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The Physical Geography and Geology of Northeast Langkawi

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ABSTRACT The Northeast Langkawi is underlain by the Lower Paleozoic Setul Limestone Formation. Uplift and erosion of this sequence resulted in a karstic topography leaving a landform of limestones hills and mogote, caves, arches and sea stacks. The lower portions of the river basins, estuary, coasts and coral reefs constitute the NE Langkawi wetland complex. The infilling of the valley by sediments and later colonized by mangrove swamps and forest on the limestone hills imparted a contiguous mangrove and limestone forest landscape to that area. Steep rocky coasts of the limestones line most of the coast. White sandy beaches of quartzose sand and bioclastic grains are found on the bays facing open sea while muddy tidalflats dominate the protected coasts. In the offshore area, favouvarable conditions allowed coral reefs to grow and flourish. Unchecked development in the drainage basins let to increased sedimentation to this area and threatened the health of the ecosystem.

ABSTRAK Kawasan Timurlaut Langkawi dialasi olih Formasi Batukapur Setul berumur Paleozoik Bawah. Pengangkatan dan hakisan turutan ini menghasilkan topografi kars yang terdiri dari bukit dan mogot batukapur, gua gua, batu gerbang danb stak laut. Bahagian hilir lenbangan sungai, estuary, pesisir dan terumbukarang membentuk satu kompleks tanahbencah Timurlaut Langkawi. Pengisian lembah olih sediment dan dikolonikan olih hutan paya bakau, serta hutan batukapur menjadikan kawsan ini satu persambungan intim antara dua jenis hutan ini. Pinggir batu yang curam membentuk kebanyakan garis pantai manakala pantai pasir yang terdiri dari pasir kuartza yang putih dan butiran bioklastik terdapat di kawasan teluk yang berdepan dengan lautan terbuka. Dataran pasang-surut yang berlumpur terdapat di bahagian pesisir yang terlindung. Di kawasan lepas pantai, terdapat terumbu dikawasan yang sesuai untuk karang hidup. Penbangunan yang tidak terancang di lembangan lembangan tadahan mengakibatkan banyak bahan enapan dibawa masuk kedalam kawasan ini dan mengancam kesihatan ekosistem nya.

(Northeast Langkawi, Lower Paloezoic limestones, wetland complexes, mangrove and coral reefs)

INTRODUCTION

The Island of Langkawi

The Langkawi archipelago consists of a group of 104 islands. Langkawi island which is the largest lies off the northwest coast of Peninsular Malaysia and located approximately at latitude 6°20'N and longitude 99°40' and has an area of 47848ha. Langkawi Island is mainly covered by forest, mangrove, shrub, agricultural land, sand beaches and newly expending developed urban areas. The topography varies from flat coastal plains to hilly areas and rugged mountains rising to 881m above sea level at Gunung Raya. Its geology consist of quartzite sandstone of the Machinchang Formation in North western part overlain by Setul limestone which shows various degrees of metamorphism , shale and minor sandstone of the Singa formation and a massive dolomitic limestone sequence of the Chuping Formation. The sedimentary sequence is intruded by Triassic Raya granite forms the highest peak of Gunung Raya. The coastal plains are covered by alluvium. Administratively, Langkawi Island is divided into 6 mukim namely Kuah, Ulu Melaka, Air Hangat, Bohor, Kedawang and Padang Matsirat.

The Northeastern Langkawi Region

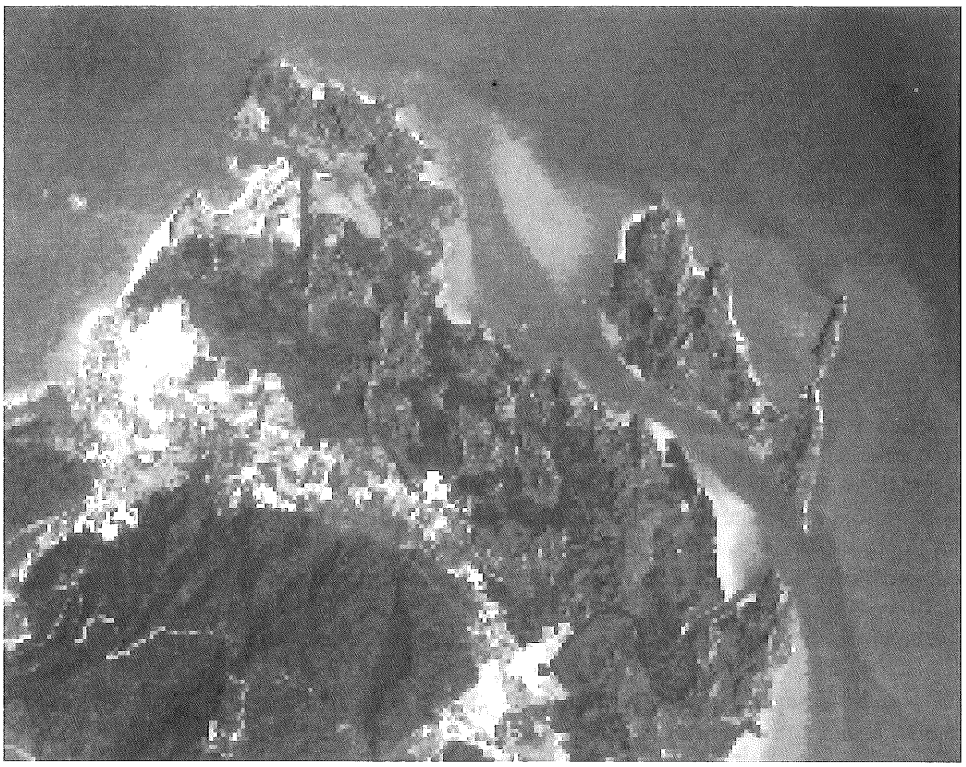


Figure 1. Satellite image of the Northeast Langkawi area.

The Northeast Langkawi region (figure 1) (after this is referred to NE Langkawi) consists of
i) Northeastern portion of Langkawi Island which are part of 3 mukims ; Kuah, Ayer Hangat and Ulu Melaka.
ii) 2 main islands, Pulau Langgun & Pulau Tanjung Dendang
iii) 16 other small Islands, P.Anak Tikus, P. Anak Berangan, P.Kapal, P.Peluru, P.Anak Kilim, P.Tanggok, P.Chempulin, P.Tk.Jong, P.Anak Gua Cherita, P.Gua, P.Belibis, P.Kelam Baya, P.Chabang, P.Pasir, P.Gasing, P.Dangli

Hydrology of the NE Langkawi

The hydrological components of NE langkawi are:

River basins of Northeastern (NE) Langkawi Island

There are 3 main river basins in NE Langkawi, the characteristics of which are summarized in Table 1.

Table 1. Three main river basins in NE Langkawi

Characteristics	Air Hangat Basin	Kilim Basin	Kisap Basin
Main water source	Gunong Raya	Gunong Raya	Gunong Raya and Selat Panchor forest reserve
Length of the river	11.7 km	6.4 km	13.3 km
Maximum width	600m	271m	272m
Mean salinity – lower stream	35.92ppt	36.25ppt	34.67ppt
Mean salinity – upper stream	0.01-0.1ppt	0.01-0.1ppt	0.01-0.1ppt

All the rivers have their source from the Gunong Raya Mountain, with the Selat Panchor Forest Reserve providing additional source for the Kisap river basin. Sg Kisap is the longest river (13.3km)

while the Sg. Kilim is the shortest river. The widest parts of the river are at the river mouths, and Sg. Kilim is 600m wide. Both Sg Kisap and Sg Air Hangat are about 270 meters wide. All the lower courses of these rivers have salinity of sea water and feesh water at the upper courses.

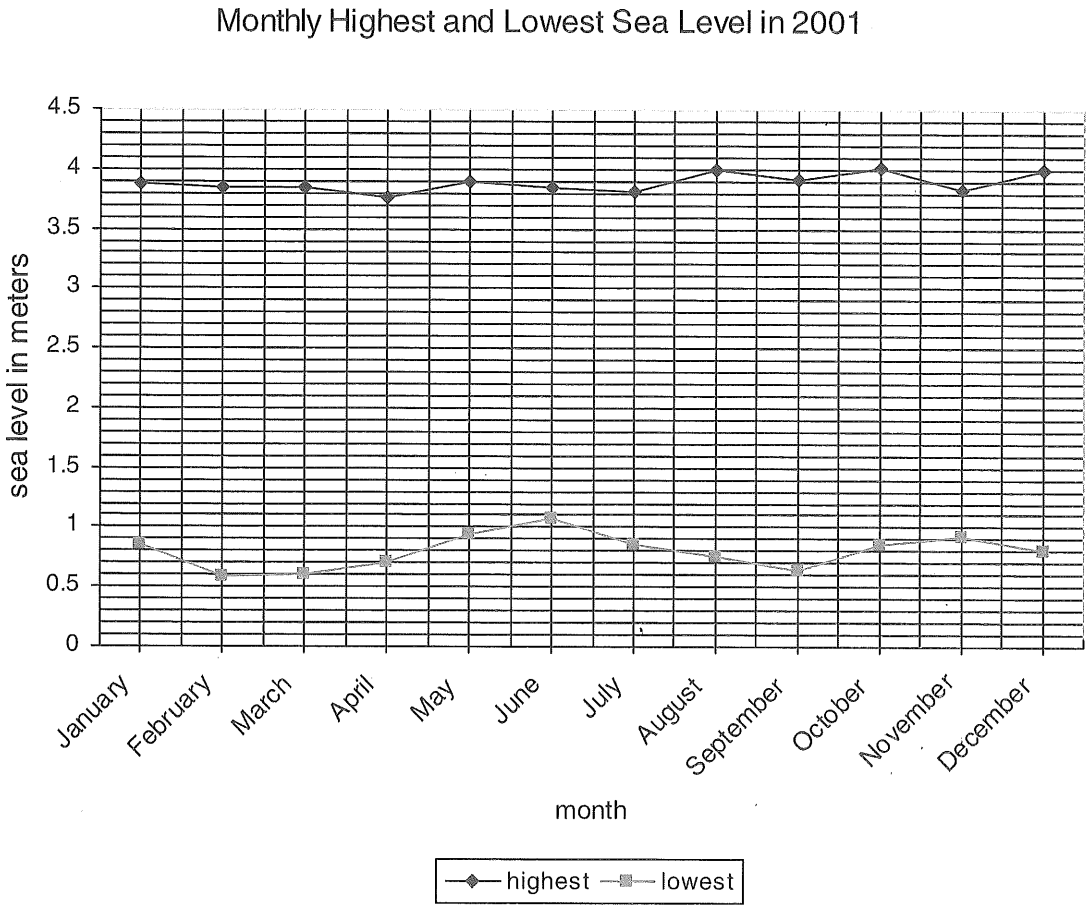
Sinkhole Lake in P. Langgun

The lake is 5.1ha in extent, surrounded by steep slopes (cliffs) about 30 meter high. It has a maximum depth of 6 meters

The man-made canals in Ayer Hangat are 3 km in total length.

Mangrove swamps are present in lower part of Sg. Ayer Hangat, Sg. Kilim and Sg. Kisap basins. Sea water occupy Selat Pulau Peluru, Selat Tikus, Selat Tanjung Dendang

There is no specific rainfall record for NE Langkawi. However, for the whole of Langkawi, the annual average rainfall is between 1600mm – 2500mm and daily average temperature is about 31°C.



Canals

Tides

The tide in Langkawi is semi-diurnal, where there are two highs and two lows each day. All tidal heights and levels are referred to the Zero mark of Tide Gauge at the Telok Ewa Jetty, which is located at 6° 25.9" N and 99° 45.9" E. The monthly mean sea level in 2001 ranges from 2.187m to 2.336m, with the lowest mean sea level occurring in February and the highest occurring in August. The monthly highest sea level is 4.01m in October while the lowest sea level is 0.58m in February.

Geomorphology of Northeastern Langkawi

The NE Langkawi Wetland Complex

The NE Langkawi wetland complex comprising of the lower Sg Kisap, Sg Kilim and Sg Air

Hangat basin, the coasts of the Pulau Langgun and Pulau Tanjung Dendang and the area covered by shallow marine water less than 6meters depth at low tide form the NE Langkawi Complex. The major components of this complex are described below.

The NE Langkawi Complex is interpreted to habe been built around a shallow bay with limestone islands through fluvial deposition and subsequent longshore current reworking. This bay infill was then colonized by mangroves in the shallower part and in the deeper part by coral reefs on to the solid geology acting as hard substrate. Recent channeling connects the three basins hydrodynamically and we consider them as one complex.

Components of the NE Langkawi Wetland Complex

Mangrove
Extensive mangrove swamps are found on the banks of the lower courses of all the three river basins of NE Langkawi and as a thin veneer in some part of Pulau Langgun and Pulau Tanjung Dendang. The landwards side of these mangrove swapms are the man-made bunds which now separate them from human settlements and roads.

Tidal flats
The tidal range for NE langkawi is about 3.5 meters, and it provides a good condition for the formation of tidal flats. Sandy tidal flats are found in Tanjung Rhu area as well as the lower course of Sg Air Hangat. Around the other river mouths, Sg Kilim and Sg Kisap, muddy tidal flats dominate the shore lines. A very large muddy tidal flat is found on the north side of the Sg Kisap river mouth.

Beaches
An extensive sandy beach is found in Tanjung Rhu. Towards the eastern portion of the beach, additional sand has been brought in recently to replenish the beach caused by the slow erosion. Examination of old topographic maps of this area suggests that there was a larger arcuate sand body in this area prior to 1960.

Several other beaches are found in NE Langkawi. The shores of several bays around northeast of Gua Cerita promontory are lined with white sandy beaches where calcareous bioclastic grains forms the dominant sediments. Similar bioclastic sediments are found in beaches of north and northwest of Pulau Langgun and southeastern Pulau Tanjung Dendang and the western seaside of Pulau Pasir. Around Teluk Mempelam and Teluk Cina in Pulau Tanjung Dendang, where the underlying geology is composed of sandstone and shale of the Detrital Bands of the Setul Formation, the beach is gentler and more quartz grains are found in the beach sediments.

Estuaries
All the lower courses of Sg. Air Hangat, Sg. Kilim and Sg. Kisap form estuaries. However, the largest is the Sg Air Hangat with very large body of water, bounded to the northeast by the Gua Cherita promontory. In Sg. Kilim basin, an opening the Setul Limestone provides the path for the river to discharge into the sea. Northeast of this opening the river mouth is very large, and towards the back of this opening a river widens again.

Rocky marine shores
Rocky marine shores dominate the coastlines in NEL. The precipituous karstic slopes of the Setul Limestone are found on the shore of the main Langkawi Island and all the smaller islands in NE Langkawi. Marking the idundation of water on these rocky shores are the barnacles and oysters. The rocky marine shores are around limestone landforms present which include promontories and headlands some of which have associated sea caves, arches and sea stacks.

Coral reefs
Coral reefs signatures interpreted from enhanced Landsat 5 and 7 satellite imageries and aerial potographs were ground-truthed. The main areas in which the field investigations were carried out were the coastlines around Pulau Tanjung Dendang, Pulau Langgun, Tanjung Gua Cherita in the NE Langkawi.

Coral reefs line the eastern coast of Pulau Tanjung Dendang and trends 190 parallel to the coast line, which is interpreted as a fault-controlled coast. The width of the reef is about 50 meters. An exception is at the northeastern tip where the coast swings northwesterly. Here the reef structure is almost triangular being bounded by the northwest fault and 190 fault. On the western coast of Pulau Tanjung Dendang no fringing reef is seen except at the Telok Cina. The clastic sediment underlying the Telok Cina weathers deeply to form a low relief on land and

a gentle slope beneath the sea. This supports a broad reef structure both to the east and west of Telok Cina. To the south of the western P Tg Dendang, small patches of reef occur but are largely covered by sediments.

Mud up to 10cm thick covers much of the reefs on the western coast of Pulau Langgun. This mudcover thins as towards the northeastern where reefs are found rimming the headlands and bays. The largest reef is located at Telok Mempelam but is poorly preserved with a large population of sea urchins in the eastern side and sediment cover in the western side. Hard corals make up most of the coral cover in both Pulau Tanjung Dendang and Pulau Langgun.

On the Gua Cherita promontory, narrow reefs rim the headlands and patch reefs of soft corals, sea anemone and seaweeds dominate the bays Telok Jong, Gua Cherita and Pasir Panjang and Telok Dedap. In the western side of the promontory, a large bay in which Pulau Gua is located, the shallow floor supports the growth of coral knobs, However, the proximity to the Air Hangat estuary inhibit the growth with the high deposition of muddy sediment.

Sinkhole Lake

A large sinkhole whose wall is steep and is about 30 meters high is present in Pulau Langgun. This sinkhole is periodically filled with rainwater and is ephemeral. In the dry months of February and March, this sinkhole may be dry.

Karst topography and features

The Setul Limestone forms typical karst topography of isolated steep range hills and mogote with the larger hills having an average height of about 100m. Due to its low dips, the top of many of these hills and mogote appear to be near horizontal and have similar morphology of a wave-cut platform when viewed from afar. Coastal erosion of these limestone cliff result in the formation of notch and overhanging cliffs, sea caves, bridges and arches. Where erosion has been severe, arches and collapse and result in the formation of sea stacks. Several sinkholes are found, and 3 of these are in Pulau Langgun. The largest of this is filled with water as described under the components of wetlands complex. More than 18 caves of various sizes and of different heights from sea level are found within the Setul Formation in NE Langkawi. The most famous of these caves is Gua Cherita. Gua Kelawar on a distributary of Sg Kilim is often visited for the bat-watching. Both of these are about 3 meters above the water level. Gua Buaya connects the Kilim Basin and Air Hangat basin and is passable by boat at low tide. Large caves are also present in the offshore islands, notably the Gua Tanjung Dendang which are popular with rock climbers as it has a steep overhanging cliff face. Cave deposits are commonly found in these caves. Stalagtites, stalagmites and lesser flowstones are the more common cave deposits. The cave floors are often covered with soils or crusts and droppings of bats and birds.

Geology of the Northeast Langkawi

Stratigraphy

The Setul Limestone Formation underlies the Northeast Langkawi area. They are generally easterly dipping with a low angle. Due to its distance from the Triassic Gunong Raya Granite intrusive, the Setul Formation in NE Langkawi has been spared recrystallisation. However, because to its karstic, direct tracing individual stratigraphic division across the different hills proved difficult. Fossils found by previous workers provide a relative good correlation between the different hills in NE Langkawi and show that the Setul Formation in NE Langkawi contains is the most complete Silurian section. The presence of two detrital bands provides excellent correlations as well as an important tool for the paleogeographic and paleoclimatic interpretation for the region. The Lower Detrital band allowed the limestone to be divided into the Lower Setul Limestone from the Upper Setul Limestone units. The best exposed sequence showing the relationships between these stratigraphic units is at Telok Mempelam in Pulau Langgun and is recognised as the international type-section for the Ordovisian-Silurian-Devonian boundaries.

The Lower Setul Limestone is exposed in hills in Kisap, Kilim, Air Hangat, southern Pulau Langgun and the southern Pulau Tanjung Dendang areas. It is composed of about 1000 m thick thickly bedded grey finely crystalline limestone with silicified fossil remains in the lower part. Fossils present indicate that the age of the Lower Setul Limestone is Ordovisian to Lower Silurian in age.

The Lower Detrital band is composed of 30 meters thick black siltstone and shale with chert beds containing Lower Silurian shelly fossils.

The Upper Setul Limestone is a 100m thick light grey limestone with sparse fossil.

The Upper Detrital band is a 150m thick sandstone shale sequence, with various colour bands of brown, grey, black and red. Abundant graptolites and tentaculites suggest a Lower Devonian age for this detrital band.

Paleonvironments and Paleontology of the Setul Limestone in NE Langkawi

The thick bedded, grey limestone of the Lower Setul contains a rich Ordovician fossil fauna, mainly silicified remains of nautiloids and sponges. Also abundant are benthic organisms in the form of gastropods and brachiopods. Sedimentological studies indicate a shallow marine, peritidal depositional environment, with the sea-bottom inhabited by a diverse benthic fauna.

Table 2. Various taxon found at Pulau Langgun and Pulau Tanjung Tembus Dendang

Group	Taxa	Pulau Langgun	Pulau Tanjung Tembus Dendang
Brachiopods	*Strophomenoid indet.*	X	X
Gastropods	*Malayaspira* sp.	X	
	Malayaspira rugosa	X	X
	Lesuerilla sp.	X	
	Lesueurilla zonota	X	
	Palaeomphalus giganteus	X	
	Helicotoma sp.	X	
	Helicotoma jonesi	X	X
	Helicotoma costata	X	X
Hautiloids	*Ormoceras langkawiense*		X
	Endoceras sp.	X	
	Discoceras (Hardmanoceras?) *chrysanthemum*	X	
	Discoceras (Hardmanoceras?) *laeviventrum*	X	
Brachiopods	*Plectambonid indet.*	X	
Gastropods	*Megalomphala sp.*	X	
	Lophospira sp.	X	
Trilobites	*Dalmanitina malayensis*	X	
	Stenopareai sp.	X	
Graptolites	*Monograptus sedgwickii*	X	
	Monograptus convolutes	X	
	Monograptus gregarious	X	
	Monograptus cyphus	X	
	Dimorphograptus malayensis	X	
	Glyptograptus persculptus	X	X
	Glyptographus tamariscus	X	
	Climacograptus medius	X	
	Climacograptus scalaria	X	
	Diplograptus modestus	X	

The black carbonaceous shales, siltstones & cherts of the Lower Detrital Member contain remains of several graptolite species, trilobites & some gastropods. The graptolites give an Early Silurian age for this unit. The predominance of planktonic organisms (graptolites) and sparse benthos, coupled with the carbonaceous nature of the sedimentary rock, indicates an anoxic to dysoxic basinal facies inhospitable to benthic life.

The Upper Setul Limestone contains fossils of hyolithids, nautiloids (eg. Ormoceras), crinoids and trilobites, which give an age from Late Llandovery to Upper Silurian. Silurian conodonts have also been reported [1]. The discovery of plated type scyphocrinoid loboliths by [2] in upper beds of the Upper Setul Limestone puts the Silurian-Devonian boundary near the top of the unit. The thin, planar bedding and predominance of pelagic fauna indicates a pelagic facies, relatively deep, with sparse

benthos inhabiting the low oxygenated bottom. The dark colour of the limestone indicates sluggish water circulation.

The black shales of the Upper Detrital Member (renamed by Meor, 2003 as the Lallang Member, see also his paper in this volume) are rich in fossils of small planktonic animals and several benthos. The most abundant taxa are the dacryoconarid tentaculitids, especially Styliolina. The genus Nowakia is used to determine a precise age of the beds. The occurrence of Nowakia (Turkestanella) acuaria acuaria puts the age as Early Devonian (Upper Pragian – Lowest Emsian). The small brachiopod Plectodonta (P.) forteyi is also found in the beds, but in fewer numbers. This brachiopod enables correlation with similar tentaculitid beds of the Pa Samed Formation in southern Thailand. Also found are graptolites such as Monograptus langgunensis. The predominance of pelagic organisms (dacryoconarids & graptolites) & sparse benthos (<5 taxa) suggest an inhospitable sea bottom. The black colour of the beds, lack of bioturbation & good fossil preservation indicate an anoxic biofacies. The depositional environment was a relatively deepwater marine basin showing low circulation due to slight restriction from the open sea & tropical climate.

Table 3. Taxon at Pulau Langgun

Lalang Member, Pulau Langgun	
Group Taxa	**Taxa**
Brachiopods	*Plectodonta (Plectodonta) forteyi*
Dacryoconarid tentaculitids	*Nowakia (Turkestanella) acuaria acuaria* *Styliolina fissurella* *Styliolina minuta* *Metastyliolina sp.*
Graptolites	*Monograptus cf. uniformis* *Monograptus langgunensis*

Geological history

The geological history of NE Langkawi begins in the Ordovician with the deposition of the Setul Limestone Formation on a carbonate platform. This carbonate platform persisted into the Silurian. Major relative rise in sealevel resulted in the drowning of this platform on two occasions with fine grained clastic deposits smoldering the carbonate deposits. A major transgression in the beginning of Devonian led to the change in sedimentation from a carbonate platform to a clastic shelf and basinal deposits of the Singa Formation. Intrusion of the Langkawi sediments by Gunong Raya Granite in late Triassic did not affect the Setul Limestone. Uplift and erosion of the landmass led to its karstification. With the lowered sealevel in Quartenary followed by sea level rise in the Holocene, the valleys between these limestone hills and mogote were drowned and later filled with sediments derived from the higher relief area of Gunong Raya brought down by the major rivers, the Air Hangat, Kilim and Kisap Rivers. Reworking of the sediments on the northern shore of NE Langkawi by longshore currents resulted the construction of the large Tanjung Rhu spit effectively narrowing the Air Hangat river mouth and the creation of a major estuary. In the other lower energy environment along the coastal plains, mangrove colonization began. Offshore, favouvarable condition allowed the deposition of calcareous beds and growth of coral reefs. The myriad of coastal habitats in the three river basins and the smaller islands resulted in the emergence of a complicated and varied wetland complex in NE Langkawi.

CONCLUSION

Major geological events and the interplay of present-day tides, waves and fluvial processes resulted in the development of the NE Langkawi Complex. Recent channeling across the three river basins connects them hydrologically and they are thus considered as one wetland complex. Major threats to this complex appear to be uncontrolled land development on the hinterland and pollution from human settlements.

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