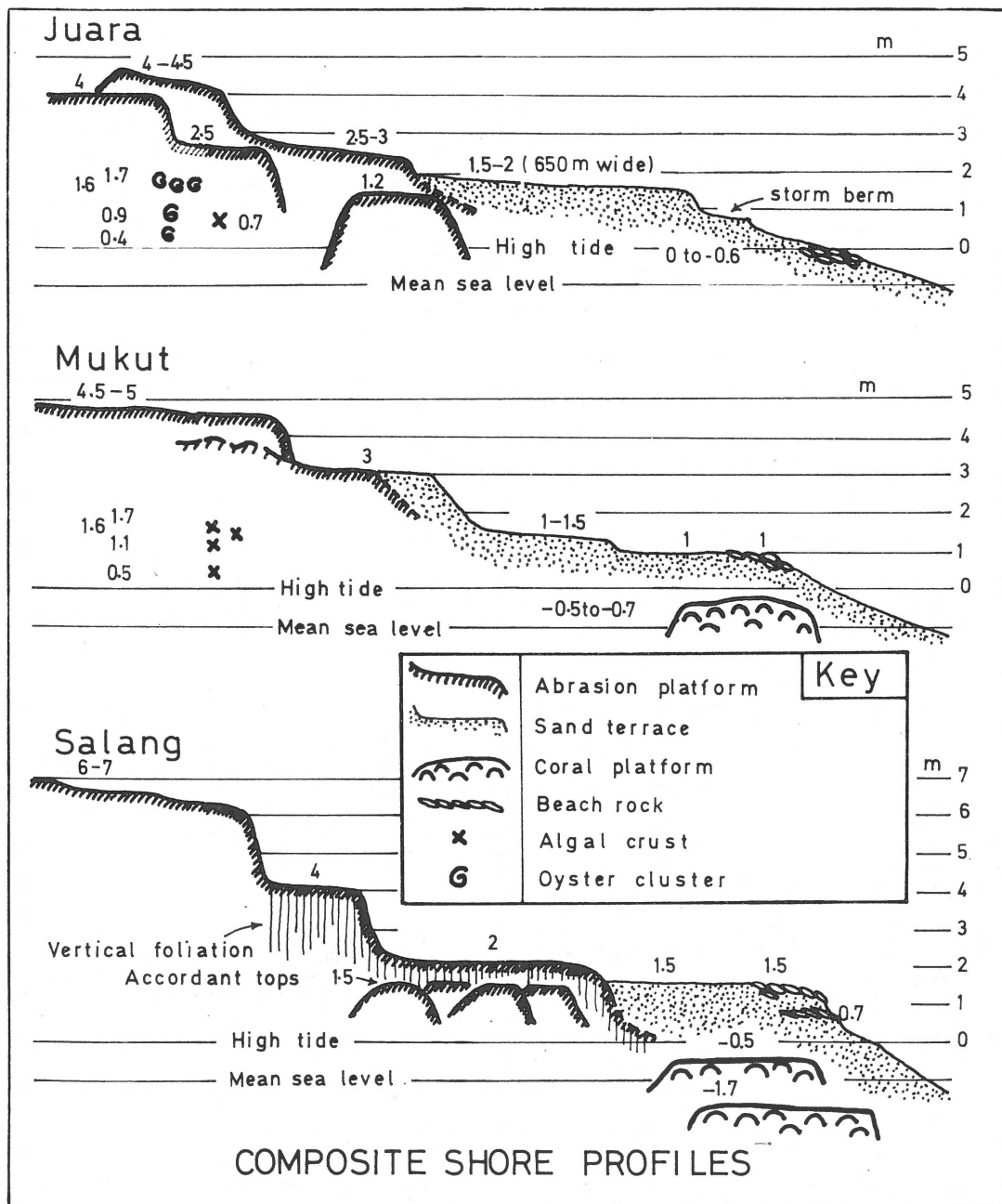


Fig. 2  
Schematic, composite profiles of shores at Tioman. Horizontal distances are not to scale; the sand terrace at Juara reaches up to 650 m across, that of Mukut is in the order of a few tens of metres, while the sand terraces of Salang occasionally reaches up to a hundred metres across.

of coast. All beaches are narrow and some may be elongated parallel to the shoreline. The sand and shingle surface is 1 to 1.5 m above high tide level. In the fractures of metavolcanic rock slabs of calcareous material may be found cementing pebbles and blocks of noncalcareous rocks. These beach breccias or beach conglomerates may occur as high as 1 m above the present high tide mark and were probably formed during a higher sea stand. Two kilometres west of Mukut is a remnant of a sand terrace at 4.5-5 m above high tide. Near the east end of the village are remnants of abrasion platforms and

depositional terraces at 3 m above high tide. In the same area there is a platform consisting of dead coral colonies at 0.3-0.5 m above mean sea level. The platform grades down seaward into living coral colonies that live up to the present low tide level, which is 1.5 to 1.3 m lower than the platform of dead corals.

In the steeply dipping to vertical clefts in metavolcanic rock one often finds calcareous algal crusts of a few centimetres thickness. Sometimes mollusc shells have been incorporated into the crusts. We collected algal crusts from several

TABLE I. Shoreline Indicators of Tioman Island

Age, years B.P.	Type of shoreline indicator	Present position with respect to M.S.L.	Amount of emergence
940 ± 90 GaK-9563	Coral reef now being abraded; abrasion surface is 0.3 m above low tide mark	-0.7 m	+0.3 m up to a few metres
1900 ± 90 GaK-9559	Oyster shells cemented by calcareous algae forming crusts on underside of very large, non-calcareous boulders	+2.1 m	+2.1 m
2370 ± 120 GaK-9566	Oyster shells (dead) still attached to huge boulders of metavolcanic rock	+2.6 m	+2.6 m
2640 ± 120 GaK-9567	Oyster shells (dead) still attached to huge boulders of metavolcanic rock	+1.4 m	+1.4 m
3160 ± 170 GaK-9565	Oyster shells (dead) still attached to huge boulders of metavolcanic rock	+1.9 m	+1.9 m
4160 ± 150 GaK-9564	Oyster shells (dead) still attached to huge boulders of metavolcanic rock	+2.7 m	+2.7 m
4480 ± 150 GaK-9561	Calcareous algal crust in a vertical cleft through metasedimentary and granitic rocks	+1.5 m	+1.5 m
5330 ± 140 GaK-9558	Calcareous algal crust cementing some dead oyster shells and filling a vertical cleft in granitic rock	+2.7 m	+2.7 m
5940 ± 160 GaK-9560	Coral reef being abraded; abrasion platform is 0.3 m to 0.5 m above M.S.L., or 1.3 m to 1.5 m above low tide level	+0.3 m to +0.5 m	+0.3 m up to a few metres
6540 ± 190 GaK-9562	Coral reef being abraded; abrasion platform is +0.5 m above M.S.L., or 1.5 m above low tide level.	+0.5 m	+0.5 m up

M.S.L. = mean sea level; tidal range is approximately 2 metres.

localities at elevations of 0.5 m, 1.1 m, and 1.6-1.7 m above high tide. The following samples were dated:

- (1) GaK-9559, algal crust with some molluscs attached to the underside of large boulders at a rocky cape 2 km west of Mukut village; elevation 1.1 m above high tide; age 1900 ± 90 a BP.
- (2) GaK-9561, algal crust in vertical fissure in metasediment and granitic rock at a cape 3 km east of the village; elevation circa 0.5 m above high tide; age 4480 ± 150 a BP.
- (3) GaK-9558, algal crust incorporating some oyster shells in a vertical cleft at a cape 2 km west of the village; elevation is 1.7 m above high tide; age 5330 ± 140 a BP.
- (4) GaK-9560, coral limestone from abrasion platform at the east end of Mukut village; elevation 0.5 to 0.7 m below high tide level; age 5940 ± 160 a BP.

In Fig. 2 a composite shore profile at Mukut is shown.

### Salang

Salang is located along an open bight near the north end of Tioman. It consists of a sand terrace 1.5 m above high tide. Beach conglomerate occurs in patches up to 0.7 m above high

tide. Seaward the sand terrace slopes down to an abrasion platform composed of dead coral colonies at 1.7 m below high tide level or about 0.3 m above the top limit of live corals (that occur still farther offshore). Coral limestone (GaK-9563) has a radiocarbon date of 940 ± 90 a BP.

Abrasion platforms on rocks, accordant tops of large boulders, raised beach conglomerate, and other reef platforms consisting of dead corals have also been investigated at other localities along the northern shore of Tioman. These features are summarized under 'Salang' in Fig. 2.

### Dungun

A small bay at Dungun on the east coast (Fig. 1) is fringed by a reef platform consisting of dead corals at circa 0.5 m below high tide level. The sample GaK-9562 is part of a colony of dead corals from the platform and is dated at 6540 ± 190 a BP.

## SEA LEVEL FLUCTUATIONS

The coastal morphology, occurrence of beach rock and elevated biogenic shoreline indicators show that higher sea levels

had once surrounded Tioman island. We base our interpretation of ancient sea levels on the following criteria:

- (1) Coral lives up to low tide level and a coral platform very probably indicates such level.
- (2) The top limit of oyster concentration is the high tide mark.
- (3) Calcareous algae live in the tidal zone and their top limit is a few decimetres below high tide level.
- (4) Beachrock is formed in the tidal zone.
- (5) Abrasional terraces are formed at wave base. Close to shore wave base probably coincides with the low tide mark on the sea side and with mean sea level on the land side.
- (6) The surface of depositional coastal terraces may be between wave base level and the height of storm waves. However, the level of wide sand terraces, such as at Juara, very probably corresponds with a position within the lower part of the tidal range.
- (7) We assume that during the Holocene sea level fluctuations (in the order of 3 metres), the tidal range was about 2 metres or similar to the present low tide – high tide range.

On Fig. 3 are plotted the ten new radiocarbon dates discussed in this paper and sample GaK-5484 (coral limestone from a position of 3.7 m above mean sea level from Sungai Baru at Juara and published earlier in TJIA ET AL., 1977). In the figure

coral samples are indicated by vertical solid arrows which also suggest that the corresponding sea level may be somewhat higher than indicated on the graph. Our interpretation of sea level fluctuations between 6000 BP and 1900 BP is shown as a heavy solid line. We consider these fluctuations to be eustatic since Tioman island is situated on a stable platform. The graph further indicates that during that period sea level remained above present high tide level at elevations between 0.4 to 2.7 m and that sea level fluctuated with an amplitude of 1 to 2 metres. It is further suggested by the graph that sea level rose faster (one metre in 300 years) but descended at a slower pace (1 to 2 m in 1400 years).

The dotted line on Fig. 3 represents eustatic sea level fluctuations that were interpreted from about 40 radiocarbon ages of shoreline indicators in Peninsular Malaysia (TJIA ET AL., 1977). For the period 6000 BP to 1900 BP the Tioman sea level curve resembles that of the entire Peninsula. The main difference seems to occur in the period since 2600 BP. There are indications that Holocene sea level was also lower than present mean sea level, but the samples that we have determined up to now were mostly collected from raised shorelines and this bias can be expected to crop up in the sea level curve. It is obvious that we need more samples, especially for the period between 2600 BP and about 1000 BP.

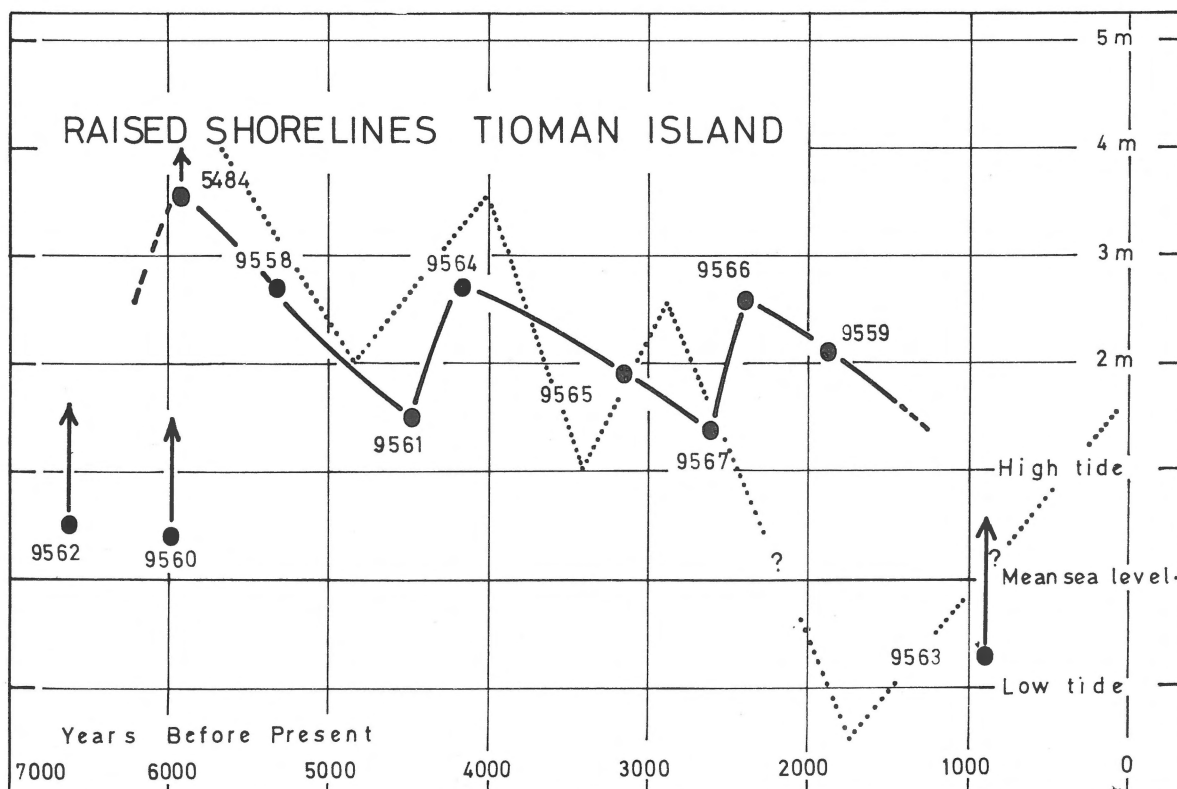


Fig. 3

The heavy solid line is our interpretation of sea level behaviour based on the ten indicators on Tioman island; the dotted line is that on the shores of nearby Peninsular Malaysia and is based on many samples. All shoreline indicators for Tioman have been dated at Gakushuin University. Prefixes GaK have been omitted from the sample numbers.

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