

# PART 1 ENVIRONMENT & PHYSICAL FEATURES



Figure 1.  
Location of the  
proposed Semporna  
Islands Park.

## 1.1. PHYSICAL SETTING AND SUMMARY OF FEATURES

- The proposed Semporna Islands Park lies off the east coast of Sabah at the entrance to Darvel Bay between latitude 4°33'N to 4°42'N, and longitude 118°37'E to 118°51'E. It is about 350 km<sup>2</sup> in size.
- The site is near the edge of the Borneo Island Shelf, with average depths of 50 metres off the western edge of the proposed park, and 130 – 145 m to the east.
- The large, central islands are formed of volcanic rock. The outlying islands are low limestone platforms or sand cays.

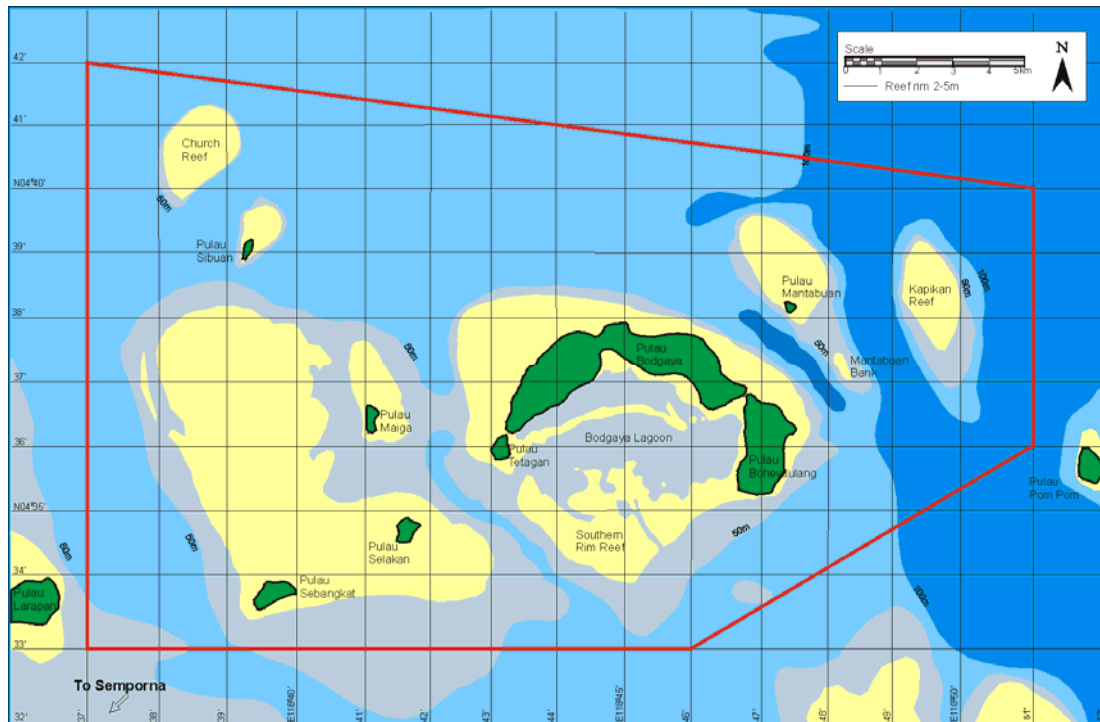


Figure 2. Location of islands and reefs in the proposed Semporna Islands Park

- There are eight islands in the proposed park. Bodgaya, the largest, is about 8 km long and 1.5 km wide. It is 795 ha in size and has three peaks between 455 and 360m in height. The smallest island is Mantabuan, which is a low sand cay of about 10 ha.
- The closest island to the mainland is Sebangkat, which is only about 10km from Semporna, while Mantabuan is at least 25 km away. The other islands in the group are Boheydulang, Tetagan, Selakan, Maiga and Sibuan.
- Fringing coral reefs occur on the outside of all the main islands and smaller outlying islands of Maiga, Sibuan and Mantabuan. Church Reef and Kapikan are both patch reefs which have no island, but are dry in places at low water. To the south of Mantabuan is a submerged reef with the top an extensive plateau at a depth of about 10m.
- Fringing, patch and ribbon reefs also occur within the large lagoon that is enclosed by Bodgaya and Boheydulang to the north and the submerged Southern Rim reef to the south.



Figure 3. Bodgaya and Boheydulang in the background, with Selakan in front, viewed from the Sebangkat reef top.

## 1.2. GEOMORPHOLOGY

The three central islands (Bodgaya, Boheydulong and Tetagan) together form a semi-circular group marking part of the rim of a large volcanic crater now partially dissected and inundated by the sea. The crater rim continues below water as a belt of coral reefs between the southern point of Boheydulong and Tetagan (the Southern Rim reef).

Volcanic rock is unusual in Sabah, with occurrences only in the Semporna peninsula (Kirk 1962). These rocks are mainly of late Tertiary (Pliocene) and Quaternary origin and appear to be related to other volcanics that run in an arc from Semporna through Tawi Tawi island to Zamboanga in Mindanao. The Semporna volcanic sites include the Mt Magdalena–Mt Wullersdorf area behind Tawau (Lim 1981), the Mt Pock area east of this (Lee 1988) and the Bodgaya islands off Semporna.

The Semporna islands are formed from Quaternary pyroclastic material, which was ejected during explosive volcanic activity (Kirk, 1962). There is a mixture of tuff (fine-grained), volcanic breccia (larger angular fragments up to 0.5 m across embedded within the fine material), and agglomerate (large fragments that are more rounded). Beaches on the main islands are formed mainly from coral sand and cobbles of volcanic rocks.

The rocks forming the high cliffs and large shore outcrops are mainly pale to dark grey in colour, depending on the amount of dark minerals they contain (Kirk 1962). There is also some evidence of silicification, as some of the rock material includes quartz grains, and quartz-crystal-lined cavities can be found occasionally. Brown flow-stains over parts of the rock outcrops probably indicate the presence of iron oxide (Sugau *et al.* 1998).

Sebangkat and neighbouring Selakan appear from above-water to be separate from the ‘Bodgaya volcano’. However, despite the 50m deep channel between the two groups of islands, it is likely that Sebangkat and Selakan are part of the same formation – possibly the remnants of a subsidiary (lower) volcano. Evidence for this comes from the atoll-like shape of the Sebangkat-Selakan-Maiga reef complex, and also the presence of a hill of volcanic rock at the northern end of Selakan.

Sebangkat and Selakan are referred to as raised limestone platforms (Kirk, 1962). There is presumably volcanic rock many metres below the surface, with a cap of old reef limestone on top. The reefs were once submerged, but came above the surface as a result of Quaternary sea level changes and tectonic movements which caused recession of the sea from the coast of the Semporna peninsula and uplifting of the land. A later recession of sea level of about 8 to 10 metres in relatively recent times has caused the emergence of other older coral reefs in nearby islands (Kirk 1962).

Also within the proposed park is a bank reef (Mantabuan) and two patch reefs (Church Reef and Kapikan Reef), which may be submerged reefs originally associated with mounds on the seabed. Maiga, Sibuan and Mantabuan are sand cays evidently built from the eroded remains of the surrounding coral reefs. Each has an elevation above sea level of about 1-2m and is situated at the southern end of their respective reef which is generally oval to elongate in shape.

## 1.3. CLIMATE, SEA CONDITIONS AND HYDROLOGY

### Climate

The climate is tropical with two monsoon periods separated by transition periods. The north-east monsoon develops during December and January, bringing rain and steady winds from the north-east. The south-east monsoon occurs during June and July. During the transition periods (March to June and September to November) winds and rainfall are more changeable. These seasons are based on average conditions and in any given year can vary according to the strength of the monsoons.

Mean annual rainfall for Semporna (data from Semporna Agriculture Station) between 1976 – 1995 was 1,866 mm (range 939 – 2,483). Recordings from Tawau Airport over the same period was 1,864 mm with the lowest rainfall from February to April and higher levels during the rest of the year, especially in July and August. Mean annual air temperature over this time was 26.6°C with monthly variation less than 1 °C.

The Bodgaya Islands are partially sheltered from the south-westerly winds by the Semporna Peninsular and Pulau Bum Bum but are relatively open to the north-east. The greater influence of the winds from the latter direction explains the position of the sand cays on Mantabuan and Sibuan at the southern (sheltered) side of the reef top. Full-scale hurricanes do not occur in Sabah, but their residual impact is sometimes felt and strong storms can occur, causing heavy seas.

### Water currents

Overall, there is a prevailing flow of water from the Pacific Ocean through the South-east Asian region to the Indian Ocean. This is driven by the south-east trade winds and is most noticeable in the upper few hundred metres of the water column. One consequence of this is that the Semporna reef fauna and flora has more affinity with marine provinces to the east than to the west.

Within the general pattern of water movement there are many complex patterns at a local level. The current flows around the islands result not only from the influence of ocean currents, but also tide, seabed morphology and other factors. The weakest currents are in the deeper waters of the Bodgaya lagoon, while the strongest are in areas where the seabed or islands deflect or restrict the flow of water. This happens, for example across the top of the Mantabuan Bank reef, through the shallow lagoon entrance between Bodgaya and Boheydulang, and between the Selakan reef and Bodgaya.

There is a diurnal tide, and measurements taken during the 1980 survey showed that the tidal range varied between 1.2 - 2.0 metres (Wood, 1987).

## Water quality

A survey carried out for the Semporna islands Project (Komilus *et al.* 1999) found well-mixed water characterized by high salinity, high dissolved oxygen and high transparency. Levels of suspended solids were low although there was some variation between sites, due partly to influence from the mainland. This was very evident during the diving surveys, with the more turbid, silty reef conditions recorded in the west (e.g. around Sebangkat and Selakan), and clearer conditions to the north and east (e.g. Church Reef and Kapikan). The highest turbidity and levels of sedimentation are in the Bodgaya lagoon.

At the time of the survey in November 1998, water temperature at the sampling sites ranged between 28.8°C and 29.8°C (mean 29.1°C) within the 20-meter water column, and was generally evenly distributed with depth (Komilus *et al.* 1999). Temperature measurements taken during diving surveys from 1998 – 2000 revealed a temperature range from 27°C to 31°C, but generally the temperature was about 28°C. Lower temperatures were encountered on only a few reefs, below about 20m depth, where cool currents were flowing. High temperatures were recorded on the reef top, particularly at low tide. There was an overall slight increase in seawater temperature in late 1998, connected with the global 'El-Nino' event.

## 1.4. ISLAND FEATURES

Detailed maps of the islands are in Part 3 of the Management Plan.

### Bodgaya

This is a high island formed from volcanic rocks, and is the largest in the group, covering an area of 796.4 ha. It is about 8km long and 1.5km wide (Figs 5,6 & 7).

The ground slopes steeply upwards from the shore, leaving a narrow, wave-cut shingle terrace. Mangrove is established along much of the coastal fringe and there are no coral sand beaches as there are on the other islands. Access is possible to most shorelines at high tide, but becomes increasingly difficult at low tide.

The main rock outcrops have steep slopes which begin at elevations of between 10-100m above sea level and have average inclines of 45-60° (Sugau *et al.*, 1998). There are two peaks on the western 'arm' of the island. The main one (Mt Bodgaya) reaches a height of 455m, and to the east of this is a peak that reaches a height of 427m. Another peak (366m) is found on the eastern 'arm' of the island. The two 'arms' are separated by a valley, which cuts through from the north to the south side of the island.

The island terrain is rugged with precipitous faces and wooded valleys. Volcanic rock is exposed in many places, while elsewhere there are deep layers of soil covered with fallen leaves and decaying vegetation. The sheltered slopes and valleys have the richest vegetation and tallest trees. There are a number of freshwater streams on the island, particularly on the north side.

## Boheydulang

This is another high island formed from volcanic rocks, and has an area of 313 hectares. It is separated from Bodgaya by a shallow channel.

The ground slopes upwards from the shore, in some places very steeply, and the island terrain is similar to Bodgaya. There is a ridge running along the length of the island that has three separate peaks. The southern one (Boheydulang Peak) is the highest (353 m), and has a radio mast on the top.

It is possible to walk round the island at low tide by following the narrow fringe of beach and mangrove, although in places this involves scrambling over rocks or through vegetation. Sandy beaches are best developed on the west (Fig 5) and east shorelines, but are largely covered at high tide. Access to most shorelines is possible at high tide, but as the tide falls it becomes increasingly difficult to navigate over the shallow back reef.

There are a number of rock pools on the east side linked by a stream. The pools are 2–3m across and some are fed by small waterfalls. Other streams form if there is heavy rain.

## Tetagan

This island is separated from Bodgaya by a shallow channel and has an area of 30.24 ha.

It is considerably lower than the other two islands, with a maximum elevation of about 80m (Sugau *et al.* 1998). The slopes rise fairly steeply and in places rocks are exposed, but this island has few of the precipitous faces characteristic of its larger neighbours.

The shoreline is rocky in many places, with a narrow beach along the northwest side. This extends into a sand spit at the northern tip of the island (Figure 7). The easiest access is adjacent to the beach, but even here it is difficult to cross the shallow back reef at low tide.

## Sebangkat

Sebangkat is located on the southwest corner of the Sebangkat-Selakan reef complex. It covers an area of 51 hectares. There are two tiny islets of reef limestone to the north of Sebangkat, in the middle of the reef top plateau (Figure 8).

The island consists of coral limestone, raised a few metres above sea level. The limestone bed has been eroded and undercut to form a rocky shoreline around much of the island. There is a good sandy beach at the southwest corner of the island (where the kampong is situated) and this stretches for some distance along the south coast (Figure 9). There is another small stretch of sand on the north-east coast.

Sebangkat has a jetty to provide access to the village. The rest of the island is accessible at high tide, but landing is difficult in the rocky areas.

## Selakan

The island is located on the southeast corner of the Sebangkat-Selakan reef complex. It covers an area of 32 hectares.

The island consists of coral limestone, raised a few metres above sea level. The limestone bed has been eroded and undercut to form a rocky shoreline around much of the island.

There are small stretches of sandy beach around the kampong, and also at the north end of the island. Patches of mangrove occur along the northwest coast.

Selakan has two jetties, so providing easy access to the village. The rest of the island is accessible only at high tide, but landing is difficult in the rocky areas.

## Maiga

Located north of Pu Selakan, it covers an area of 20.16 hectares.

Maiga is a low, sandy island, rather than a raised limestone platform (as Sebangkat and Selakan). However, it appears to be linked to the Sebangkat-Selakan formation, and presumably there may be volcanic rock many metres below the surface, with a cap of old reef limestone on top.

There is a sandy beach running right round the island. The easiest access is at the south-west corner where there is deeper water fairly close to the shore. The rest of the island is accessible only at high tide, provided the boat has a shallow draught.

## Sibuan

Sibuan is located at the southwest corner of a reef which stands alone to the northwest of Bodgaya (Figure 10). It covers an area of 15.12 hectares.

The island is a sand cay that has probably built-up entirely from the eroded remains of the adjacent coral reef. It has an elevation above sea level of about 1-2m.

Limestone beach rock has been formed in several places, particularly at the northern end of the island where there are separate outcrops at various levels on the beach.

Erosion is occurring along the eastern side, especially in the south where the sand and soil at the back of the beach is cut away to a height of about 0.5 m (Figure 11). There is sand spit at the southern end of the island, and it is possible that the island is slowly growing in this direction.

## Mantabuan

Mantabuan is located about 2.5km from the north coast of Bodgaya, at the southwestern corner of the Mantabuan reef. It is the smallest island in the proposed park, with an area of 10.08 ha.

The island is flat with a sandy beach running all the way round (Figure 12). The ground in the centre of the island is hard and compacted, but there are no rocks visible.

There is easy access at high tide along a short section of the southwesterly facing shoreline, where the reef flat is relatively narrow. At low tide this can still just be negotiated provided the boat has a shallow draught.

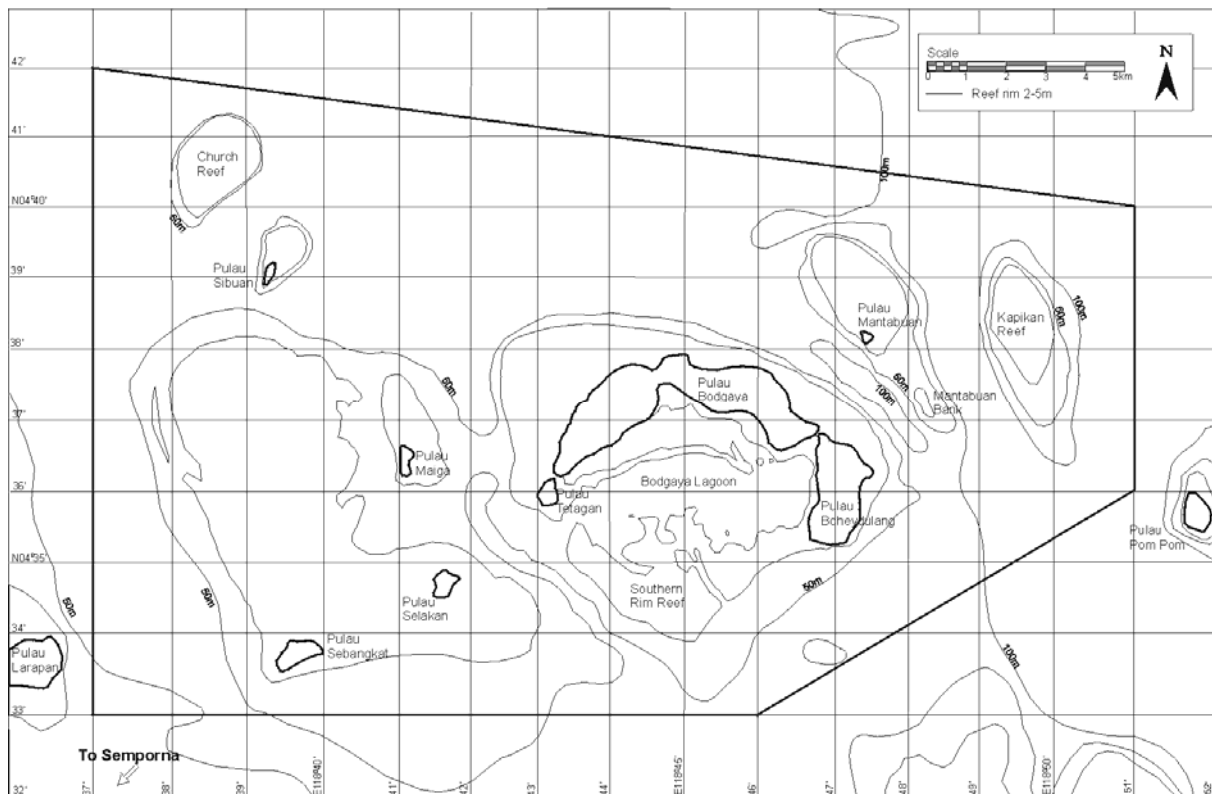


Figure 4. Distribution of Semporna islands and reefs



Figure 5. Bodgaya and the lagoon viewed from Boheydulang. An outcrop of volcanic rock is in the foreground.

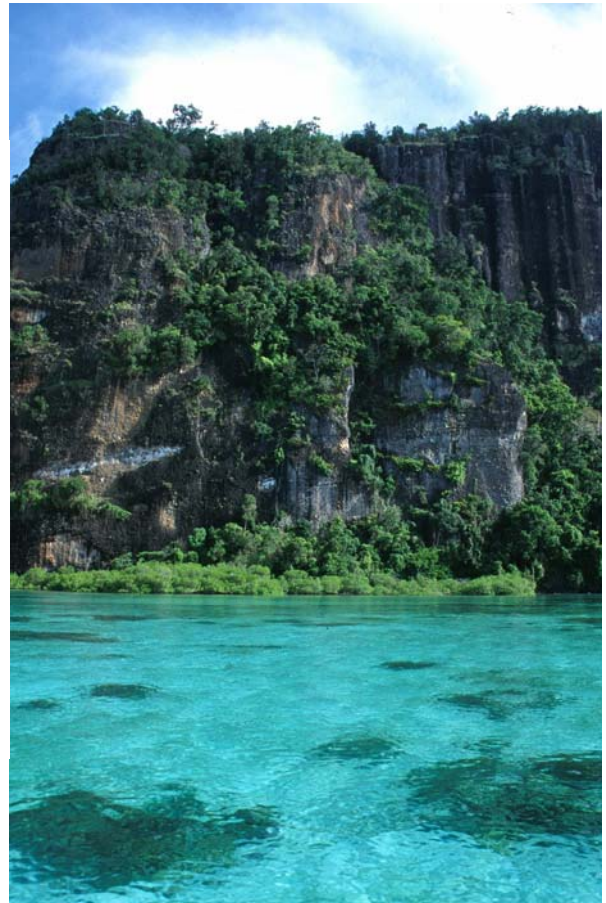


Figure 6. Sheer cliffs on the north side of Bodgaya, beyond the shallow back reef



Figure 7. Sand spit on the north end of Tetagan, with Bodgaya on the other side of the channel.



Figure 8. Isolated outcrop of eroded reef limestone on the Sebangkat-Selakan reef top.

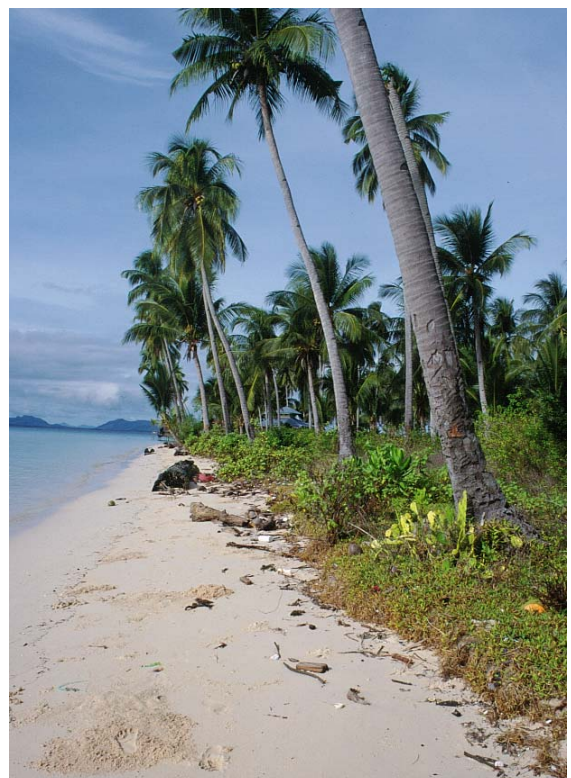


Figure 9. Beach on the south side of Sebangkat.



Figure 10. Pulau Sibuan, seen from the west side.

Figure 11.  
Eroding shoreline on the east  
side of Sibuan.



Figure 12. North beach on Mantabuan.



Figure 13. Seaward rim of the Sibuan fringing reef.



Figure 14. Shallow reef top at Church  
Reef.

## 1.5. REEF FEATURES

### Boheydulang-Bodgaya lagoon

#### Ribbon reef

A narrow ribbon-like reef runs across the lagoon. It is up to 1.5 km from the southern shore of Bodgaya, and is about 5.2 km long. The base of the reef slope on the north side reaches a maximum of around 5 m, but on the south side the reef base is at about 20 m. The slope on the south side is generally fairly steep and indented. Sedimentation is high and the visibility is poor below the reef rim, where there are no currents.

Figure 15.  
Profile of Bodgaya  
lagoon ribbon reef



#### Fringing reef

A fringing reef runs around the inside of the main islands, starting close to the narrow 'neck' on Bodgaya and following along the coast of Boheydulang. It is about 6 km long. The maximum depth of this reef is just over 20 m.

Sedimentation is high and the visibility is generally poor below the reef rim. Moderate surface currents occur near the lagoon entrances either side of Boheydulang, but little water movement was encountered elsewhere.

#### Lagoon side of Southern Rim Reef

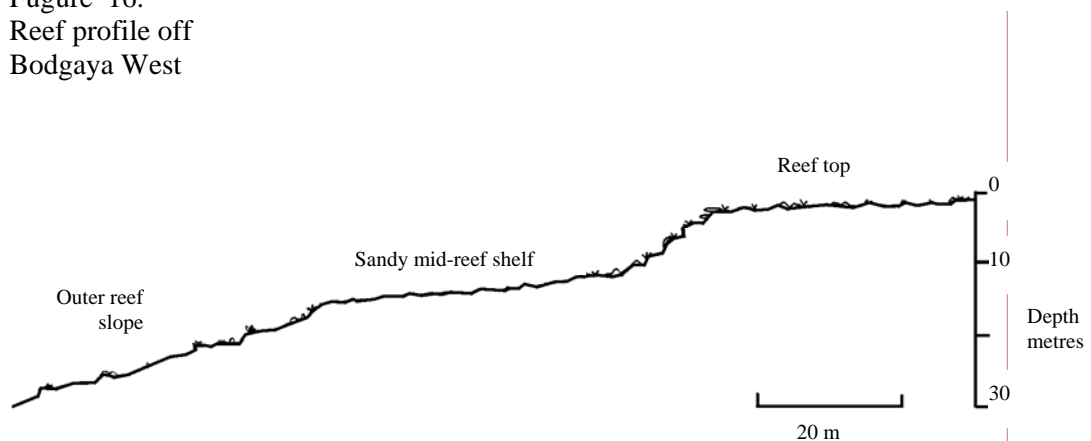
This is a continuation of the fringing reef described above. It reaches a depth of about 20m at the eastern end, but at the western end is no deeper than 10m, and is more gently sloping. There are a number of isolated patches of reef and the shape of the reef is highly convoluted and dissected by shallow channels. Sedimentation is high and visibility is generally poor below the reef rim.

## Tetagan- Bodgaya -Boheydulang outer reef

A continuous fringing reef about 19 km in length runs from opposite Tetagan around the outside of the main islands. The reef front is about 2.5 km from the north-west shore of Bodgaya, but is only a few hundred metres away off the southern end of Boheydulang.

The reef off **Tetagan** and the **west side of Bodgaya** slopes fairly gently, and is shallower and more sheltered than other parts of this reef system. For example, it reaches to about 18 m off Tetagan and generally not more than 25 m elsewhere. There may be a sandy shelf between the inner and outer reef slope.

Figure 16.  
Reef profile off  
Bodgaya West



The **north side of the Bodgaya reef** is more exposed, and reaches a depth of 50 m or more in many places. There is a wide back reef, especially at the western end where the reef rim is over 2km from the shore. There is a fairly steep drop (30° and 45°) from the rim to a depth of about 20m, and then a 'mid-reef plateau' of varying width, but up to a hundred metres or more. Beyond this, the deep outer reef drops very steeply. There is usually an almost vertical section between about 30 to 45 m depth, and below this is a sand slope or plain.

Due north-east, off the **eastern end of Bodgaya** (i.e. facing Mantabuan), the reef drops at an angle of about 45° to a depth of about 22 metres. There is then a very gentle slope at about 20° to a depth of at least 33 metres. This is mainly sand and rubble overlying limestone rock, with the outcrops more prominent towards the outside. Moderate currents occur on this reef, as water flows through the Mantabuan-Bodgaya channel.

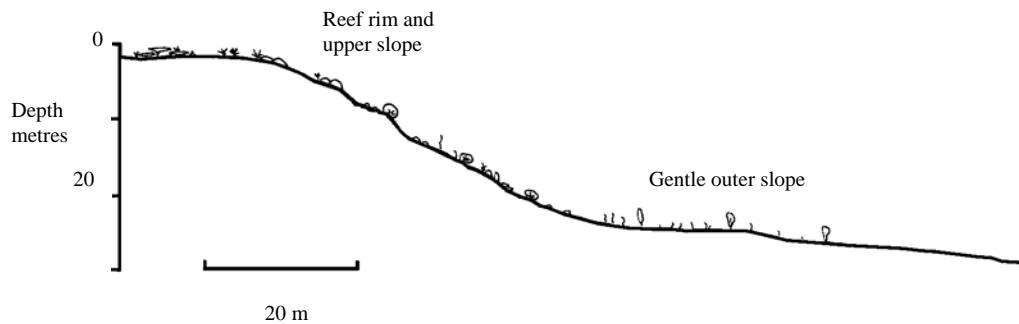


Figure 17. Reef profile off Boheydulang NE

The reef off the **north-east and south coast of Boheydulang** drops fairly steeply at an estimated angle of  $45^{\circ}$  to a depth of about 22 m where there is then a very gentle lower slope of coarse sand and rubble which continues outwards, becoming flatter at about 30 m depth. The reef off the **east coast** has a more gently-sloping profile but reaches the same depth.

### Southern Rim Reef

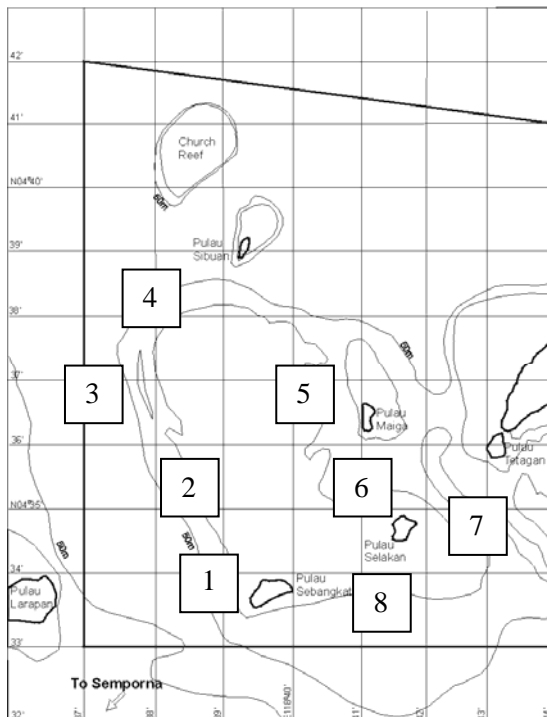
This reef is based on the sunken southern rim of the Bodgaya volcano. It is about 10 km long and reaches a depth of about 30 m at the east end and 20 m at the west.

It consists essentially of a shallow shelf varying in width but generally becoming wider towards the west. The inner side is exposed at low spring tides whilst the outer rim lies in about 3 m of water.

The western end of the Southern Rim Reef (by the lagoon entrance) is completely sandy, and coral growth does not begin until about half way along the south-western facing part of the reef. On this sector of the reef the upper reef slope is quite steep and there is then a fairly flat sandy shelf before the outer reef slope is reached. This ends at about 26m. The rest of the Southern Rim Reef reaches a similar depth but has a more uniform profile, sloping down at about  $45^{\circ}$ .

Towards the southern tip of the reef, about mid-way along its length, there is a channel (**Dead End Channel**) about 100 m wide and almost 1.5 km in length. The channel is open to the seaward side but does not lead into the lagoon (thus the name). The way in which this channel has been formed is not clear, but it may be to a fissure in the sunken crater rim upon which the reef is built. The sides are coral slopes, and they lead to a sandy bottom starting at 18 to 20 m at the base of the reef slope and dipping to 25 m in the centre of the channel.

## SEBANGKAT-SELAKAN



The rim of this reef complex is over 31km long, and encloses a shallow lagoon. There are coral heads in the lagoon and on the reef flats, but the best coral growth is on the seaward side. The deepest reef is to the north and north-west, with poor development on the east side, facing on to the Maiga channel.

The **westerly-facing reef north of Sebangkat** [1] has a fairly uniform and gentle profile of about 30°. The reef ends at a depth of 30 m, below which there is a slope of coarse sand. Further north [2] of the reef the profile changes slightly. The reef rim is at about 6m and drops at an estimated angle of 40 - 45° to a depth of about 20 m. There is then a mid-reef shelf that extends outwards for a distance of about 20m before the outer rim is reached. The final slope is at an angle of about 30° and ends on coarse sand at a depth of 28m.

Towards the **top end of the west-facing reef** [3] there is an outer 'ribbon' reef, separated from the inner reef by a sandy-bottomed lagoon about 20 m in depth. The inner reef slopes at an angle of about 45° and the outer slope is also steep.

Where the reef turns the corner to face **north** [4] the profile changes again. The rim is at about 5 m depth and there is then a very steep (80°) drop-off to 30 m, below which is a lower reef slope of 40° before sand is reached at 38 m. Further to the east the reef still goes down to about 30 m, but the slope is about 45° overall, without any vertical sections.

The **eastern side** [5] faces towards the Maiga reef, from which it is separated by a sandy-bottomed channel. Coral growth along this section is best developed towards the northern end, but the slope becomes progressively sandier towards the south. The **north-facing slope to the west of Selakan** [6] is also sheltered by the Maiga reef, but there is some coral growth here, with the reef reaching a depth of 17 to 22 metres.

To the **east of Selakan** [7] the reef faces on to the Selakan-Southern Rim Reef channel. Coral development is restricted due to the sandy conditions and the base of the reef is at about 12 m. Fairly strong currents sweep along this channel. Coral development on the **southern side of the Sebangkat-Selakan formation** [8] is fairly good. The reef begins to slope very gently downwards at about 4 m depth, with a gentle curve at about 10m leading to an inner slope of about 45°. This ends at 18 m where there is a terrace about 20 m wide before the outer slope is reached. This ends on fine sand at about 30 m depth.

## Maiga

Pu. Maiga is separated from the Sebangkat/Selakan reef formation by a channel about 1-2 km wide which has a charted depth of 40 m. The reef around this island is fairly shallow, except on the north side where it drops to 40 m or more. The length of the reef rim is approximately 7.8 km.

Directly **south from the island**, on the south-facing reef, there is a back reef lagoon about 10 m deep in places and the reef top and rim are at about 5m depth. The seaward reef drops steeply to the reef base at 21 m, and there is then a coarse sand slope of about 25°.

On the **west side**, just north of the island, there is a slope of about 45° from the shallow reef rim down to a depth of around 20m. Beyond this is flat, silty sand. The **east side** of the reef, towards the northern end drops steeply to a depth of about 14 m, beyond which is a sandy plain with occasional rock and coral outcrops. At the **south-east** corner, the reef consists of rock, corals and sand dropping at a fairly uniform angle of 25° to sand at 20m.

The **northern end** of the Maiga reef is much more extensive than other parts. The **north-facing** section drops fairly steeply from the shallow rim at about 2 m to a rock and coral platform at a depth of about 10 m. This drops very gradually to about 15 m over a distance of several hundred metres. At the outside, there is a gently-curving rim leading to the deep reef slope which drops at an angle of about 40° and grades into a steep sand slope at 35 m. To the **north-west**, the channel between Maiga and Sebangkat narrows. The seabed in the channel is sandy with coral outcrops.

## Sibuan

At the **southern end** of the island a white sand beach drops steeply downwards without the formation of a reef, but elsewhere the reef is well developed. The reef is steepest at its northern end, where it reaches a depth of 50 metres. The length of the reef rim is approximately 4.2 km.

The **south-west reef** (just to the north of the island) has a very gentle slope (about 15°) from a depth of about 2 to 10 m. There is a barely discernable rim at 10 m depth and the reef then slopes slightly more steeply (about 25-30°) to 23 m where it grades into a sand and rubble slope. This continues downwards to 30m, where reef limestone re-emerges and drops steeply at an angle of about 50° to the sandy reef base at around 50 m depth. The reef on the **south-east** side slopes initially at an angle of about 45°, flattening off slightly at 25 m depth to a coarse sand slope.

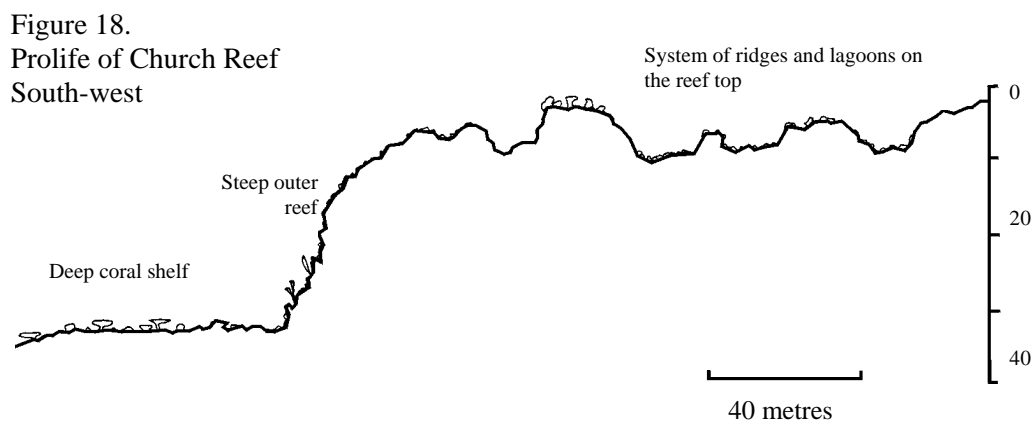
The reef has a steeper profile towards its **northern end**, sloping fairly uniformly at an angle of 45° or more. The reef base is at about 35 m. The very **top end** of the reef, facing due north, has a reasonably well-developed spur and groove formation most obvious between about 5 to 20 m depth. Some sections of the upper reef slope here have an almost vertical profile, on the spurs, while the grooves are steep sand and rubble slides about 10 to 15m wide. The slope continues down at an angle of about 45°, becoming slightly less steep towards the reef base at around 37 m. The lower coarse sand slope continues downwards at an angle of about 35-40° to a least 45 m.

## Church reef

The reef rim has a circumference of about 7.5km. The reef is steep on all sides, with the steepest section in the north-west. The water is generally quite clear and water currents experienced during the surveys were only slight.

There is an extensive shallow reef top and back-reef, with sandy-bottomed and coral-fringed lagoons in many places. A complex system of deeper lagoons occurs at the south-western end of the reef. The depth in these may be 10m or more, and they become almost cut-off at low tide by the outer reef crest.

The **south-west** facing outer reef has an interesting profile with a deep shelf. It drops off very steeply, often at an estimated 80°, with some almost vertical parts and some less-steep chutes. The slope becomes much less steep at the base of the reef at about 35 m, where it then either levels off, or dips down into trough. In places, the base of the trough is as deep as 43 m. From there it rises up again to a depth of about 35 m. This is the start of a rock and coral platform that extends outwards for a hundred metres or more. The shelf slopes extremely gently until a depth of about 40-42 m and then drops very steeply.



In the **north-west** there is a section of reef which has well-developed spurs and grooves and forms a more or less vertical wall between a depth of about 5 to 40 m. This wall has caves and recesses going back about 1m, especially towards the base of the drop-off. At about 40 m depth there is a rock and boulder scree leading to a steep sandy slope.

To the **north-east**, the reef rim curves gently at a depth of about 10 m, followed by a slope of about 45° to a depth of about 20 m. The middle section of the reef then slopes less steeply (about 25°) and in places flattish ledges are formed. This slope continues to a depth of 35m where the profile changes again as the outer reef drops very steeply to sand at about 40 to 45 m depth.

The **south-east** facing reef has a discernible spur and groove formation. The rim is at about 5 m depth, and the reef drops fairly steeply, at an angle of around 45°. The base of the reef is at approximately 26 to 28 m, and below this is a steep, sandy slope.

## Mantabuan

The reef has a circumference of about 10 km, and is shallowest in the southwest where it reaches a depth of about 20 m. It is deepest along the east side, reaching 40 m or more. In many places the reef top is wide and gently sloping. Visibility is generally good.

At its **southern-most point** the reef drops fairly steeply (about 45°) to a depth of 26 m, where it then flattens out slightly to an angle of about 30° as a sand and rubble slope. The reef immediately to the west of the island is shallower and narrower than other parts of the reef. It slopes fairly steeply to about 20 m where there is very gently-sloping sand.

The stretch of reef on the **west side** from the island up to the northern end has wide shallow reef top and a gently-sloping profile overall. There is an indistinct rim at about 10m depth. The main reef slope is at an angle of about 30° and continues to at least 33m, but is mainly rubble and sand below 17 m.

At the **north tip, facing west** there is an extensive shallow reef top (probably 75 to 100 m wide) from a depth of 1 to 6 m. The reef rim is not well-defined, but exists as a very gentle curve between about 6 to 10 m depth. The mid slope between 10 to 20 m depth is gentle (about 15 - 20°), and then grades into a steeper (up to 45°) reef slope which continues on as sand below 35 m depth. The **top end, facing north**, also has a wide reef top, but the upper reef slope is slightly steeper, dropping at an angle of about 45°. The base of the reef is just below 40 m. Beyond that is a sand plain.

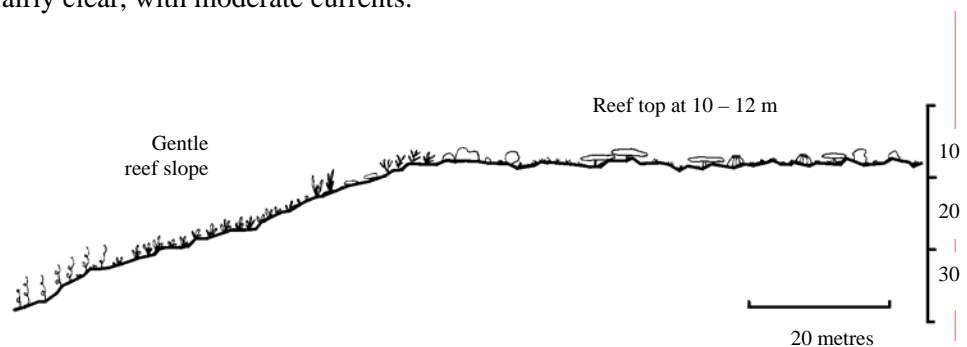
The long sweep of reef in the **north-east** runs in a south-easterly direction from the northern tip and is characterised by a wide reef top with good coral development. There is a gentle slope (about 25 - 30°) from the shallow reef to the start of the deep slope at a depth of about 30 metres. At this point the profile changes to a steep slope dropping at an angle up to about 55°, and in places almost vertical.

## Mantabuan Bank

This reef is situated just over 1 km south of the main Mantabuan reef. It has a circumference of about 2 km, and a flattish top at a depth of 10 to 12 m. The rim curves extremely gently and the upper slope drops at an angle of only about 15-20°. It may then become slightly steeper, but does not exceed about 30°. At 30m depth on the north side it flattens out so that the slope is only 15°, but on the south side it is steeper (about 45°).

The water is usually fairly clear, with moderate currents.

Figure 19  
Mantabuan  
Bank reef

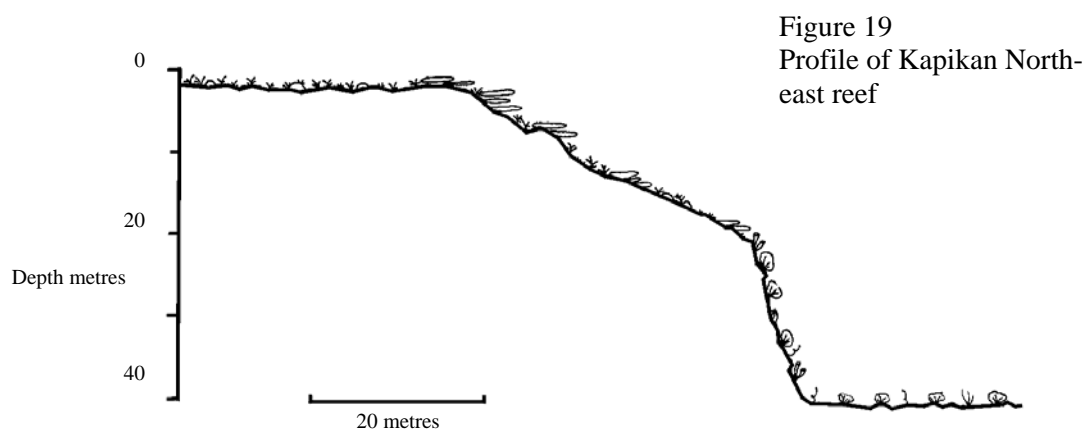


## Kapikan reef

This reef is approximately 3 km long by 1.5 km wide and the reef rim is about 7.3km long. There is no permanent island, but sandbanks appear at low spring tide towards the southerly end, in a comparable position to Pulau Mantabuan. The reef profiles tend to be steeper than on Mantabuan, presumably because of the deeper surrounding water.

On the **west side** of Kapikan facing towards the Mantabuan Bank, the reef drops at an angle of about  $45^\circ$  to 24 m and then flattens out. This deeper section runs downwards at about  $30^\circ$  and consists mainly of coarse sand and rubble with some rock outcrops. Just to the north of this the reef curves round to face due west rather than south-west, and the reef has a different profile. It again slopes down at about  $45^\circ$ , but then continues steeply (about  $40^\circ$ ) to sand at about 50 m depth.

At the **northern end** there is an extensive reef top at a depth of 1 - 5 metres. The top and rim then curve extremely gently (about  $20^\circ$ ), with a slight increase below about 13 – 15 m. By 20 m the slope is about  $45^\circ$  and this continues to a depth of about 34 – 36 m where the reef drops almost vertically to sand at about 40 m depth. The **north-east** facing sector has a similar profile except that the vertical wall starts at a depth of about 22 m.



About half-way down the **east side** of Kapikan, the reef changes direction to run due south. The profile also changes. The reef top is still very wide and fairly gently sloping overall, but with low mounds and undulations. The reef rim is ill-defined but there is a slight change at about 10 m, where the slope is discernable. The reef continues gradually downwards at about  $20^\circ$ , until a depth of about 26 m where it becomes steeper. The slope is about  $35-40^\circ$  and continues down until it reaches sand at about 40 m.

At the **southern** end of the reef, on the east side, the profile is fairly similar, with a wide reef top followed by a gently-curving rim and then the main reef slope. This drops at an angle of about  $30^\circ$  and ends on a sand plain at 36 m depth.