EXPEDITION TO MALIAU BASIN, SABAH

APRIL - MAY 1988

FINAL REPORT

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YAYASAN SABAH FORESTRY DIVISION IN CONJUNCTION WITH WWF - MALAYSIA PROJECT
NO. MY5 126/ 88

EXPEDITION TO MALIAU BASIN, SABAH

APRIL - MAY, 1988

FINAL REPORT

Organised and Sponsored By

YAYASAN SABAH FORESTRY DIVISION (RAKYAT BERJAYA SDN BHD) P O BOX 11623 88817 KOTA KINABALU	and	WORLD WIDE FUND FOR NATURE MALAYSIA P O BOX 10769 50724 KUALA LUMPUR
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Compiled By

Clive W. Marsh
Yayasan Sabah
Kota Kinabalu
June, 1989

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All the participants owe a very large debt to the Royal Malaysian Airforce (Region II) which ferried us all safely in and out of a very remote site. Without this helicopter support there would have been no expedition. The only casualty of the expedition was Puan Anthea Lamb, who broke her leg when a tree top fell on her shortly after landing. She was immediately splinted up and ferried to hospital in Kota Kinabalu. The organizers would like to thank especially Brigadier-General Datuk Huang Chew Siong, Lt. Kol. Sharkawi Hj. Hasbie and Major Benjamin Yong for permitting and arranging these flights.

Yayasan Sabah Forestry Division staff at Luasong Forestry Centre, near Tawau, kindly relayed our radio messages and the Yayasan Sabah Tawau Regional Forestry Manager, En. Gerald Hiu, also visited the camp by helicopter one day and brought some welcome additional rations!

Back in Kota Kinabalu, Tengku Adlin provided essential liason in mustering the participants for the second phase of the expedition. Having hoped to participate himself, Tengku eventually dropped in for a day with a special visitor, the Sabah Chief Minister, Y.A.B. Datuk Joseph Pairin Kitingan. We were all very honoured by the Chief Minister's evident interest in the expedition and the area.

With regard to technical assistance after the expedition, this is acknowledged by section authors, but it is appropriate to mention here that the identification of the Rafflessia specimens is due to En. Kamarrudin Mat Salleh of the Universiti Kebangsaan Malaysia - Sabah Campus, while the identification of fish specimens was checked by Datuk Chin Phui Kong, the former Director of the Sabah Fisheries Department. En. Lawrence Frederick and En. Malik Guriaman kindly traced several of the maps for this report. Cik Jessie Tan skillfully and cheerfully retyped all the original material, reset many of the figures on the computer and guided the report through several drafts.

To all these people, Yayasan Sabah and WWF-Malaysia are most grateful.

CLIVE MARSH
EXPEDITION LEADER

EXECUTIVE SUMMARY

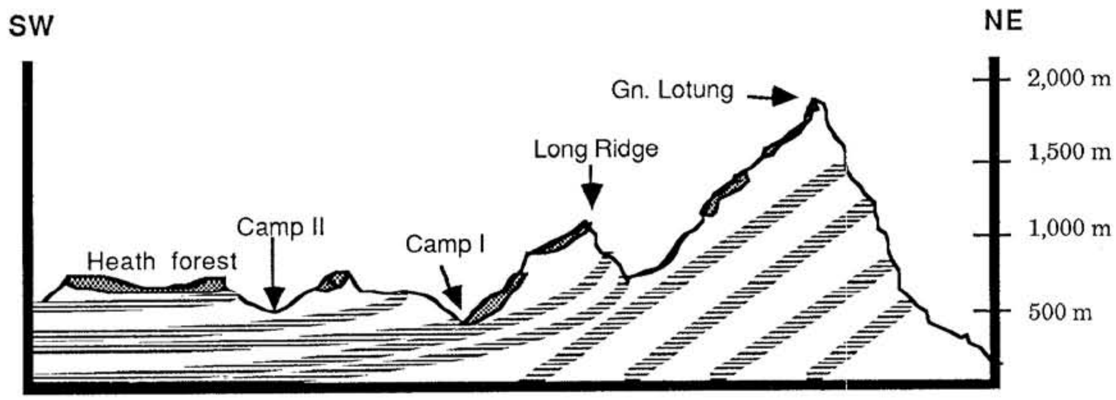
This report presents the findings of a three-week expedition by 43 people in April-May, 1988, to the 390 sq. km. Maliau Basin, in south-central Sabah. The Basin is subcircular in shape, 25 km in diameter and surrounded by a scarp up to 1,500 m in height around most of its perimeter. The highest point is Gn. Lotung on the north rim which is about 1,900 m a.s.l., but has never been accurately surveyed. Drainage of the Basin is via a narrow gorge on the south-east side through which the Sg. Maliau passes before joining Sg. Kuamut and thence the Sg. Kinabatangan.

The Maliau Basin forms one of two Conservation Areas within the Sabah Foundation Forest Concession. The objectives of the expedition were to document the ecology and conservation value of the area, to publicise its attractions and to obtain information on which to base possible future development of the area for visitors. The area is in pristine condition and until 1988 had rarely been visited by anyone, and never by a large scientific group.

Base Camp for the expedition was located near the centre of the Basin beside the Sg. Maliau at 490 m elevation and 2.5 km upstream of the spectacular Maliau Falls. A second camp 3 km south at 880 m elevation was set up close to an area of stunted, heath forest developed over shallow, sandy soils. Principal findings were as follows:

Geology

The Maliau Basin contains the Tanjong Formation, which consists of exceptionally deep (12,000 m) sedimentary beds of gently inclined sandstone and mudstone strata of lower to middle Miocene age. The presence of carbonaceous material and coal seams indicate an estuarine to brackish environment of deposition, comparable to the present day Baram delta. An interpretive cross-section from NE to SW of the Basin looks like this:



Basin structure is not concentric and the south rim heath forest zone near Camp II is located on the youngest sediments. Deeper strata curve upwards as dip slopes and ridges which end abruptly in steep scarps representing the result of weathering and river incission. Spectacular waterfalls, such as the Maliau Falls, also owe their origins to erosion of the interface of hard sandstone with softer mudstones. Of the two largest steps in the Maliau Falls, the upper one measured 28 m and the lower one was estimated at 15 m.

Embedded in some of the mudstones are thin strata of medium to high grade coal. One of these seams which surfaces outside the Basin on the north rim is reportedly as much as 2.5 m thick and has been the subject of a recent commercial survey. There are also good prospects for oil, which would probably concentrate along fault lines flanking the Basin on the east and west sides.

Soils

Soils were investigated in a series of pits and augerings along an altitudinal transect from Base Camp to the heath forest. In the heath forest, a layer of peat up to 50 cm deep directly overlies weathered sandstone with the consistency of hard clay. Although a spodic (iron) horizon is only weakly developed, these are essentially podsols, extremely poor in nutrients. Elsewhere on the main trail slope, soils are better developed but young (probably cambisols), except in the narrow riverine strip where more fertile silts predominate.

Hydrology, Geomorphology and Climate

The Maliau River waters tend to an acid condition (ph 4.5-6.8) and are deeply tea-coloured, due to humic substances leached from vegetation in the heath forest zone. Besides discolouration, flood waters also carry a high load of fine silt due to constant erosion and slumping of the steep valley slopes which are mostly of soft mudstone. The riverbed alternates between shallows with sandstone boulders and muddy-bottomed deeper pools. The potential for accelerated soil erosion following any disturbance in these valleys is extreme.

Rainfall during the expedition was low (the visit was deliberately timed for the dry season) but 7 rainy days were recorded with a maximum fall of 30.8 mm. Maximum temperatures at Base Camp ranged from 28-35°C and minima from 19.5-21°C. Interestingly, recordings along an altitudinal transect showed that both the lowest and highest temperatures occurred at 1,110 m in the heath forest, because this is a particularly exposed environment.

Plant Studies

Although there was relatively little flowering activity during the expedition, six groups of botanists between them observed or collected over 450 species.

Lowland forest near Base Camp was the most intensively worked zone, with many dipterocarps (Shorea, Dipterocarpus, Parashorea, Hopea spp., etc.) and other lowland genera. Fruit trees (Nephelium, Artocarpus, Durio and Garcinia) seemed particularly abundant on the gentler slopes, where many Fagaceae (Lithocarpus and Castanopsis spp.) were also observed fruiting. One mango collected proved to be a new record for Borneo. Palms generally, and especially large rotans, were noted to be common throughout the area. Notable discoveries were made of two flowers of the newly described Rafflessia tengku-adlini. These were collected and filmed.

A transition from lowland to lower montane coniferous forest occurred close to Camp II at 990 m elevation and was very sharp. Agathis dammara, Podocarpus polystachyus, Phyllocladus hypophyllus, and Dacrydium beccari are all common in the coniferous forest together with Casuarina sumatrana and seraya bukit (Shorea platyclados). Canopy height is lower and more even than in the lowland forest and an abundance of saplings gives a "pole-forest" impression.

Above this narrow coniferous zone lies a large plateau of lower montane heath forest at about 1,100 m with a relatively open canopy to about 12 m in height, dominated by Tristania spp. and Dacrydium beccari. Closer to the ground is a dense, mossy tangle of low species diversity, including Ternstroemia spp., Calophyllum spp., Syzigium spp., as well as pitcher plants (Nepenthes spp.), rhododendrons (Ericaceae) and orchids (Orchidaceae). The dry conditions meant that little fertile orchid material was collected but the rhododendrons R. duronifolium and R. longifolium were flowering. Two important discoveries were of an apparently new hybrid between two pitcher plants (N. veitchi and N. stenophylla), and a first record in Sabah of N. hirsuta, otherwise known from Sarawak and Brunei. Among the orchids there are at least two new records for Sabah - Bulbophylum limbatum, Nephelaphylum trapoides and two possibly new species of Bulbophylum and Coelogyne.

At higher elevation on the north rim that was not closely studied during this expedition, lower montane heath forest grades into an upper montane formation of lower, gnarled stature which includes many of the same species present, but also abundant bamboo and mosses.

Vegetation mapping from aerial photographs indicated that only 11.7% of the Maliau Basin comprises lowland (hill dipterocarp) forest below 2,500 ft (672 m) elevation. 20.5% is classed as small-crowned (heath) forest while 62% comprises a lower montane forest of medium crown-size. This category includes both oak and conifer dominated areas.

Animal Studies

Taxonomic coverage was patchy, focussing mainly on the higher vertebrates. However, some collections were made of insects and fish. The fish fauna was remarkable for its paucity of species. A single small catfish (Mystus nemurus) dominated catches from the main river with only one other species (Puntius sealei) apparently present either above or below the Maliau Falls. A small "fighting fish" (Betta unimaculata) was common in the nutrient-poor streams draining heath forest.

Only a few incidental observations of amphibia and reptiles were made (including a very large reticulated python), but 175 bird species were recorded. One outstanding rarity seen in the heath forest was a male Bulwer's Pheasant – apparently the first record for Sabah in several years. In general, the list for heath forest (20 species) is much shorter than for the lowland forest. A surprising observation in all habitats was a scarcity of raptors, which has no obvious explanation.

Mammal studies included standard diurnal transect walks, nocturnal mist-netting for bats and small-mammal trapping. 47 species were recorded in all. The lowland fauna is abundant in pigs, deer and monkeys and generally typical of hill dipterocarp forest. Rarities sighted include proboscis monkeys (at 650 m elevation and 600 km from the sea by river!), clouded leopard, Sumatran rhino (spoor only), the squirrels Glyphotes simus, Rheithrosciurus macrotis, and an unconfirmed sighting of Nannosciurus melanotis, which could be a new record for Sabah. Small mammal trapping results were disappointing but supported the notion that the heath forest is a far poorer habitat than the lowland forest.

A notable feature of the mammal fauna is a large migrating population of bearded pig (Sus barbatus). Breeding nests about 1-2 months old were commonly seen and it seems likely that pigs occasionally migrate in large numbers into the Basin to exploit areas of fruiting oaks or dipterocarps. The natural game trail through the heath forest, known as "Jalan Babi" is apparently a prime migration route into the more fertile lower parts of the Basin from a low point on the southern rim. With the exception of pigs, the Basin appears a largely "closed" ecosystem with little movement across the rim or up the steep Maliau River gorge.

Human Impacts

The Basin appears to be almost uniquely free of human visitation or exploitation. However, a glazed stoneware fragment was found, which probably represents evidence of former visitation by a hunting party. Even very rare (but thorough) visits of this sort could have a profound effect on rhino populations for several decades. The apparent rarity of rhino in the region is otherwise puzzling.

Future Management

The Maliau Basin and its surroundings have proven coal deposits and potential for petroleum reserves. The coal seems unlikely to be economically attractive for some years, but if it is ever mined, it would probably be taken out laterally from the base of the north escarpment of Gn. Lotung. Oil, if present, would probably be drilled for from outside the Basin, near the Pinangah or upper Kuamut Rivers. Even if mining or drilling occurred outside the Basin, related activities would still have a serious impact on the Basin, through increased access to prospectors, hunters and rotan collectors, beside wider effects on the Ulu Kinabatangan generally. Before any decisions are made on resource exploitation of this kind, it is essential that a detailed Environmental Impact Assessment be carried out with geographic terms of reference to include the entire upper Kinabatangan region. The hydroelectric potential of the Maliau Gorge may also one day be considered and, from the planning standpoint, the absence of human habitation and favourable rock exposures are attractive features. However, Sabah still has numerous other sites with hydro potential which are much closer to urban centres and could be developed more cheaply and without sacrificing such a valuable protected area.

Logging is another potential threat. Workable dipterocarp forest comprises only 9.1% of the Basin area and being in the centre of the Basin this is all highly inaccessible. The ridges at higher elevation support scattered Agathis trees but these would only be accessible by a circuitous road system running around the rim and then inwards along ridges towards the centre of the Basin. Recent logging right to the rim outside the Basin on the west side at about 1,100 m a.s.l. shows that access would be feasible in places. However, unit extraction costs for a large operation within the Basin would be high and as noted above, resulting erosion would be extreme. Yayasan Sabah is committed to leaving the entire Basin undisturbed as a Conservation Area.

In the context of Sabah's protected area system, the Maliau Basin contributes, firstly, an outstandingly undisturbed and self-contained ecosystem with a rich lowland and montane fauna and flora. Secondly, the montane heath forest and associated transitional coniferous forest supports a quite distinct assemblage, the like of which is not currently protected elsewhere in the State. Thirdly, the scenic spectacles of the gorge, the Maliau Falls and the north rim escarpment are outstanding. By any reckoning, the Basin ranks as one of the finest wilderness areas in Malaysia.

One modest addition to the existing 390 sq. km. Conservation Area would add a further major feature to it at very little cost in terms of foregone timber. This is Lake Linumunsut in the Inarad lowlands immediately north of the summit of Gn. Lotung. The lake has been quite well studied by Forest Department expeditions in the 1970s and merits protection as a rare landform with a rich lowland flora set against a magnificent 1,500 m escarpment. By Murut legend, the lake is also inhabited by a dragon! Following minimum catchment boundaries the Linumunsut extension would add only about 6 sq. km. to the Maliau Basin Conservation Area, of which about half would otherwise have been commercial forest.

In view of the likely future pressures to exploit mineral or other resources in the Maliau Basin, it is proposed that the area be developed to give limited visitor access. Timing for this will depend on the development of logging roads near to the area but may be appropriate by the early or mid-1990s. The proposed strategy is to build a road access up the south rim at its lowest point and to create the reserve headquarters on a stream close to the south rim heath forest. Entry beyond this point would be on foot via Jalan Babi to expedition Base Camp, the Maliau Falls and Long Ridge. Great care should be taken to retain the outstanding wilderness value of the Basin.

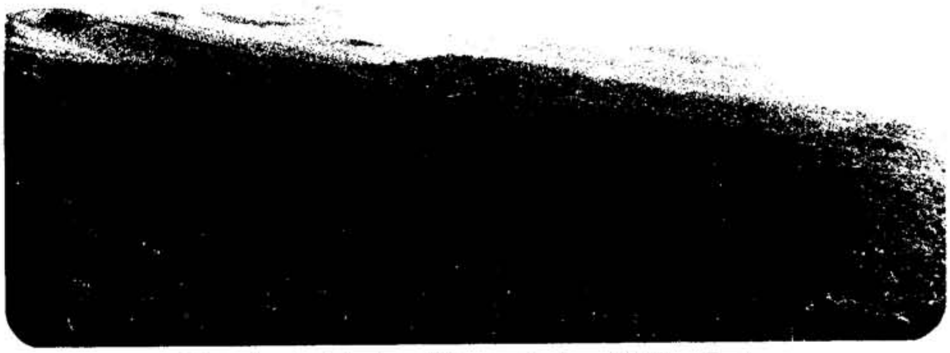


Plate 1. Aerial view of the north rim of Maliau Basin

Plate 2. Aerial view of Lake Linumunsut from near Gn. Lotung

Plate 3. Members of the first phase of the expedition assembled on the helipad.

Plate 4. The expedition is indebted to R.M.A.F. for providing helicopter transport for both phases of the expedition.

Plate 5. Base Camp was located beside the Sg. Maliau, 2.5 km upstream of the Maliau Falls

Plate 6. Sg. Maliau opposite Base Camp.

Plate 7. Upper Maliau Falls from the side

Plate 8. Upper Maliau Falls from above

Plate 9. RTM producer, En. Henry Kininjim and cameraman, En. David Foo

Plate 10. Australian cameraman, En. Simon Akkerman beside Maliau Falls

Plate 11. En. Saikeh Lantoh collecting insects at a light trap

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Plate 14. Lesser mousedeer, ***Tragulus javanicus*** : a common ungulate in Maliau Basin

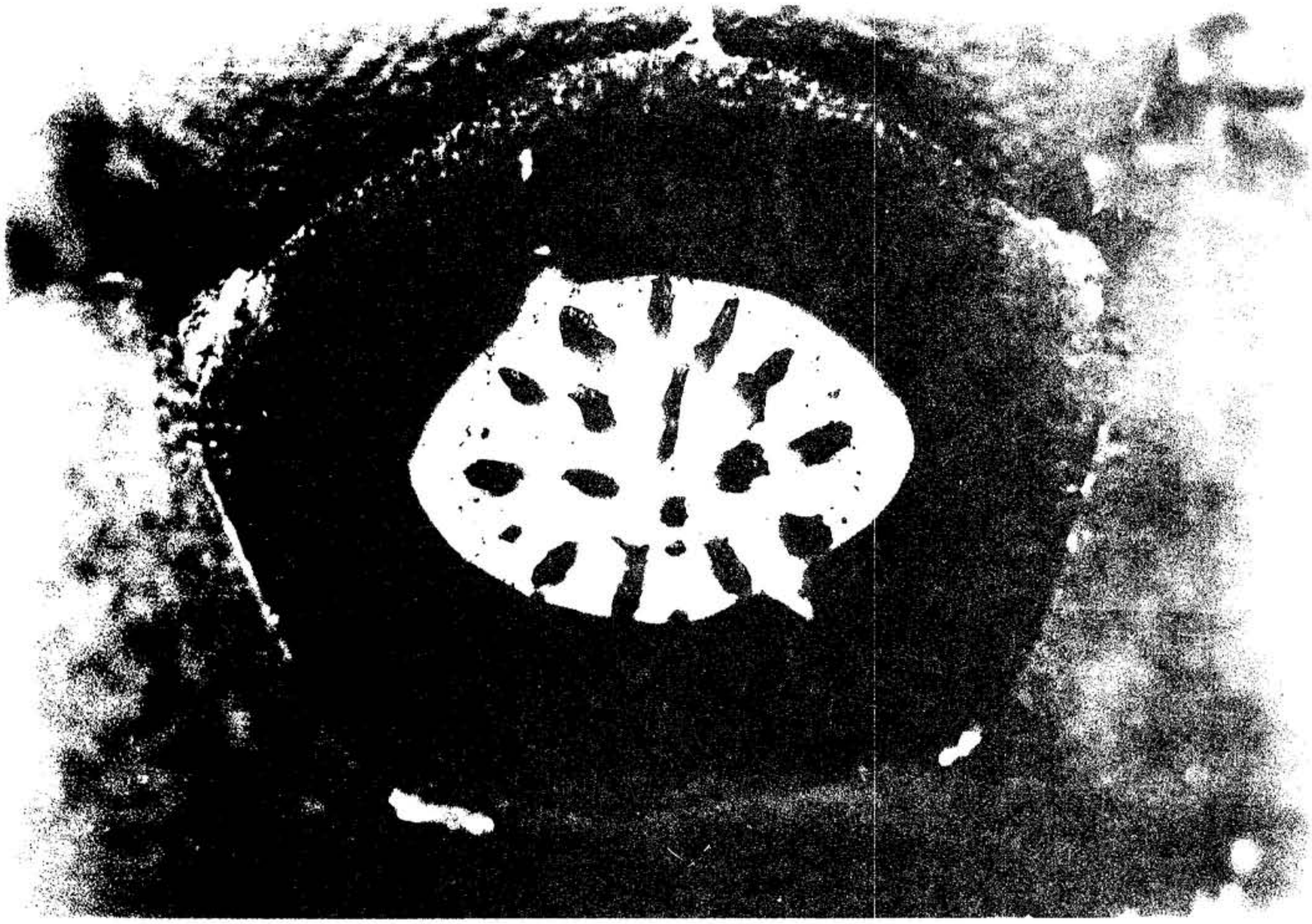


Plate 15. ***Rafflessia tengku-adlini*** : a newly described species of a rare and endangered genus of parasitic plant, which boasts the world's largest flower

Plate 16. En. Sabran Ali beside a large specimen of seraya kuning siput (*Shorea faguetiana*)

Plate 17. En. Alin Cheen Hong in the heath forest near the south rim

Plate 18. Puan Elaine Gasis in a clearing on a natural pig trail ("Jalan Babi") through the heath forest

Plate 19.
Mr. Tony Lamb inspecting the pitchers of ***Nepenthes veitchei***

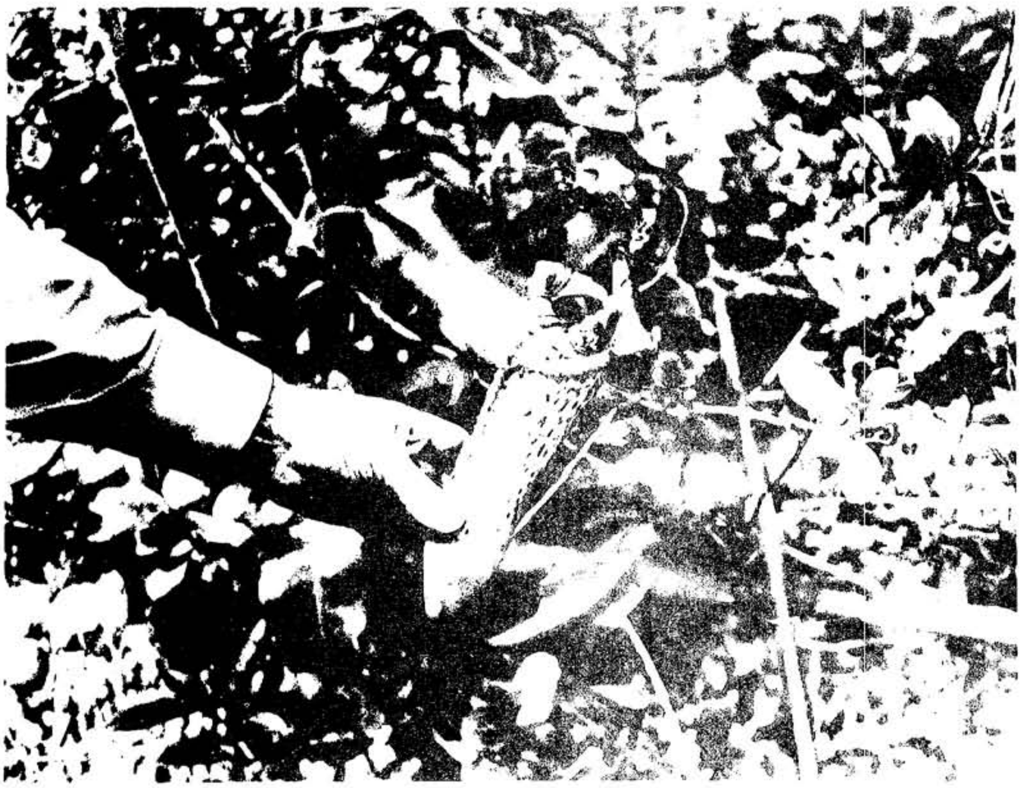
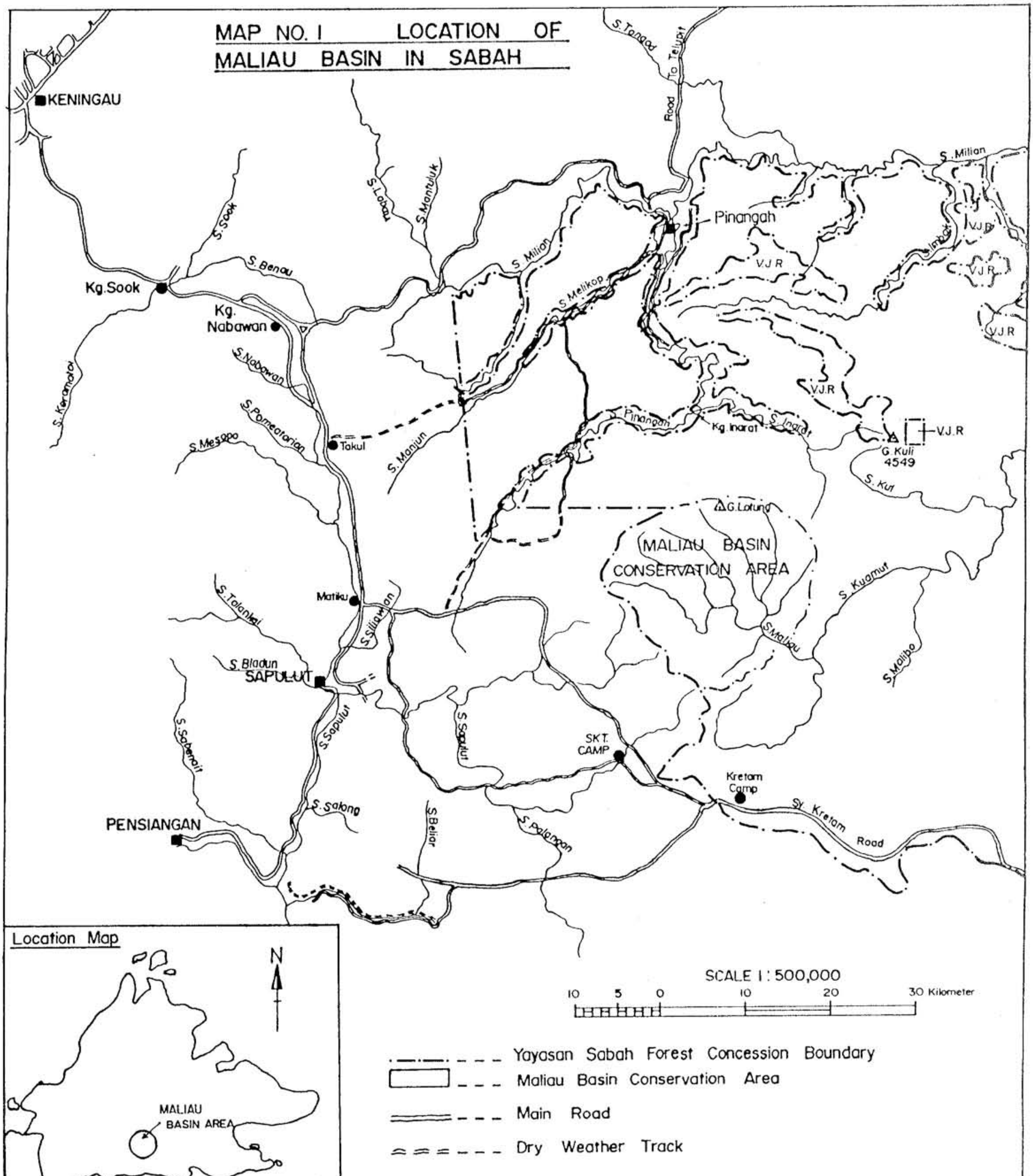


Plate 20.
Close up of a hybrid ***N. veitchei x N. stenophyllum***

Plate 21. Sabah Chief Minister, Y.A.B. Datuk Joseph Pairin Kitingan examining an exhibit of pitcher plants at Base Camp during his visit on May 3, 1988

Plate 22. The Chief Minister with Dr. Ibrahim Komoo, one of the expedition geologists


MAP NO. I LOCATION OF MALIAU BASIN IN SABAH
KENINGAU
Kg.Sook
Kg. Nabawan
Takul
Matiku
SAPULUT
PENSIANGAN
Pinangah
Kg. Inarat
G. Kuli 4549
G. Lotung
MALIAU BASIN CONSERVATION AREA
SKT. CAMP
Kretam Camp
Sy. Kretam Road
Road To Telupit
S. Tangod
S. Milian
S. Melikop
S. Labau
S. Mantuluk
S. Sook
S. Benau
S. Keramatoi
S. Nabawan
S. Pameatorian
S. Mesopo
S. Manjun
S. Pinangah
S. Inarat
S. Kuamut
S. Maliau
S. Malibo
S. Kuli
S. Tolankai
S. Bladun
S. Siliawan
S. Sapulut
S. Sabenait
S. Salong
S. Beliar
S. Palangan
V.J.R
Location Map
N
MALIAU BASIN AREA
SCALE 1 : 500,000
10 5 0 10 20 30 Kilometer
Yayasan Sabah Forest Concession Boundary
Maliau Basin Conservation Area
Main Road
Dry Weather Track

SECTION ONE - INTRODUCTION

LOCATION OF STUDY AREA

The Maliau Basin is one of the most spectacular and pristine natural features in Malaysia, and indeed, Southeast Asia. It is located in south-central Sabah, about 40 km north of the Indonesian border at between 116° 40' - 117° 2' E and 4° 40' - 4° 50' N (Map 1). While all of this region is rugged, remote and forested, the Maliau Basin is distinguished by its almost circular perimeter, which is sharply delimited on all sides by cliffs or very steep slopes upto 1,500 m in height, making it insurmountable on foot from most directions. The size of the enclosed Basin is 390 sq. km. with a maximum diameter of 25 km. The highest point is Gn. Lotung, on the north rim which is about 1,900 m elevation, but has yet to be accurately surveyed. While resembling a volcanic caldera, the Basin is in fact a sedimentary formation comprised mainly of gently inclined beds of sandstone and mudstone. It is drained by a set of radiating tributaries of the Sg. Maliau, one of which descends a series of waterfalls, known as the Maliau Falls. The river then drains through a gorge out of the southeast corner of the Basin into the Sg. Kuamut. This in turn feeds into Sg. Kinabatangan, which is the longest river in Sabah.

The Maliau Basin is almost unvisited and completely uninhabited. However, to the west and north are scattered Murut villages, the closest being Kg. Inarad, which lies about 10 km from the north rim escarpment. People there claim never to have climbed the escarpment but roving groups of Muruts from further west around Sapulut have occasionally entered the Basin in search of resin (damar) or rhino horn. "Maliau" is a Murut word for milky or murky, which undoubtedly refers to the Maliau River. The origin of the name "Lotung" is less clear, but it is the Murut word for a slow loris. According to legend, some people were rowing a canoe near the mountain during a great flood when they heard the crying sounds of a slow loris. Hence, the name of the mountain.

At the foot of the Gn. Lotung escarpment and therefore outside the Basin itself, is a beautiful lake of about 20 ha size, named Linumunsut, which was formed by a landside blocking a small tributary of the Sg. Pinangah. Although not strictly part of the Maliau Basin, L. Linumunsut is a notable attraction of the area.

BACKGROUND TO THE EXPEDITION

None of the early exploratory trips through Sabah during colonial times appear to have discovered the Maliau Basin. The 1906 Chartered Company Expedition in search of a rail route from Tenom to Tawau passed well to the south and makes no reference to it. Early aviators over Sabah also seem to have missed it, until 1947, when a pilot reported almost flying into the cliff of a large, cloud-covered mountain that was not marked on his map!

In the early 1960s, a team from the Geological Survey Department reached Kuala Maliau but did not enter the Basin (Collenette, 1975). In 1972, 1976 and 1978, groups from the Forest Department carried out botanical surveys in the area between Kg. Inarad and L. Linumunsut. Members of the 1976 trip, attempted an ascent of the escarpment behind the lake but just failed to reach the rim (see Lamb, 1988). In 1980, a group led by Mr. R. Goh of the Sabah Museum reached the rim on the easier west side, but was forced to turn back because of illness and lack of supplies.

Since 1970, the area has formed part of a large timber concession assigned to Yayasan Sabah. Since 1981, however, the Maliau Basin and one other large area, Danum Valley, have been designated Conservation Areas within the Foundation's long-term Forest Management Plan, to remain unlogged for purposes of wildlife conservation, education and research. The Yayasan Sabah concession boundary follows the rim of the Maliau Basin for about 32 km on its western side. To demarcate this boundary, the Foundation in 1981 dropped in survey parties by helicopter to cut a *rentis* and three helipads on the rim. Then, in 1982, Yayasan Sabah arranged for a small scientific group to be dropped in the centre of the Basin by helicopter. This 8-day reconnaissance trip involved a walk to the north rim and back. The team also reached the top of the Maliau Falls and gathered preliminary information on which to plan the 1988 expedition reported here (see Lamb, 1988).

In the six years between these visits surrounding land-use has changed considerably. A logging road linking Kalabakan with Matiku, near Sapulut, was completed in 1984 by S K Timbers Company. This permitted an adventurous trek, in 1986 by four men, led by Mr. A. Simon, who walked into the Basin from a logging road 10 km away, upto the north rim and back out to Kuala Maliau. The group then built a raft and took it all the way to Bukit Garam on the lower Kinabatangan, completing a remarkable journey of 25 days. During the first part of their trip they came across a pig track, later dubbed "Jalan Babi", which traverses the south rim heath forest and proved an extremely useful route during the present expedition.

By 1988, other timber concessionaires had logged right to the rim of the Basin on the western side, which is outside the Yayasan Sabah concession, and where the escarpment is in places not too steep. All the rest of the rim perimeter lies within the Yayasan Sabah concession and the surrounding lowlands are likely to be logged during the next 5-10 years. Thus, an area which 10 years ago was several days walk from the nearest road or navigable river is now much more accessible - and vulnerable.

This latter point was made very clear during an aerial reconnaissance for a base camp site for the present expedition when a large, recently-cleared helipad was discovered nearby. It transpired that an international mining company has begun prospecting in the area for coal. Subsequently, in December 1988, the national oil exploration company, Carigali Petronas, announced the leasing for exploration by two foreign oil companies of a large tract of southern Sabah. The press release mentioned specifically the Maliau Basin as a promising area for hydrocarbon deposits. Clearly, a more careful assessment of the scenic, scientific and conservation value of the Basin is needed before any major decisions on its future are taken. This was the context for planning the present expedition. While the reconnaissance visit in 1982 had concentrated on reaching the north rim, it was decided this time to devote most of the expedition to work near the south rim, which is much lower and is a logical point for any road access into the Basin.

OBJECTIVES

(1) To document as much as possible on the geology, soils, hydrology, botany and zoology of the Maliau Basin, so as to assess its scientific and conservation value.

(2) To obtain background information for any future management decisions on the use of the area. Options here include mineral exploitation, timber extraction and conservation.

(3) To inform the public at large of the wonders of the area through the media of newspaper articles, scientific papers and documentary films.

PARTICIPATION

Forty-three personnel took part in the expedition in two main phases as follows :-

Advance Party	:	April 14-17, 1988, four Yayasan Sabah staff led by Deputy Expedition Leader, En. Joseph Gasis.
Phase I	:	April 18-26, twenty-three scientists and supporting staff.
Phase II	:	April 26 - May 6, thirteen new arrivals plus fifteen personnel remaining from the earlier phases.

On May 3, 1988, the expedition was honoured with a visit by the Sabah Chief Minister, Y.A.B Datuk Joseph Pairin Kitingan, who arrived by Sabah Air helicopter, accompanied by Yayasan Sabah Deputy Director, Tengku D. Z. Adlin and others. The Chief Minister was briefed on the scope and scientific findings of the expedition, and taken to see the site of the Rafflessia tengku-adlini flower.

Organisations represented on the expedition included Yayasan Sabah, WWF-Malaysia, Sabah Forest Department, Agriculture Department, Geological Survey Department, Forest Research Institute of Malaysia, Sabah Museum, UKM-Bangi, the British universities of Aberdeen, Oxford, Stirling and Manchester (three individuals linked to projects at the Danum Valley Field Centre), Radio-Television Malaysia and an Australian film team contracted to Channel 9, Perth. Membership of the expedition is given in Table 1.

TABLE 1

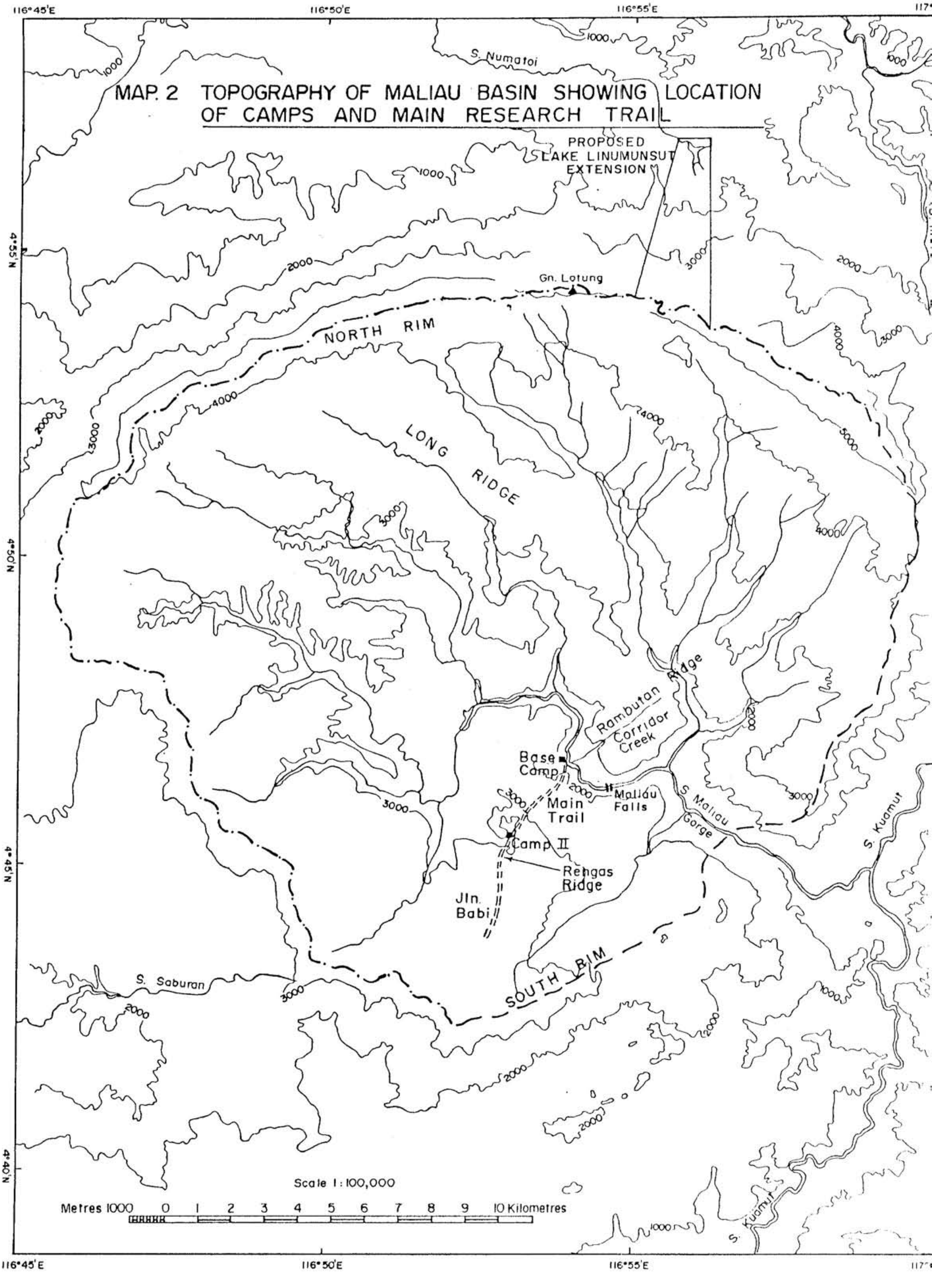
LIST OF EXPEDITION PARTICIPANTS

NAME	AFFILIATION	FUNCTION/SPECIALITY	ADVANCE PARTY	PHASE I	PHASE II
SUPPORT STAFF					
Clive Marsh	Yayasan Sabah	Expedition Leader (+ fish collection)		x	x
Joseph Gasis	"	Deputy Leader (+ large mammals)	x	x	x
Sabran Ali	"	Labourer	x	x	x
Alin Cheen Heng	"	Labourer	x	x	x
Steven Kolis	"	Labourer	x	x	x
Borhan Mohd. Noh	"	Paramedic/Radio Operator		x	x
Robert Chong	"	Cook		x	x
Lee Kow	"	Assistant Cook		x	x
Sub-Total : 8 persons					
SCIENTISTS					
Tungah Surat	J. Kajibumi	Geology		x	x
Louis	"	Geological Assistant		x	x
Pius	"	Geological Assistant		x	x
Pawkin	"	Geological Assistant		x	x
Lim Peng Siong	"	Geology			x

Tjia Hong Djin	UKM-Bangi	Geology			x
Ibrahim Komoo	"	Geology			x
Donson Simin	J. Pertanian	Soil Science		x	
Hamish Mykura	U. Manchester	Hydrology		x	x
Anthony Lamb	J. Pertanian	Botany (orchids)		x	
Anthea Lamb	"	Botany (shrubs)		x	
William Wong	"	Botany (fruit trees)		x	
Aninguh Surat	"	Botanical Assistant		x	
Elaine Gasis	U. Stirling	Botany (trees)		x	x
Leopold Madani	J. Perhutanan	Botany (timber trees)		x	
Jarius Titin	"	Tree Climber		x	x
Saw Leng Guan	FRIM	Forest Ecology			x
Ahmad Zuhaidi	"	Forest Ecology			x
Andrew Garcia	Yayasan Sabah	Forestry			x
Francis Goh	"	Forestry			x
Joseph Guntavid	Sabah Museum	Botany (ethnobotany)			x
Nick Brown	U. Oxford	Dipterocarp ecology			x
Junaidi Payne	WWF-Malaysia	Small mammals			x
Andy Johns	U. Aberdeen	Bats and birds		x	
Ken Scriven	WWF-Malaysia	Birds		x	
Dennis Yong	"	Birds and herpefauna		x	x
Saikeh Lantoh	J. Perhutanan	Insects		x	
Sub-Total: 27 persons					
PUBLICISTS					
Patricia Regis	JKM	Journalist		x	
Henry Kinijim	RTM	Producer		x	
David Foo	"	Cameraman		x	
V. Japrines	"	Recordist		x	
Guy Baskin	Swan TV	Producer			x
Simon Akkerman	"	Cameraman			x
Alan Cox	"	Recordist			x
Danny Chew	"	Production Assistant			x
Sub-Total: 8 persons					

Transport for both the main phases was provided by Nuri helicopter of Tentera Udara di Raja Malaysia (Royal Malaysian Airforce), for which the expedition is indebted to Jen. Hwang Chew Siong, Air Force Commander for East Malaysia and Major Benjamin Yong. Some personnel and equipment came in directly from Kota Kinabalu, while the remainder was lifted from a staging post at S K Timbers' Silliawan Camp, near Matiku.

One scientist, Mrs Anthea Lamb, suffered a broken leg on arrival at the start of Phase I when a broken tree top fell on her while the helicopter was on the ground. Apparently, the tree top had snapped with the downwash from the rotor blades. Yayasan Sabah Paramedic, En. Borhan Md. Noh quickly splinted her wound and put her on a stretcher back to Kota Kinabalu, where she was transferred to Queen Elizabeth Hospital. She has subsequently made a slow but successful recovery from what proved a complex fracture of her right femur. Apart from this unlucky incident, all participants remained in good health and spirit throughout the expedition.



MAP. 2 TOPOGRAPHY OF MALIAU BASIN SHOWING LOCATION OF CAMPS AND MAIN RESEARCH TRAIL
116°45'E
116°50'E
116°55'E
4°55'N
4°50'N
4°45'N
4°40'N
S. Numatoi
PROPOSED LAKE LINUMUNSUT EXTENSION
Gn. Lotung
NORTH RIM
LONG RIDGE
Rambutan Ridge
Corridor Creek
Base Camp
Maliau Falls
Main Trail
Camp II
Rengas Ridge
Jln. Babi
S. Maliau Gorge
S. Kuamut
S. Saburan
SOUTH RIM
1000
2000
3000
4000
5000
Scale 1:100,000
Metres 1000 0 1 2 3 4 5 6 7 8 9 10 Kilometres

FIELD ARRANGEMENTS AND PLACE NAMES

The Base Camp site had been chosen in advance to provide an initial landing site in the riverbed with access to both heath forest near the south rim of the Basin and to the central ridge running towards the north rim. The site was also only 2.5 km upstream from the top of the Maliau Falls, and thus strategically located from all viewpoints (Map 2). The Camp itself consisted of 10 large tarpaulins erected on flat land beside the river close to a large cleared helipad. Sleeping, mess, kitchen and storage areas were established and rough tables set up with plywood sheets. A small genset and SSB radio were installed.

From the Base Camp at 490 m a.s.l. a Main Trail of 3 km was cut in a south-westerly direction up a steep escarpment and a second camp erected beside a small stream at 880 m a.s.l. This was a single tarpaulin with space for five hammocks. The habitat between Base Camp and Camp II was essentially hill dipterocarp forest, that could be further divided into riverine, slope and ridge subtypes. Similar habitat on gentler slopes was accessible by an 8 km loop trail on the other (left) bank of the Maliau River. This was known as "Rambutan Ridge" on account of many fruiting Sapindaceous trees, while the small stream it surrounded was named "Corridor Creek". The Rambutan Ridge horseshoe is actually the southernmost two spurs off "Long Ridge", which traverses the Basin for 16 km in a northwest-southeast direction.

From Camp II the trail continued upward a further 1 km by way of "Rengas Ridge" to enter first a narrow band of lower montane coniferous forest at 990 m and then a broad plateau of heath forest at about 1,050 m a.s.l. named "Southern Plateau". This dense habitat could be traversed for 2 km by a natural game trail dubbed "Jalan Babi" and for a further 2 km by a less clear route to reach the south rim.

In addition to these principle survey routes, the riverside walk to the falls was popular and small scientific sub-parties undertook wider excursions, as shown on Map 4. The Geological Survey team traversed a wide area of riverbeds on the eastern side of the Basin, and a group of four men walked up Long Ridge to the northern rim. In all, about half the Basin could be said to have been visited. The terrain of the remainder looks comparable and it is believed that a good representational coverage of habitat types was achieved.

An important unifying feature of the expedition was the maintenance at Base Camp of a "Log Book", into which members were encouraged to record on return from the field any observations of note, regardless of whether they are related to their own specialty. Besides maximizing the scope of natural history observations obtained, this habit quickly facilitated a concensus on place names.

SCOPE OF THE REPORT

Editing of this report presents a problem. Expedition participants have submitted specialized reports, some in annotated diary form and with inevitable overlap in general observations. To synthesize these efforts into a unified account is a difficult task which risks significant omissions of detail. Most of the individual reports are therefore included here more or less in their original form. However, only four botanical reports are given, together with an integrated species list based on all the collections.

In reading an expedition report, intrinsic limitations of the field work should be appreciated. Firstly, even with 27 scientific participants coverage is patchy, both geographically and by topic. For example, work on fishes, birds and mammals is included, but not on amphibians and reptiles for which no adequate collections were made.

Some important plant groups, such as palms, were also little studied. Earth sciences on the other hand, are well covered and are of particular importance in view of possible coal and oil prospects in the area.

A second limitation relates to the short duration of research. The expedition lasted in total $3^1/_2$ weeks during a mostly dry spell. This was intentional and greatly facilitated the logistics and field work. However, the study of storm events and the collection of fertile plant material were constrained. Essentially, an expedition report can document many of the components of an ecosystem but can say much less about their dynamics and interactions. Nevertheless, it is hoped that the report will provide a useful overview of the area and a basis for management decisions and for planning further research.

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Collenette, P. (1965). The geology and mineral resources of the Pensiangan and Upper Kinabatangan area, Sabah, Malaysia. Geological Survey of Malaysia, Borneo Region, Memoir 12.

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SECTION TWO - GEOLOGY

2.1 : GEOLOGY OF THE CENTRAL MALIAU BASIN

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Universiti Kebangsaan Malaysia, Bangi, Selangor

INTRODUCTION

The planimetric shape of the Maliau Basin sensu stricto is round extending 25 km and 22 km along E-W and N-S axes, respectively. The larger basin area is elongated and extends 55 km in NE-direction. This structural basin is composed of lower to middle Miocene Tanjong Formation that has been estimated by Collenette (1965) to reach a thickness of 40,000 ft (12 km). Collenette assigned a Te_5-f age (Early Miocene; mistakenly considered as "Upper Miocene" in his report) based on benthonic and pelagic foraminifera. On the Third Edition geological map of Sabah compiled by Lim (1985), the Tanjong Formation is indicated as being of early to middle Miocene age.

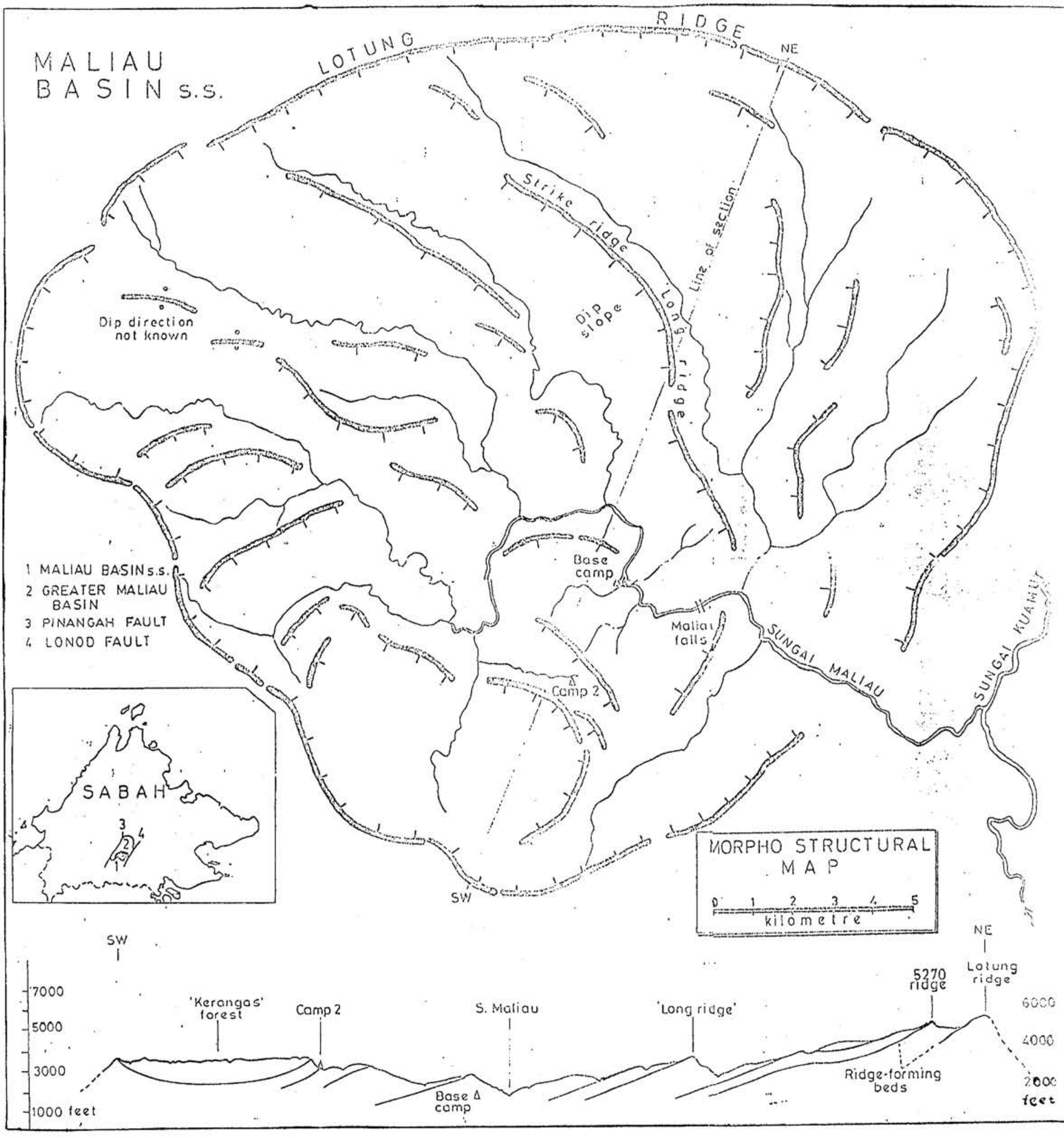
In the Maliau Basin proper, ridge-forming layers of sandstone form strike ridges with gentle dip slopes inclined at less than 15 degrees. As expected, in the central part of the basin dips are much gentler and some are horizontal.

The present report is based mainly on ten-days' fieldwork in April-May 1988 in a rather restricted area in the central portion of the Basin. Extended traverses to the north of the Base Camp up to the Lotung Ridge were carried out by members of the Geological Survey of Malaysia (Kota Kinabalu office). Geological observations along the Maliau river are included in Memoir 12 by Collenette (1965), but we know of no other publications on the field geology of the Maliau Basin sensu stricto.

LITHOLOGY

The sedimentary rocks that occur in the central portion of the Basin, that is, in the vicinity of Base Camp and Camp II (Map 3) comprise the upper portion of the Tanjong Formation. The dominant rocks are **mudstone** intercalated with thin and thicker layers of **siltstone to medium-grained sandstone**. Locally occur conglomerate, clayey lignite and thin laminae of reddish brown claystone/slate within sandstone.

The mudstone is grey to dark grey (due to high carbon content) and occurs in massive sequences or may contain intercalations of siltstone beds, hard sandstone disks, and/or small to large channel fillings of sandstone. The channel fills range in size up to 1.5 m high and may be more than 2.5 m across (Plate 23). Occasionally rectangular mudcracks appear on bedding surfaces of the mudstone. In certain sequences, as at locality 3, clay-ironstone concretions, a few centimetres long, occur parallel to the stratification.



Map 3 Morpho-structural map of the Maliau Basin sensu stricto. The strike ridges and dip slopes were interpreted from the 1:50,000 topographic map and some aerial observations. The vertical scale of the cross section is exaggerated. Note that internal strike ridges join the Lotung ridge at oblique angles.

Plate 23. Well-developed channel filling of sandstone in the dominantly mudstone lithology. Locality 1 near Base Camp.

Thin siltstone layers (sometimes carbonaceous and containing resin) form frequent intervals within mudstone occurrences. Fine to medium-grained sandstone may occur as moderately thick beds 0.5 to a metre thick and as channel fills among the mudstone sequences. Quartz grains are common but quartzitic sandstone was only seen as float among the river boulders. Other constituents are grains of mudstone, siltstone, small carbonized plant fragments, and rarely granules of lustrous coal. Several sandstone banks may occur together to form intervals of competent rock not more than 5 m thick. These intervals create rapids and waterfalls that in the vicinity of Base Camp and Camp II reach great heights in the order of 10 to almost 30 metres. The sandstone bottoms may be flat to irregular, the latter being the result of scour-and-fill processes. A host of markings may adorn the sandstone upper surfaces. Among the markings are current, interference and less commonly festoon ripple marks, organic tracks, crescentic flutes and at one locality also rain pits. In a sandstone float, slide marks suggest penecontemporaneous slumping. Internal markings of the sandstone layers comprise planar and trough cross beds, lamination in the finer grained varieties, burrows normal, oblique and/or parallel to bedding. Ophiomorpha may occur as single or branching shafts. The sandstone that forms the channel fills is usually medium-grained and may contain internal bedding as well as cross beds. Thin (not more than 5 cm) wafers of reddish brown claystone or slate sometimes occur as interbeds in the sandstone. The claystone/slate is transected by regular fracture patterns that have promoted differential weathering. In a later paragraph we will show that the fracture pattern is genetically related to the inclination of the associated beds. However, no fractures could be seen in the sandstone enclosing the claystone/slate interbeds. Flat, hard claystone pebbles and rare pebbles of other lithologies a few centimetres across may occur among the sandstone beds. They form matrix-supported conglomerate in which the matrix consists of uniform grain size. The uniform texture of the groundmass and the thinness of the pebble distribution led us to interpret the conglomerate as representing lag-gravel. Thicker (decimetre-size), clast-supported conglomerate composed of sandstone and claystone clasts often contain mollusc shells, mainly bivalves. This conglomerate and the lag conglomerate are commonly of reddish brown colour.

In the area around the Base Camp clayey lignite layers as thick as 0.5 m occasionally crop out. Lustrous coal was only seen as float.

Figures 1, 2, 3 and 4 are stratigraphic sections that are representative of the Tanjong Formation in the central part of the Basin. Detailed petrographic descriptions are listed in the Appendix.

PALAEOSLOPES

Palaeoslopes are indicated by penecontemporaneous glide planes and possibly also by normal faults of consistent strike. At locality 1.5 (Figure 5) an outcrop of mudstone with thin siltstone interbeds exhibits glide planes subparallel to bedding and are therefore interpreted as penecontemporaneous normal faults. The attitude of glide planes and drag features (including a rollover structure) suggest gliding or slumping towards southeast. Larger scale normal faults (Figure 6) indicate tension in NE-SW direction. This direction is parallel to the dominant current sense. In Figure 6, the 140/10 and 325/30 faults appear to represent listric faults. The rollover associated with the 325/30 fault and its listric nature suggest that the rocks were plastic during deformation, perhaps because the structures were formed penecontemporaneously. The clear indication of tension in NE-SW direction and prevalent currents in the same direction suggest that the palaeoslope trended NW-SE.

PALAEOCURRENTS

Many sandstone surfaces possess current ripple marks. Current structures contained by sandstone beds comprise planar and trough cross beds, preferred orientation of long pebble-axes in lag conglomerate horizons and that of elongated, carbonized plant fragments. At locality 11, crescentic flutes occur on a sandstone surface that also exhibits rain pits (Plate 24). Some of the ripple marks have been partially abraded and only current direction could be determined. Figure 7 is a plot showing the distribution of palaeocurrents determined from ripple marks (often as current sense) and long axes of pebbles. The prevalent palaeocurrent sense was towards 30° - 70°. Less common are currents towards the opposite sector. Most long pebble axes are also aligned in this direction. The prevalent current sense towards northeast is interpreted to indicate that deeper water existed in that direction.

Plate 24 Crescentic flute on a sandstone surface at locality 11 along Sungai Maliau. Current sense is indicated by the pencil.

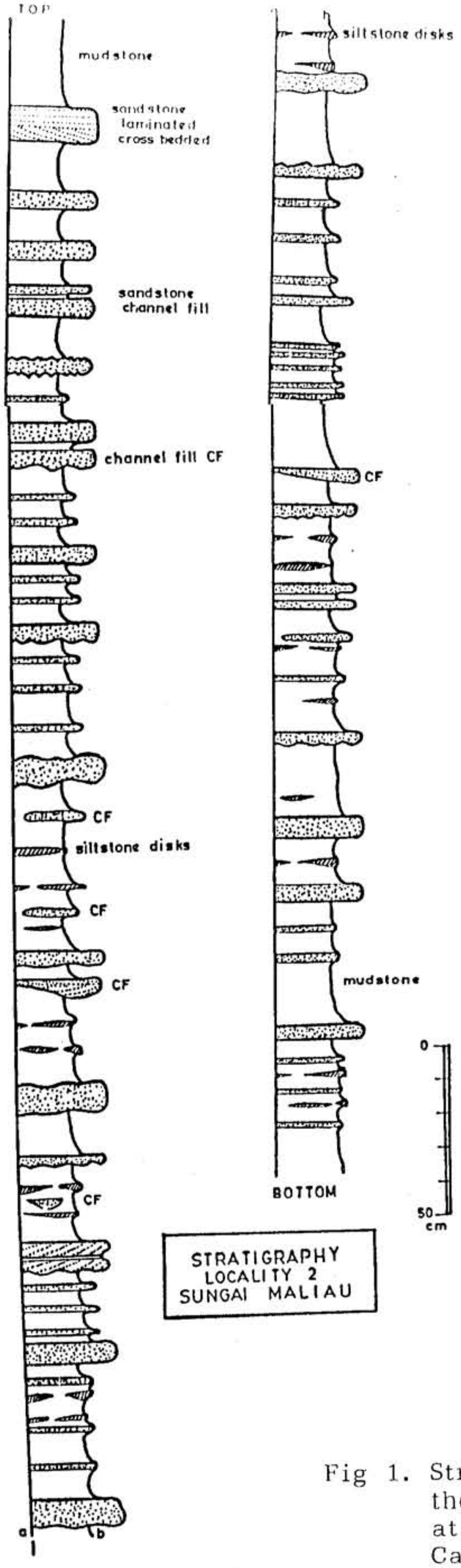


Fig 1. Stratigraphic section of the Tanjong Formation at Locality 2 near Base Camp.

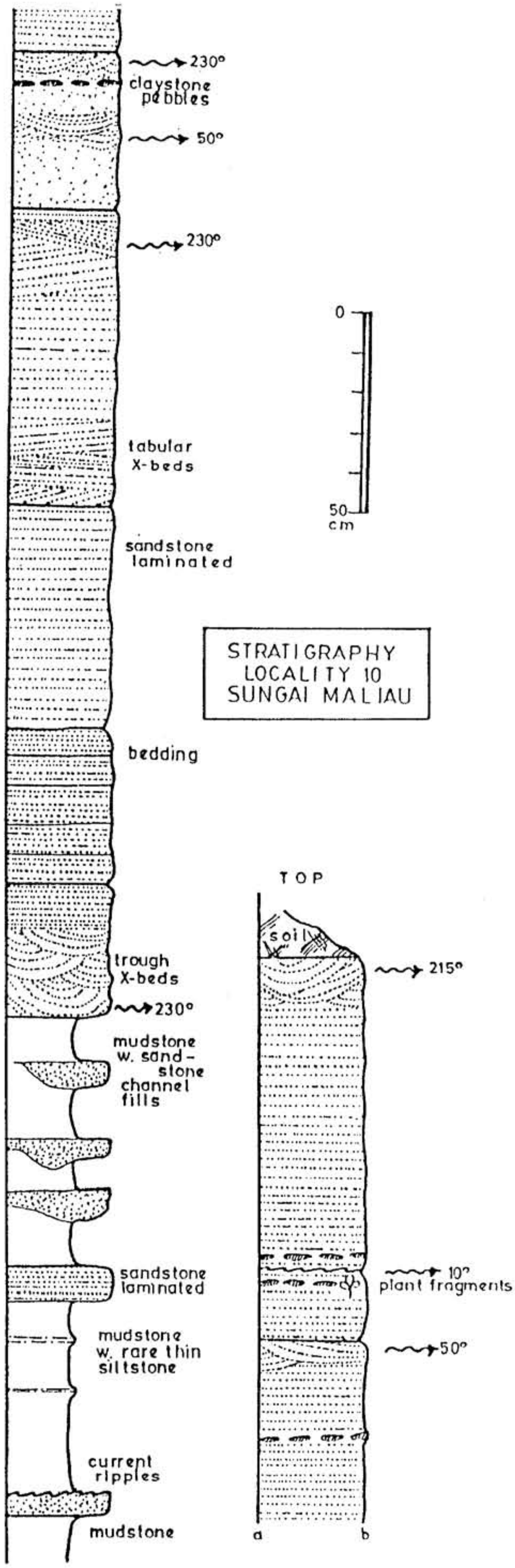


Fig 2. Stratigraphic section of a dominantly sandstone interval of the Tanjong Formation at Locality 10 along Sg. Maliau.

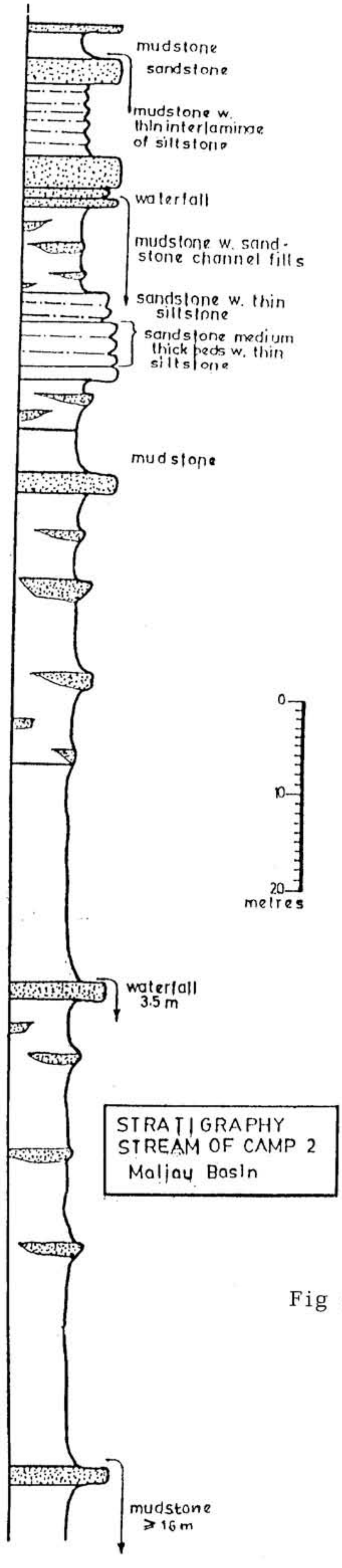


Fig 3. Stratigraphic section along a tributary of Sg. Maliau below Camp II. Note the dominance of mudstone over other lithologies and the frequent waterfalls formed by the relatively thin sandstone intervals in the section.

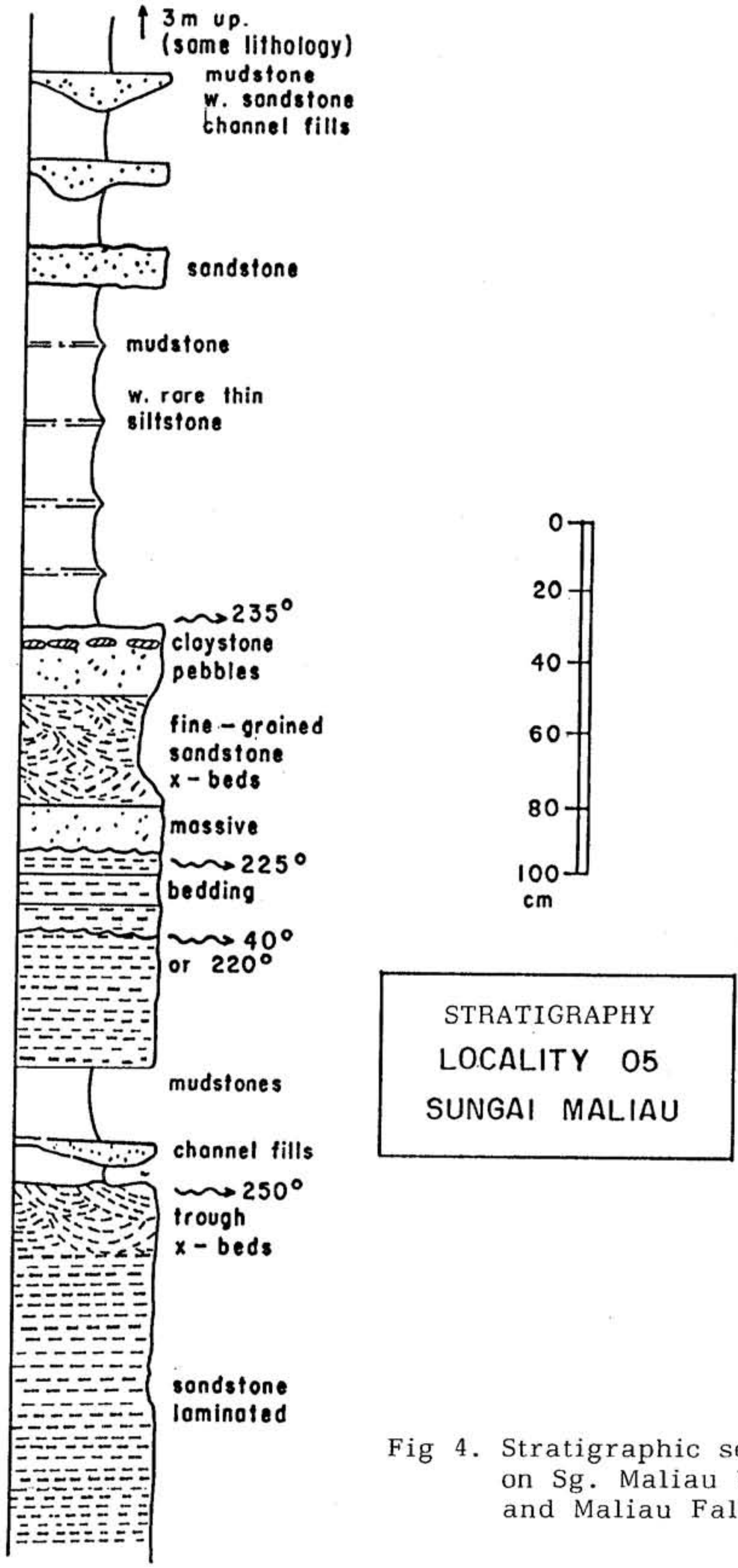
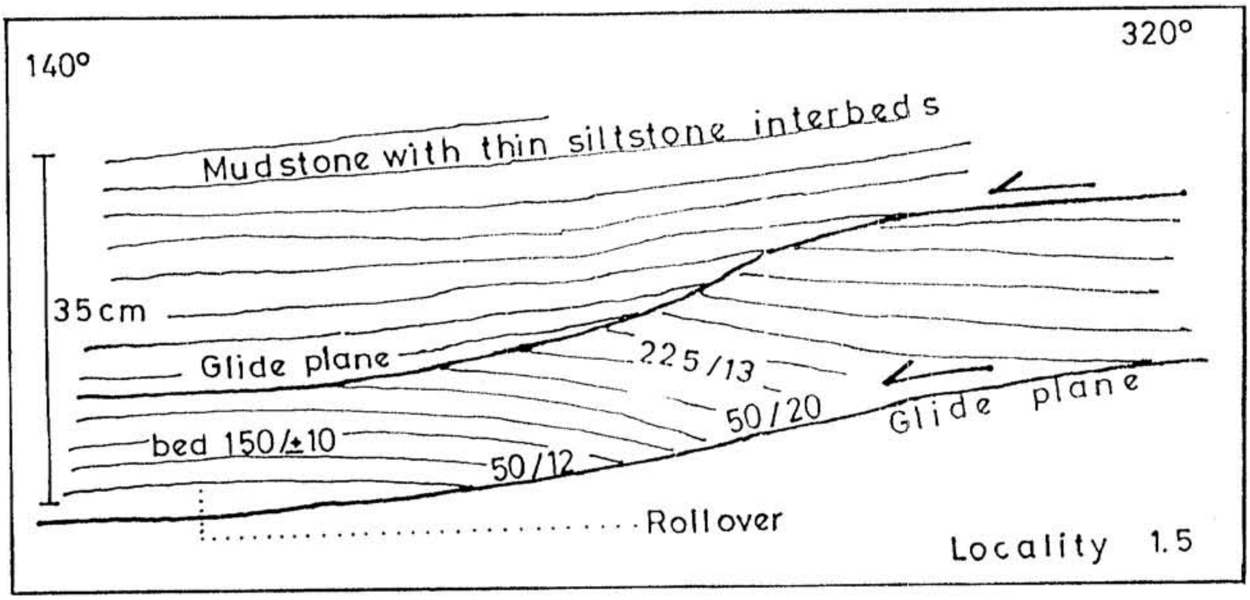


Fig 4. Stratigraphic section at Locality 05 on Sg. Maliau between Base Camp and Maliau Falls.



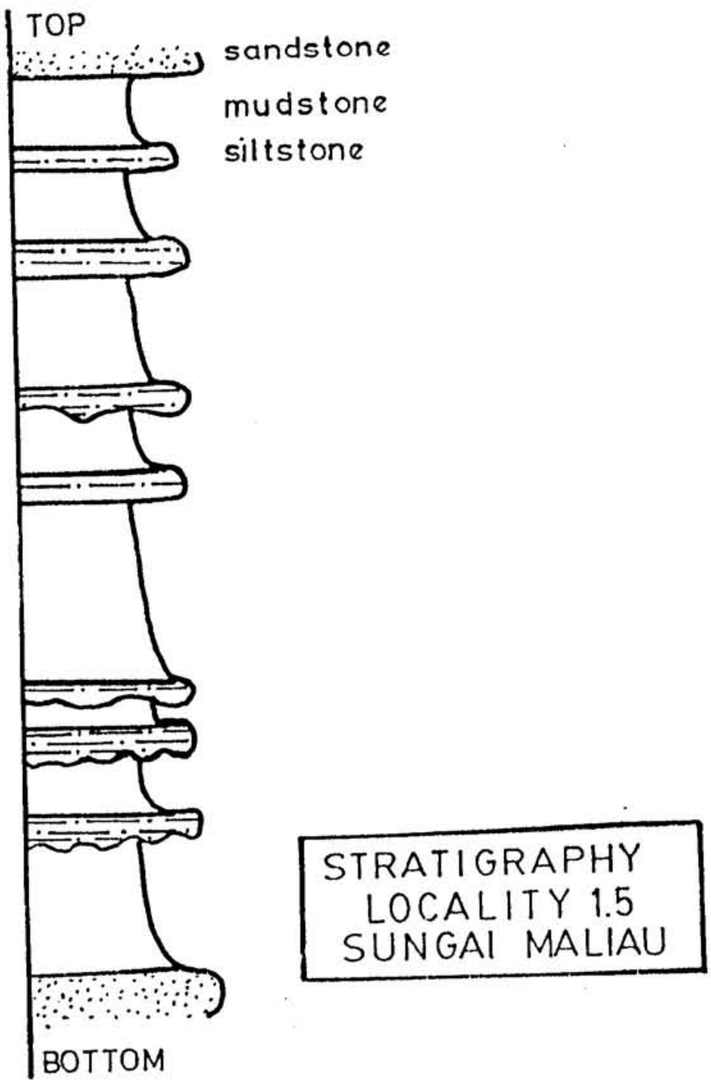
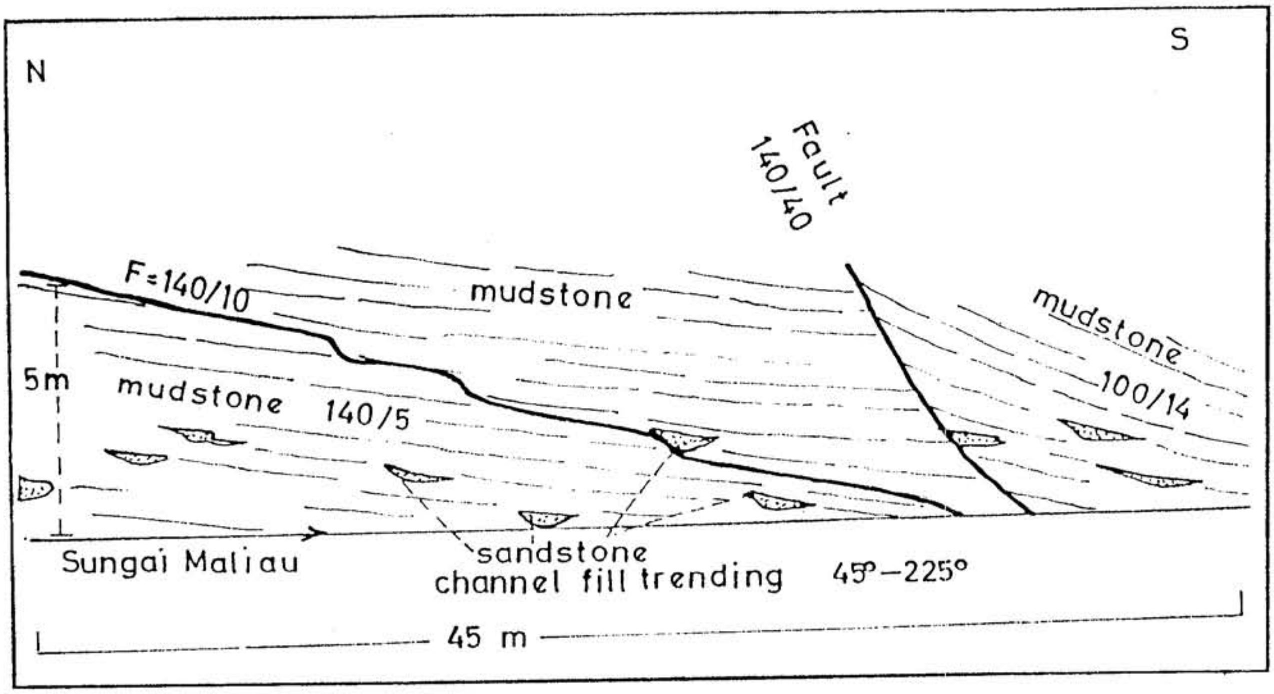


Fig 5. Penecontemporaneous slumping is indicated by glide planes sub-parallel to stratification at Locality 1.5 near Base Camp. The lower figure represents the stratigraphy of this outcrop.



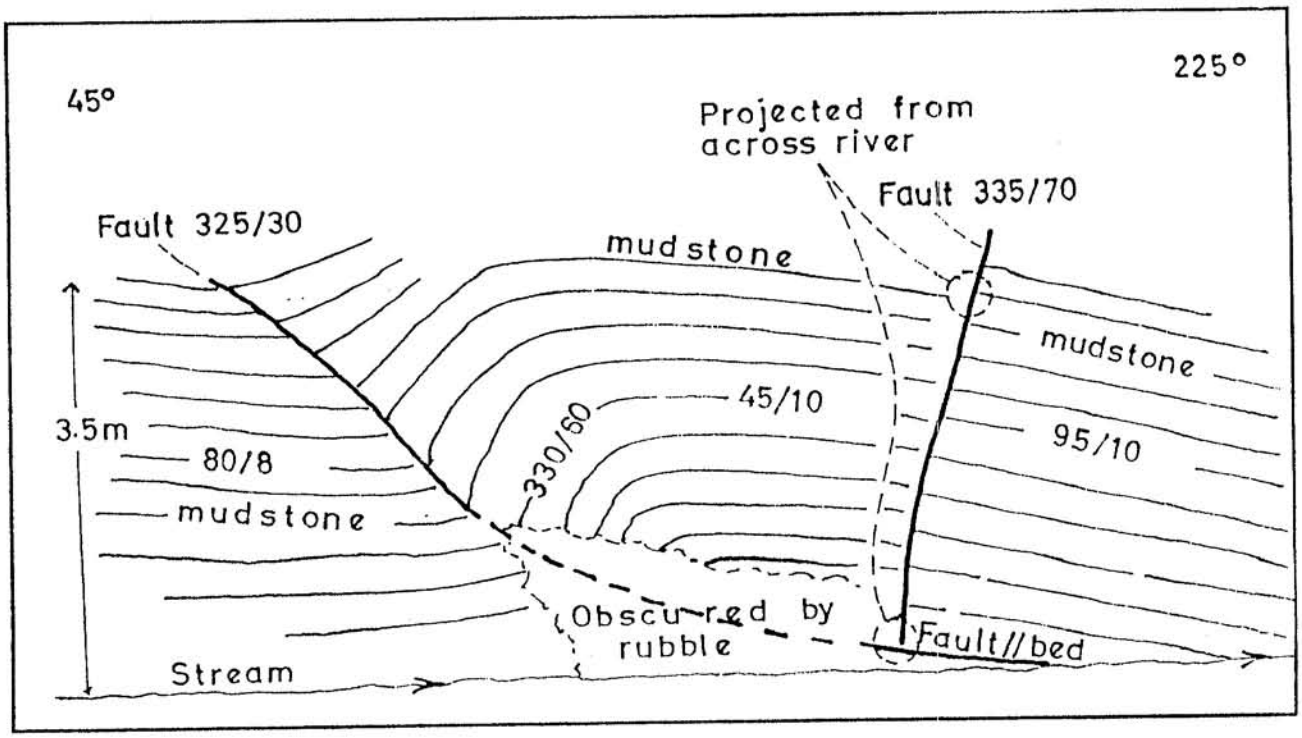


Fig 6. Normal faults in the Tanjong Formation near Base Camp (upper figure) and near Camp II (lower figure).

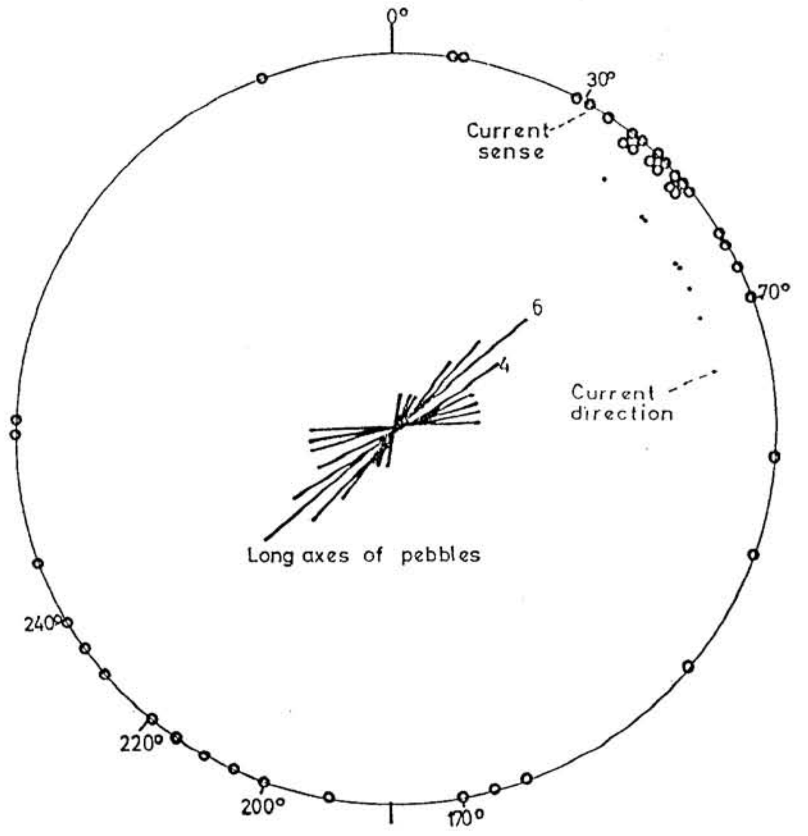


Fig. 7 Circular plot of current sense determined from current ripple marks, planar and trough cross beds; current direction; and long axes of pebbles in lag conglomerate horizons. Note that current directions are only plotted in the east half of the circular plot.

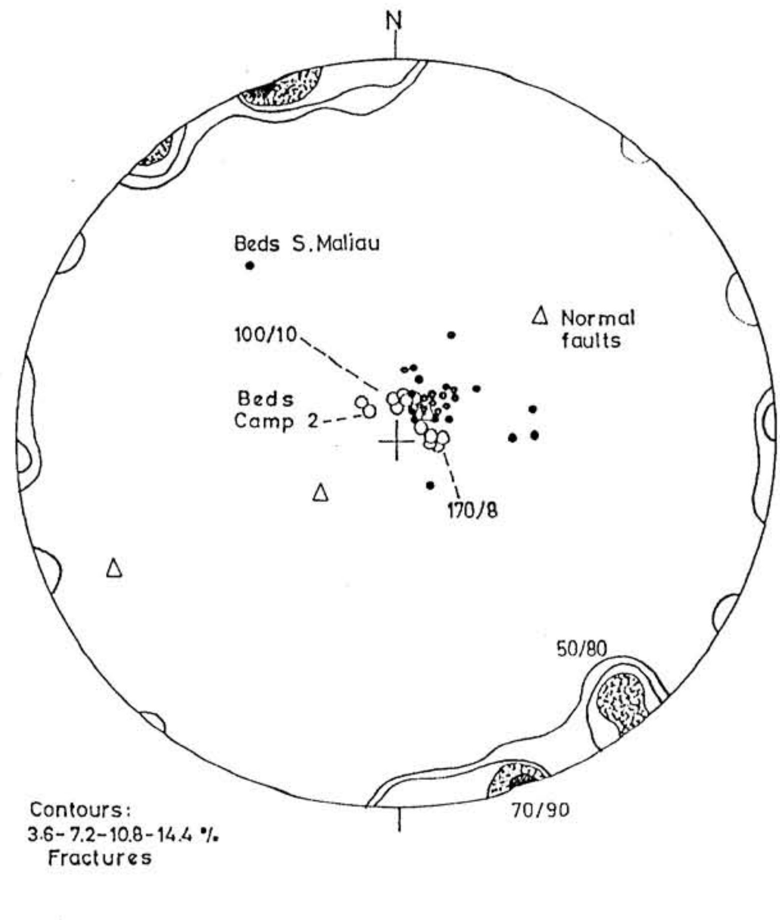


Fig. 8 Equal-area projection, lower hemisphere of beds near Camp II (open circles) and in the vicinity of Base Camp (solid dots), normal faults (triangles), and long fractures represented by density contours.

PALAEOENVIRONMENT

Ophiomorpha is not diagnostic for a particular marine environment but is abundant in littoral setting (Frey et al., 1978). The presence of sandstone channel fills in dominantly mudstone lithology suggest a very shallow near or onshore, commonly low-energy environment. Carbonized plant fragments and resin are consistent for such an environment. Current ripples and trough cross beds suggest that occasionally higher energy surroundings prevailed. Rain pits and mudcracks indicate subaerial exposure. These environment indicators can occur together in an extensive (low-energy) tidal flat or in the middle to distal parts of a large delta. The prevalent current sense suggests that deeper water occurred towards the NE. Currents towards SW probably represented those generated during rising tides or during storms. The extreme thickness of the Tanjong Formation further suggests that sedimentation took place upon a subsiding substratum.

GEOLOGIC STRUCTURES

The outcrops of the Tanjong Formation that we surveyed displayed gentle dips of less than 15 degrees. Some steeper attitudes are clearly related to faults (Figure 6). The equal-area plot of Figure 11 shows the gentle attitudes of the strata. Those near Camp II have average orientations of 100/10 and 170/8. In the vicinity of the Base Camp and the Maliau Falls gentle dips are also the rule (Figure 9). Common strikes are SE with dips of about 10 degrees towards SW. Normal faults (see also Figure 6) strike SE or NW and indicate tension in NE-SW direction.

Long fractures, up to several tens of metres long, may occur as bundles in wide zones a hundred or more metres wide (near Camp II) displaying regular spacing of approximately a metre and of 1.3-1.4 m distance. The preferred attitudes of the long fractures are 50/80 and 70/90. In other words, fault strikes are subparallel to the general dip direction. Fracture patterns occur in the thin claystone/slate interbeds within sandstone sequences. Frequently, the patterns consist of vertical to subvertical fractures parallel and normal to the local dip direction. Consequently, these small fractures appear to have formed as result of tilting of the beds. In addition, vertical to subvertical shear fractures may also be present and are disposed symmetrically about and making acute angles with the local strike direction.

The pattern of strike ridges (Map 3) indicate that while those marking the outer rim of the Maliau Basin form an uncomplicated closed figure, the strike ridges within the Basin are generally not concentric with respect to this rim. The so called "Long Ridge" and several other ridges within the Basin approach the boundary Lotung Ridge at oblique angles, suggesting the existence of an angular unconformity within the lower and middle portions of the Tanjong Formation. Tungah Surat and P. S. Lim of the Geological Survey (personal communication) confirmed that the morphologically determined attitude of the beds forming "Long Ridge" is consistent with field measurements. The ridge pattern further indicates that the structural centre of the Basin lies lopsidedly in the southern part of the Maliau Basin and underlies what has been named the "Heath Forest".

We believe that the oblique intersections between internal ridges with the rim ridge do not represent an angular unconformity, but were caused by shifting of the depocentres and progressive narrowing of the sedimentary basin (Figure 10). After the Maliau Basin subsided during Stage 1, successive subsidence occurred in a smaller NW-SE elongated portion of the original basin (Stage 2) and finally terminated as in Stage 3 on the figure. The various centres of subsidence in Figure 10 have been interpreted as the central areas of basins as suggested by the configuration of their rims in Stage 1 through Stage 3.

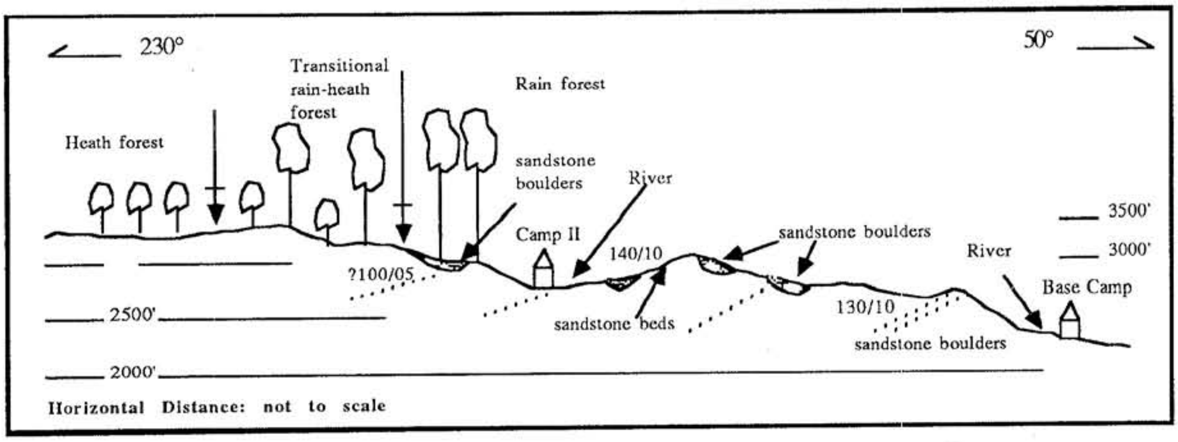


Fig 9. Schematic cross section between Base Camp and Camp II.

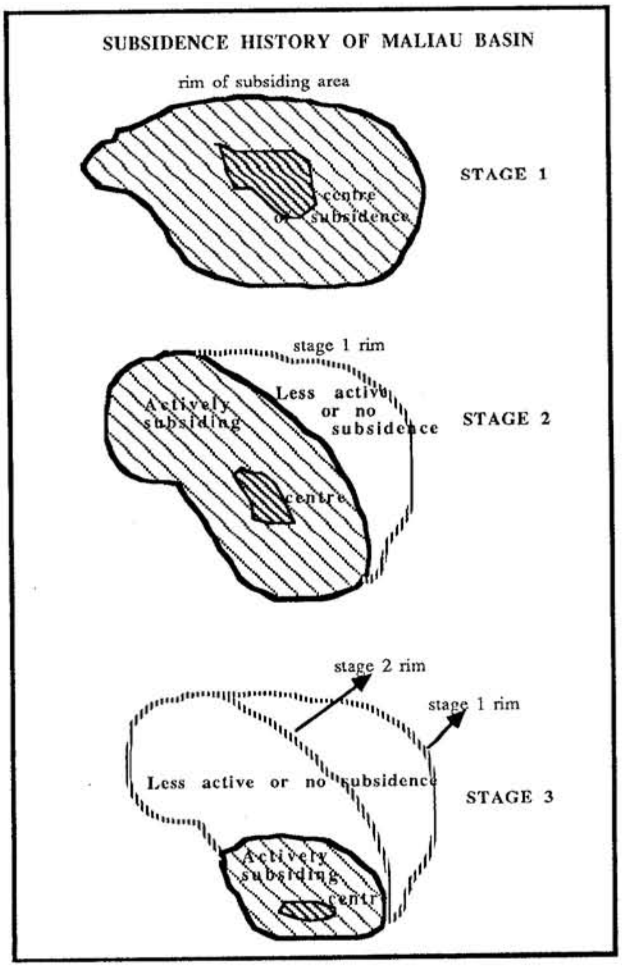


Fig 10. Progressively smaller areas of subsidence during deposition of the Tanjong Formation in the Maliau Basin s.s. The non-concentric configuration of strike ridges suggests that depocentres shifted southward (see also Fig.1)

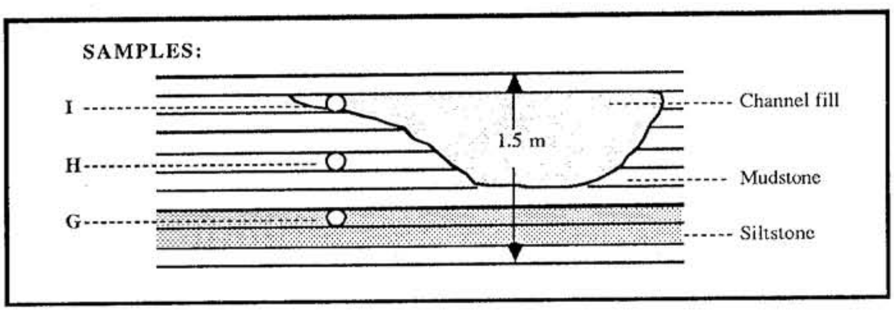


Fig 11. Index section of samples G, H and I that are associated with channel fill.

ACKNOWLEDGEMENTS

We are grateful to Professor Mohd. Nordin Hj. Hasan, Chairman of World Wide Fund for Nature Malaysia, for the invitation to participate in this expedition. We also very much appreciate the excellent transport and camping facilities organized by Yayasan Sabah. Our colleagues of the Geological Survey of Malaysia (Kota Kinabalu), Messrs Lim Peng Siong and Tungah Surat provided large scale topographic maps and allowed us to refer to some unpublished material.

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APPENDIX

PETROGRAPHIC DESCRIPTION

Nine different sedimentary rock samples were collected from the upper part of the Tanjong Formation. Six of these samples were from relatively fresh-looking boulders in the river near Base Camp, and three other samples (G, H and I, see Figure 14) represent one set of rocks associated with sandstone channel filling in a mudstone groundmass.

Sample A

In hand specimen it is a medium grained sandstone without internal structures and of light grey colour. This rock type is seen to form medium to thick-bedded sandstone in outcrops. Under the microscope it shows clastic texture consisting of rounded to subrounded quartz grains (50%); 10% felspar changed into sericite, 35% lithic clasts (mostly chert and schist) and 5% interstitial clay. Sorting is good. The rock is a lithic arenite.

Sample B

Sandstone filling an ichnofossil (burrow). It possesses clastic texture consisting of 45% quartz, 15% felspar and 35% lithics of subrounded shapes. The lithics are quartzite, schist, and chert. Clay forms 5% interstitial filling. Sorting is good. Near the walls of the ichnofossil the rock is highly carbonaceous.

Sample C

Mudstone and fine grained sandstone forming flat discs. Microscopically lamination is clearly seen and grain size is that of silt. Quartz and void-filling quartz(?) amount to 70%; the rest is clay groundmass. The rock name is laminated, clayey siltstone.

Sample D

This is a fine grained sandstone without internal structures, dark grey. In outcrops it forms thin sandstone among mudstone. Clastic texture, fine grained, and subangular grains. Quartz grains 30%, 10% felspar and 20% lithics (chert and slate). Other minerals are: muscovite, iron oxides and perhaps epidote. Clay forms 40% groundmass; poorly sorted. The rock is a lithic greywacke.

Sample E

Fine grained sandstone, laminated, grey. This rock forms sandstone beds of variable thickness and often contains cross beds. Clastic texture fine to medium grained. Subangular quartz grains (30%), 5% felspar and rare muscovite, 20% lithics of chert and slate; its groundmass (45%) consists of clay and iron oxide. Poor sorting. The rock is a lithic greywackle.

Sample F

Carbonaceous material occuring as thin to moderately thick zones. Clasts are 25% fine grained quartz, 15% felspar, subrounded, 15% lithics of slate and chert; 45% groundmass composed of clay and carbon. Approximately 5% of the carbon has changed into lignite(?). It is a carbonaceous lithic greywacke.

Sample G

Siltstone, commonly laminated, dark grey. It forms thin interbeds in mudstone. Very fine grained texture; 55% groundmass of clay; 25% quartz and 10% felspar of subangular texture; 10% slate as lithic fragments. Lamination is produced by clay mineral(s). It is a laminated silty mudstone to clayey siltstone.

Sample H

Mudstone, dark grey, partly containing carbonaceous fragments. Grains of quartz (20%) and felspar (5%) of subangular texture; slate fragments (5%) in 70% clay groundmass. Distribution of clasts is not systematic, some parts are laminated. The clay contains carbonaceous material. It is a sandy/silty mudstone.

Sample I

Sandstone, fine to medium grained, laminated or no internal structures, grey to light grey. This type of sandstone occurs as channel fills (Figure 11). Clastic, fine grained texture of 35% quartz and 5% felspar, subangular; 10% lithics of chert and slate; 50% groundmass of clay. Lamination is weakly developed; poor sorting. Probable rock name: lithic greywacke.

2.2 : GEOLOGY OF THE NORTH-EASTERN MALIAU BASIN

Lim Peng Siong and Tungah Surat
Geological Survey of Malaysia, Sabah

LITHOLOGY

A reconnaissance survey was carried out over 100 sq. km. in the north-eastern part of the Maliau Basin. The traverse map is shown on Map 4 and the observation and sampling points on Map 5. The Tanjong Formation in this area consists mainly of grey to black, commonly carbonaceous mudstone, fine to medium-grained, grey to brownish grey sandstone, coal seams and minor conglomerate and siltstone. Minor coarse-grained, whitish grey and friable sandstone occurs as thick to massive beds.

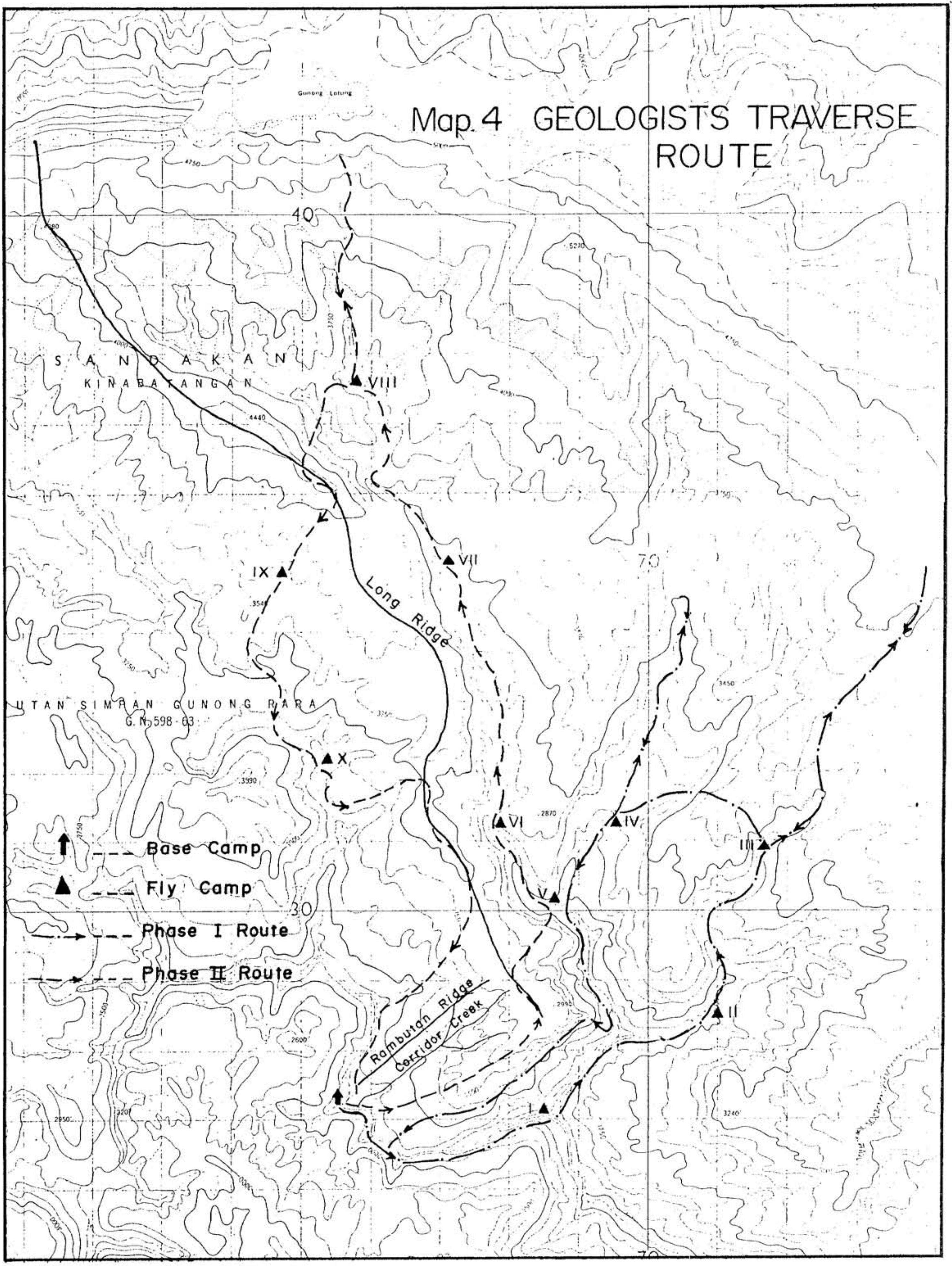
Mudstone

The mudstone occurs as massive beds (Plate 25), often with intercalations of sandstone and siltstone, or as thin (cm thick) to thick (up to 1 m) beds interbedded with thick to massive sandstone (Plate 26). the mudstone often contains rounded to spheroidal sandstone clasts which are aligned parallel to stratification. Small, flat or lenticular-shaped limonitic nodules are also found within the mudstone. The mudstone is also commonly carbonaceous and often coaly especially where it forms the roof or floor of coal seams (Plates 27 and 28). Some of the mudstone beds are also laminated and silty, the laminae being due to alternating layers of clay and carbonaceous material. Cross-laminae are present in a 2 m mudstone bed at Locality MB58 (Plate 29). The mudstone is also commonly lithified, brittle and breaks conchoidally.

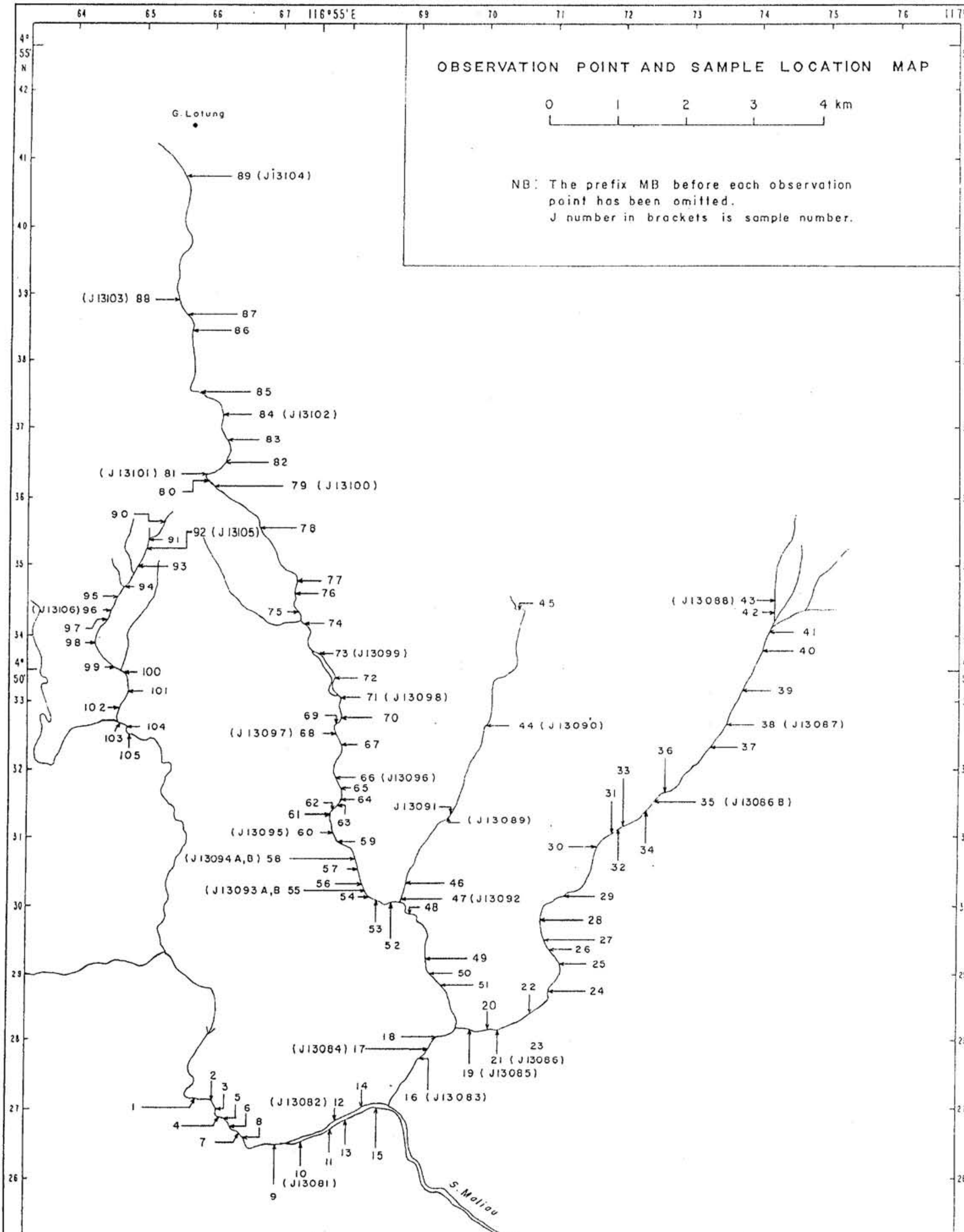
Sandstone

Hard sandstone beds form scarps, ridges and cascades and waterfalls up to 28 m high (Figure 12, Plate 30). The sandstone is predominantly fine to medium-grained with minor coarser-grained variety. It appears that the grain size of the sandstone increases towards the rim. The sandstone occurs as thin beds within massive mudstone, as thin beds interbedded with thin mudstone or as thick to massive beds with thin mudstone layers. The sandstone often contains layers of carbonaceous material and lenses of coal, especially in the vicinity of coal seams. Limonitic nodules (up to 3 mm) are sometimes present in the sandstone. The fine-grained variety is also commonly laminated, the laminae accentuated by the presence of carbonaceous material.

Mineralogically, the various varieties of sandstone are similar. Quartz is the main component and occurs as individual, subangular to subrounded, fractured grains with undulose extinction or as clusters of grains which have interlocking edges. Quartz constitutes 45 to 60% of the mode. Rock fragments constitute up to 20% of the mode and consist mainly of subangular to subrounded chert with minor basic volcanics and metomorphics. Feldspars, micas, zircon and opaques occur in minor amounts. The matrix is normally clay and fine quartz although carbonaceous material makes up a significant proportion of the matrix in the carbonaceous sandstones. The sandstones are sublitharenites according to McBride's (1963) classification.


Map. 4 GEOLOGISTS TRAVERSE ROUTE
Gunong Lotung
S A N D A K A N
K I N A B A T A N G A N
UTAN SIMPAN GUNONG RARA
G. N. 598 · 63
Long Ridge
Rambutan Ridge
Corridor Creek
VIII
VII
IX
X
VI
V
IV
III
II
I
40
70
30
Base Camp
Fly Camp
Phase I Route
Phase II Route

Map 5


OBSERVATION POINT AND SAMPLE LOCATION MAP
0 1 2 3 4 km
NB: The prefix MB before each observation point has been omitted.
J number in brackets is sample number.
G. Lotung
S. Maliau
116°55'E
117°00'
4° 55' N
4° 50'
89 (J13104)
(J13103) 88
87
86
85
84 (J13102)
83
82
(J13101) 81
80
79 (J13100)
78
90
91
92 (J13105)
93
94
95
(J13106) 96
97
98
99
100
101
102
103
104
105
77
76
75
74
73 (J13099)
72
71 (J13098)
69
70
(J13097) 68
67
66 (J13096)
65
64
62
61
63
(J13095) 60
59
(J13094 A,B) 58
57
56
(J13093 A,B 55
54
53
52
46
47 (J13092
48
45
44 (J13090)
J13091
(J13089)
49
50
51
18
(J13084) 17
16 (J13083)
19 (J13085)
20
21 (J13086)
22
23
24
25
26
27
28
29
30
31
32
33
34
35 (J13086 B)
36
37
38 (J13087)
39
40
41
42
(J13088) 43
1
2
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6
7
8
9
10 (J13081)
11
(J13082) 12
13
14
15
LPS/SK/8

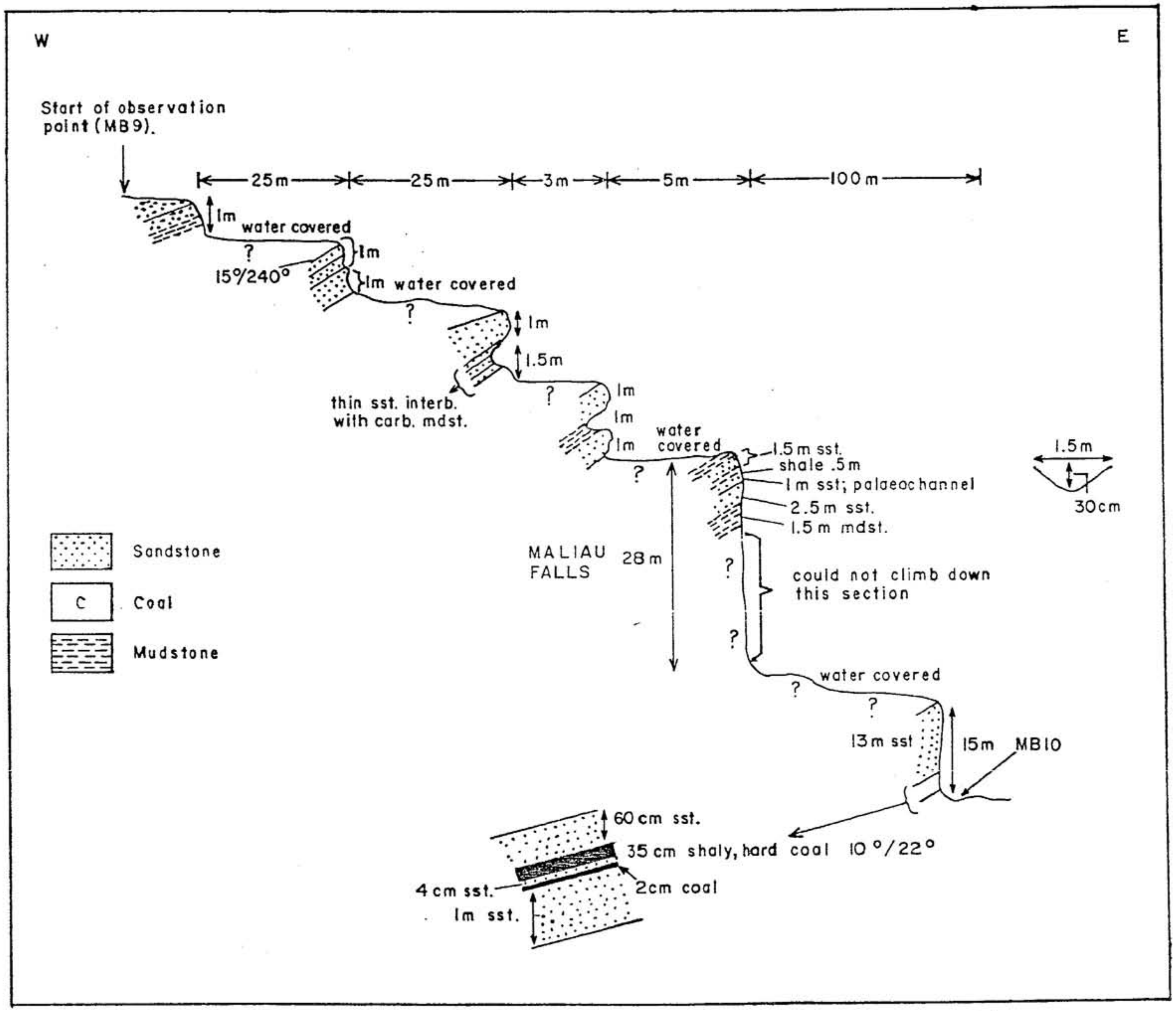


FIGURE 12 DIAGRAMMATIC SECTION ALONG SUNGAI MALIAU FROM OBSERVATION POINT MB9-MB10

Conglomerate

The thin (10 cm) conglomerate bed at the top of an erosional surface at Locality MB50 consists of rounded fragments (up to 3 cm across) of reddish brown chert cemented by fine quartz and indurated clay.

SEDIMENTARY STRUCTURES

Current and ripple marks and organic tracks are commonly found on the top of sandstone beds. Flute casts, sole markings, load casts (Plate 31) and groove marks are present at the bottom of sandstone beds. Internal structures include laminations in the fine-grained sandstone and mudstone and cross-lamination in mudstone. The cross-laminae that were observed dip gently towards SW. Groove marks at the soles of sandstone beds trend NE-SW. Palaeochannels (up to 1.5 m across and 30 cm high) are present in the thick to massive mudstone sequence (Plate 32). These palaeochannels are filled by sandstone or interbedded sandstone and mudstone and they trend NE-SW.

GEOLOGIC STRUCTURES

Strikes and Dip of Strata

The dips of the strata are fairly consistent varying from 10° to 20° although at a few localities the dips are up to 30°. The strikes of the beds are also consistent, trending NW-SE. However, variations of strike directions and dip angles occur reflecting localised faulting. The NW-SE strikes of the strata in the area south of Gunong Lotung truncates the rim at oblique angles. However, the strikes of the strata in the west-central part of the survey area are E-W, concordant with the rim. A study of the aerial photographs of the whole Basin shows that the strike ridges on the western part of the Maliau Basin also truncate the rim and that circular ridges concordant to the shape of the Basin are found over the southwestern part.

Joints and Faults

Joints, tens of metres long, are well-developed in the resistant sandstone beds. These strike NE-SW, N-S and E-W and are commonly subvertical to vertical (Plate 33). Joints parallel to lineaments observed in aerial photographs trend in the same direction as the strikes of these joints and are obviously related to them.

Faulting was rarely observed and where they occur, they are normal faults trending NW indicating tension inthe NE-SW direction. A N-S fault may be present in the eastern rim judging from the break in the continuity of the rim.

Folding has been observed at only one locality where a gentle, broad, open fold (Figure 13) is exposed.

PALAEONTOLOGY

Four mudstone samples were found to contain pollens and spores which gave a lower Miocene age for the Tanjong Formation in the area surveyed. These samples were examined by Sarawak Shell Berhad and the results are shown in Table 2. Microplankton

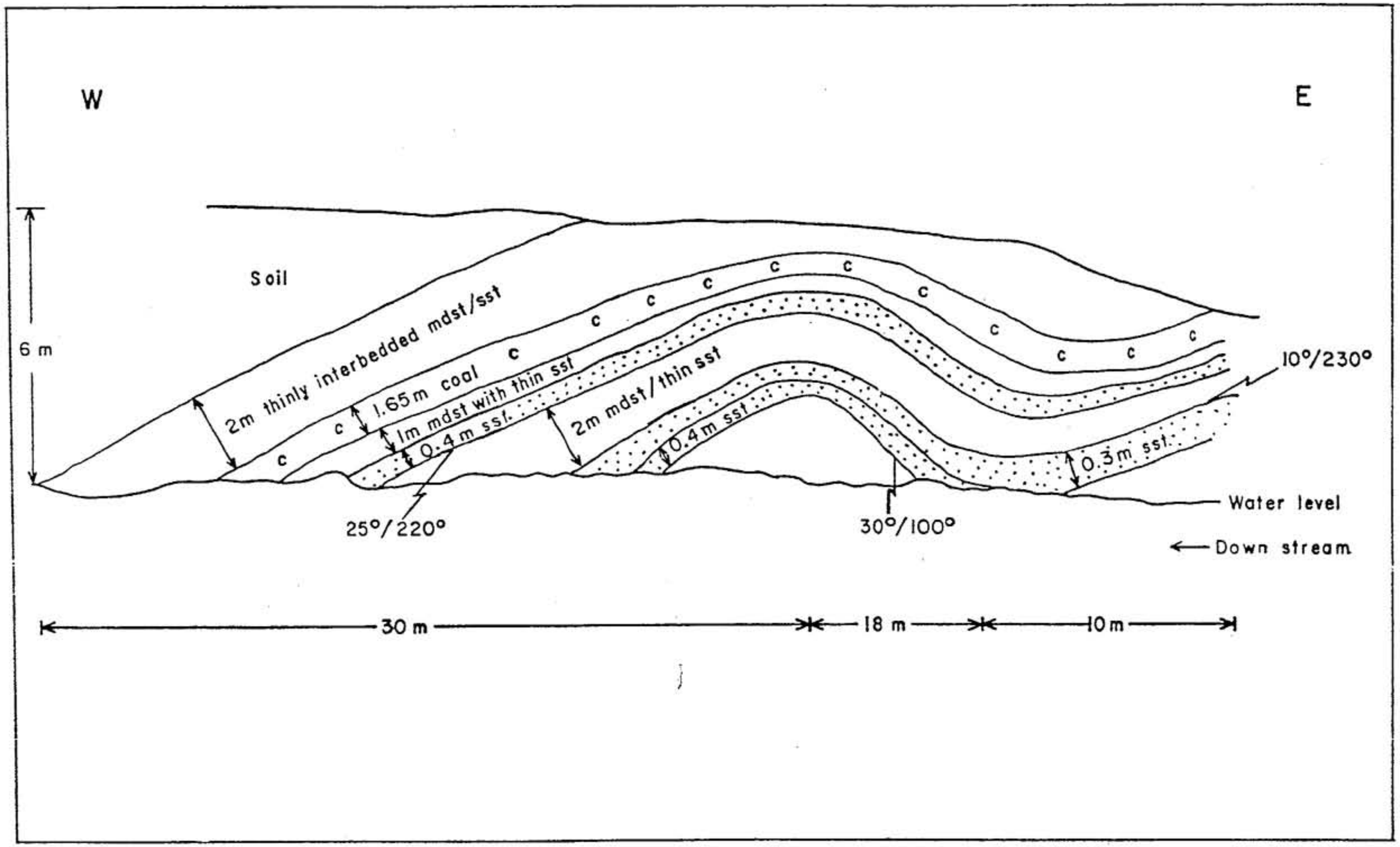


FIGURE 13 SKETCH OF GENTLE FOLD IN TANJONG FORMATION, LOCALITY MB19

was also found in samples J13086 and J13102. Foraminifera were also found in samples J13102 (Quinqueloculina sp.) and J13106 (Rotalia sp.).

TABLE 2

POLLENS AND SPORES FROM THE TANJONG FORMATION

SAMPLE NUMBER / POLLENS AND SPORES	J13086	J13088	J13102	J13106
Alangium spp.	x			
Barringtonia spp.	x	x		x
Brownlowia spp.	x	x	x	x
Casuarina spp.	x	x		
Cephalomappa spp.	x			
Dacrydium spp.				x
Durio spp.		x	x	x
Florschuetzia trilobata	x	x	x	x
Gonystylus spp.		x		x
Lycopodium phlegmaria		x		x
Hycopodium cernuum				x
Picea type	x			
Pinus type		x		
Rhizophora spp.	x		x	
Stenochlaena areolaris				x
All determinations by Palynologists of Sarawak Shell Bhd. All four samples gave a Lower Miocene age.				

Trace fossils are found at the top of sandstone blocks, among which Chondrites (Plate 34) and Granularia (Plate 35) have been identified (Crimes, written communication). Indeterminate big worm burrows 3 cm in diameter, 25 cm long are found within thick mudstone beds (Plate 36). These burrows taper towards the top of the mudstone beds.

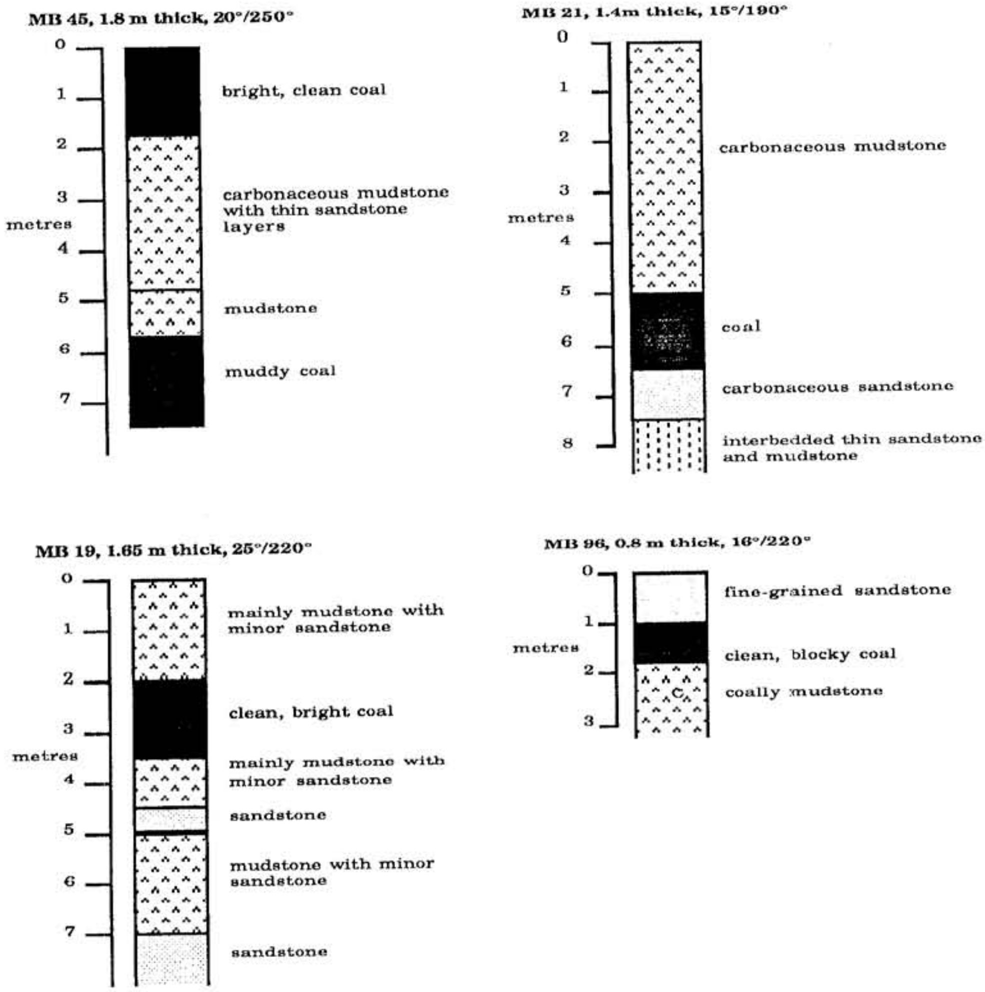
The mudstone and sandstone often contain fossilised tree stems and roots which are rimmed by a coaly zone.

ECONOMIC GEOLOGY

Coal

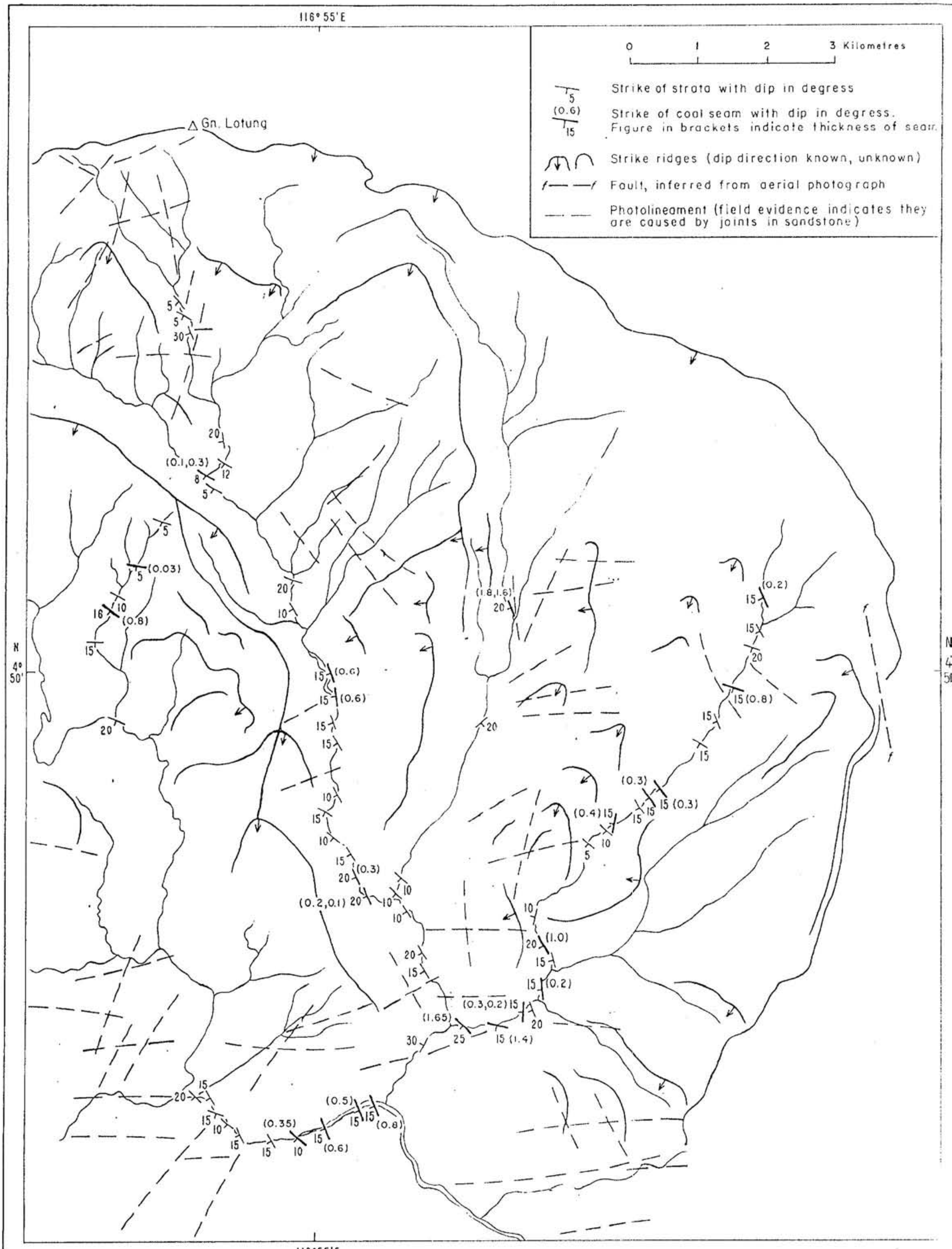
A total of 31 coal seams ranging in thickness from 0.02 to 1.8 m were observed at 24 localities (Map 6). Figure 14 shows a schematic representation of the major coal seams. The coal seams are floored and roofed by either carbonaceous mudstone or sandstone (Plate 27 and 28); however, carbonaceous and sometimes coaly mudstone usually forms the roof or floor of the coal seams. The coal is usually bright, clean and blocky Map 6 although muddy and weathered in some outcrops. The sparsity of traverse lines, lack of marker horizon and inaccurate topographic map do not permit an accurate correlation of the coal seams. However, there appears to be at least five coal seams greater than 1 m thick.

FIG. 14 SCHEMATIC REPRESENTATION OF SELECTED COAL OUTCROPS



Coal Quality : Quality tests were conducted on two coal samples according to standard methods outlined in the International Organization for Standardization (ISO).

The results (Table 3) indicates that the samples are generally low in moisture contents. Of the two samples analyzed, only sample J13098 exhibits qualities of a good coal. It has low ash content and a corresponding high gross calorific value. Carbon and hydrogen values are also consistent with the quality. The high free swelling index of 7.5 suggests that blending might further enhance the quality of the coal.



Map 6. GEOLOGICAL SKETCH OF THE NORTHEASTERN PART OF MALIAU BASIN

TABLE 3

ANALYTICAL DATA OF COAL FROM NORTHEAST MALIAU BASIN

SAMPLE NUMBER	PROXIMATE (mass-%)				GROSS CALORIFIC VALUE dry (mj/kg)	ULTIMATE (mass-%)								FSI
	Total moisture	Moisture	Ash dry	Volatile matter dry (d.a.f.)		dry				d.a.f.				
						C	H	N	Total S	C	H	N	Total S	
J13098	3.4	1.7	2.3	43.6 (44.7)	34.6	81.0	6.09	1.54	2.29	83.0	6.24	1.58		7.5
J13101	4.6	2.0	28.3	32.2 (45.0)	23.65	55.9	4.32	1.22	4.80	77.9	6.01	1.71		4.0

Note : d.a.f. = dry, ash-free; FSI = Free Swelling Index
Analysis by Coal Laboratory, Geological Survey Malaysia, Kuching

However, the swelling characteristics shown by sample J13101 appears anomalous in view of its fairly high ash content. This sample will have to be investigated further by petrographic means. The coal is classified as high volatile bitensionous A to B coal according to the A.S.T.M. classification.

Economic potential : The coal samples analyzed have good chemical properties and high heating values and are of better quality compared to those from the Silimpopon-Serudong area. Taking into consideration the thickness, quality, gentle dips of the coal seams and the relatively "undisturbed" nature of the strata, this part of the Maliau Basin has a very good potential for coal, more so because of the existence of thick coal seams on the northern side of the Lotung Escarpment.

Hydrocarbon

The great thickness of the Tanjong Formation and the presence of carbonaceous mudstone throughout the whole of the Maliau Basin suggest that it may be favourable for the occurrence of hydrocarbon accumulation. The carbonaceous mudstone could be favourable host rocks for hydrocarbons, and the Pinangah and Lonod Faults (Collenette, 1965) could be potential traps.

Hydro-Power

The size and enclosed nature of the Basin and centripetally dipping strata form an excellent reservoir. Several large waterfalls, notably the Maliau Falls, occur within the Basin and hydroelectric power could be generated from these falls should a demand for power be required for development. The damsite could be sited on the Sungai Maliau between the Maliau Falls and its confluence with Sungai Kuamut.

ACKNOWLEDGEMENTS

We are grateful to Yayasan Sabah for inviting us to participate in the expedition and the air transport facilities provided. We are also grateful to Sarawak Shell Berhad for undertaking the palaeontological examination of samples, to Dr. P. Crimes of the University of Liverpool for comments and identification of trace fossils and to our colleagues at the Coal Laboratory, Geological Survey Malaysia, Sarawak for analyzing the coal samples. Last but not least, we thank Professor H. D. Tjia and Dr. Ibrahim Komoo for the exchange of views and discussion.

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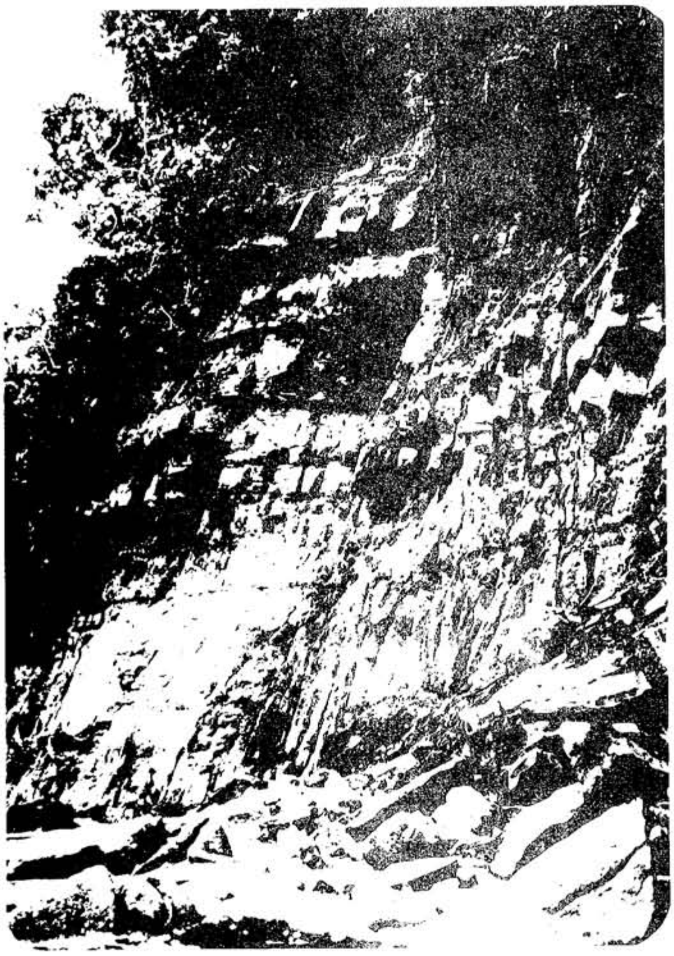

Plate 25.
Massive laminated mudstone overlain by a sequence of interbedded thick sandstone and mudstone. Locality MB 78.

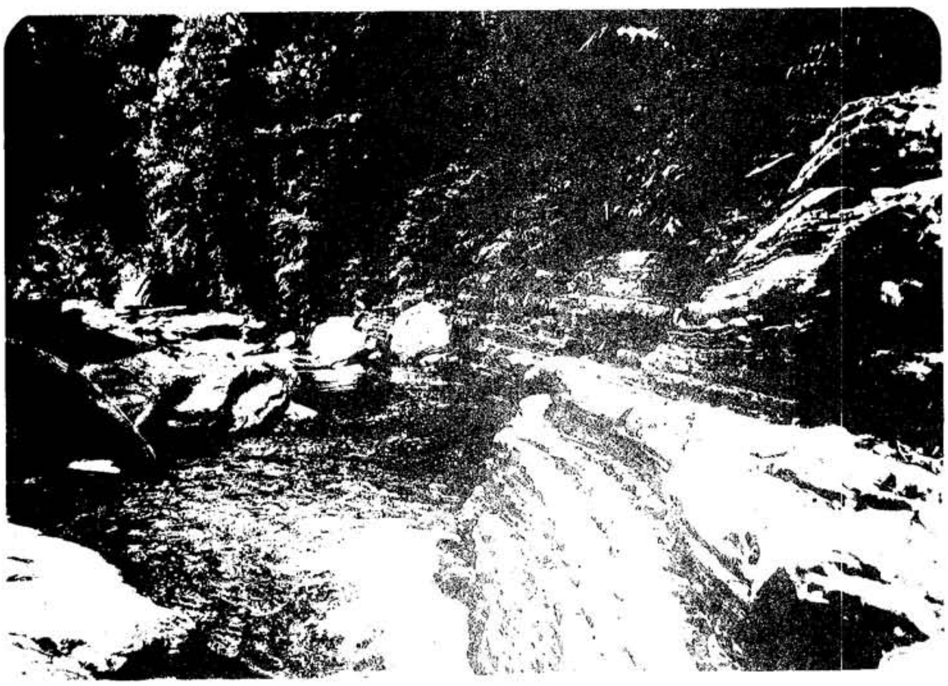

Plate 26. Thick bedded sandstone with thin mudstone overlain by thinly bedded sandstone and mudstone. Locality MB 48.

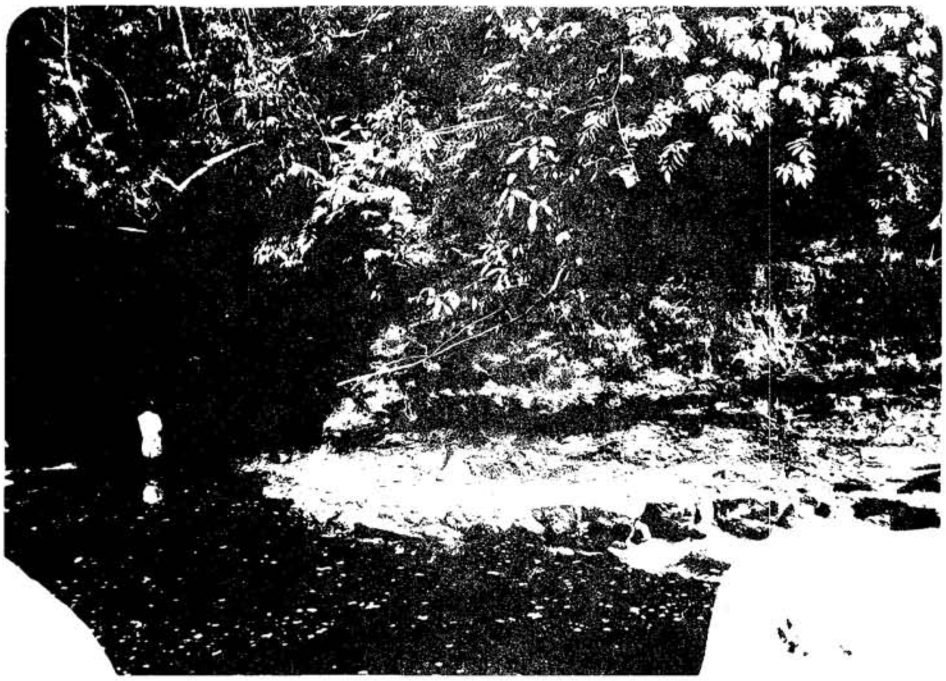

Plate 27. A 1.65 m thick blocky, clean coal roofed by a 2 m sequence of interbedded thin mudstone and sandstone and floored by a 1 m thick carbonaceous mudstone. Locality MB 19.

Plate 28. A 0.6 m thick coal seam roffed and floored by coaly mudstone. Locality MB 71.

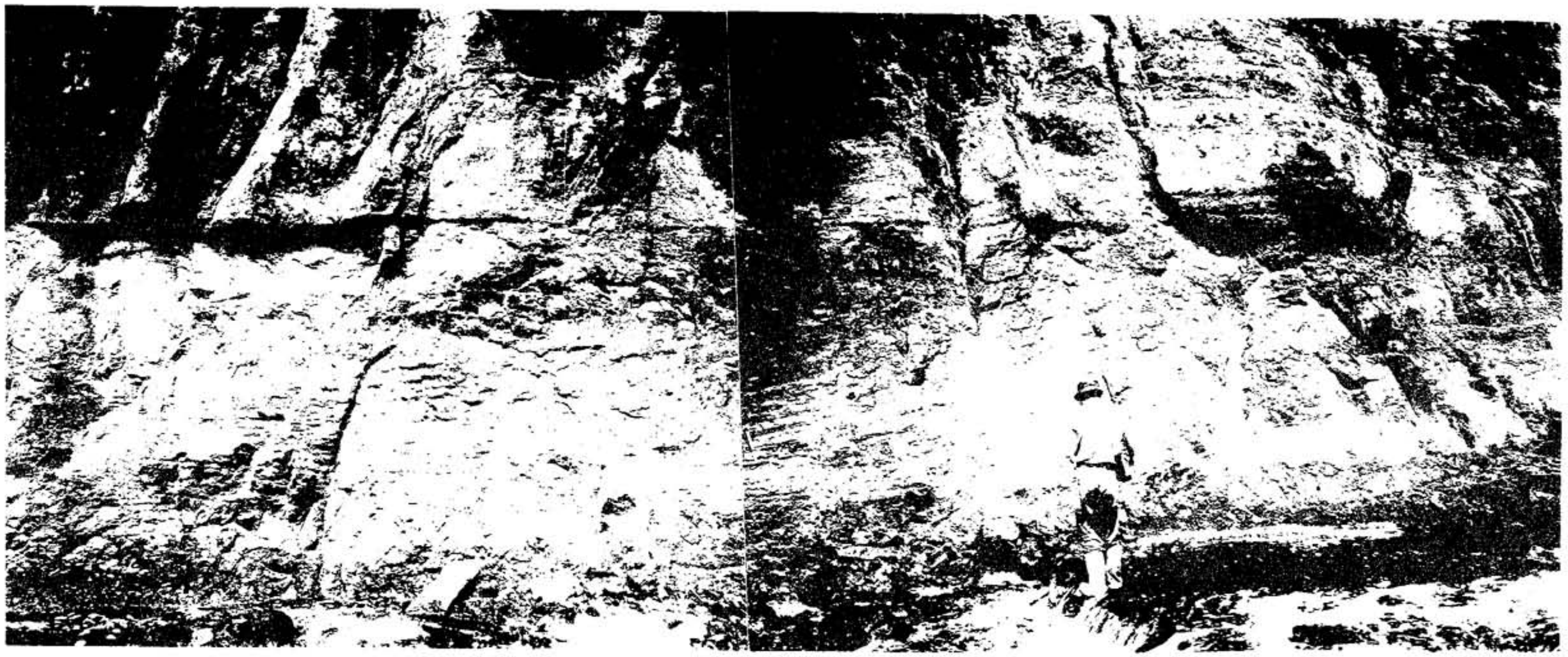

Plate 29. Cross-laminated massive mudstone in between massive tabular laminated mudstone (on top) and fine-grained sandstone (below). Cross laminae dip gently towards SW. Locality MB 58.

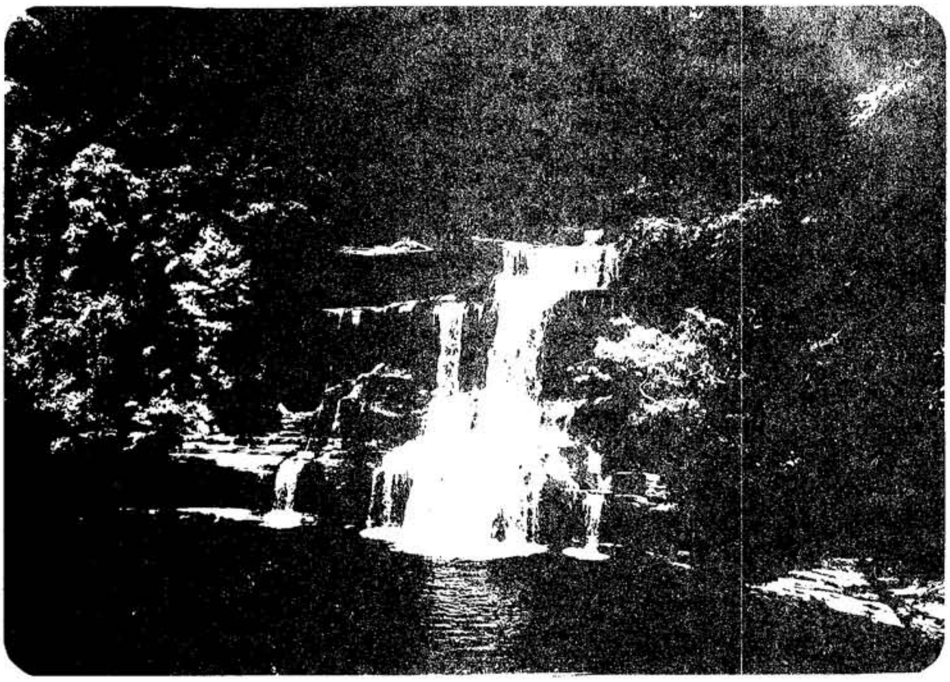

Plate 30. Interbedded thin mudstone and thin to thick sandstone beds forming the Maliau Falls.

Plate 31. Load casts at the bottom of sandstone block. Locality MB 78.

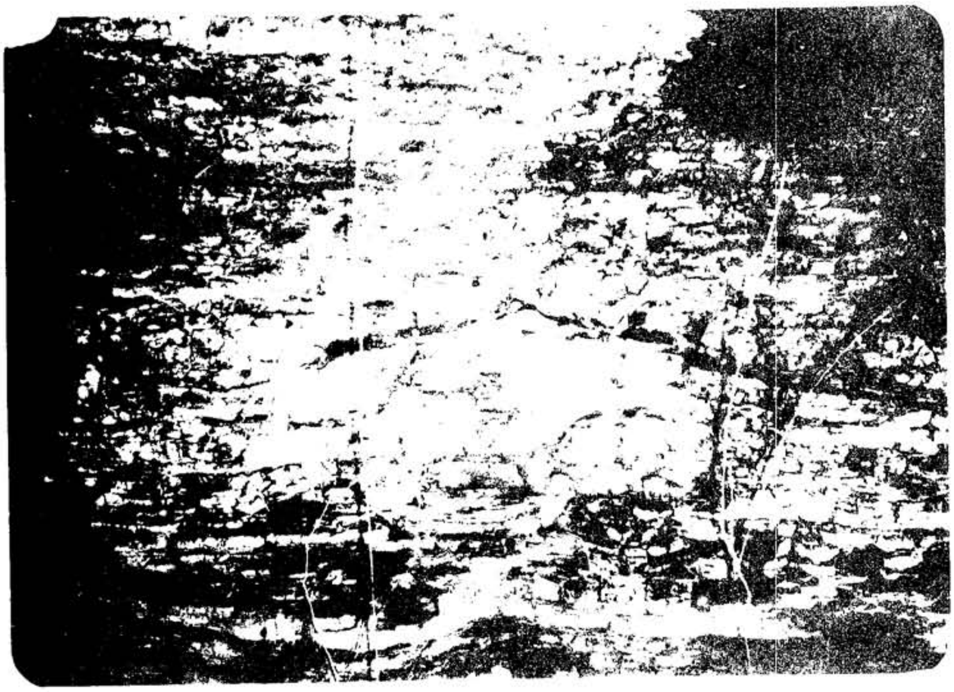

Plate 32. Palaeochannel filled with interbedded sandstone and mudstone . Locality MB 3.

Plate 33. Thick to thin sandstone beds dipping 15° SW (camera facing NW). Note prominent vertical joints which trend E-W and NW-SE. Locality MB 35.

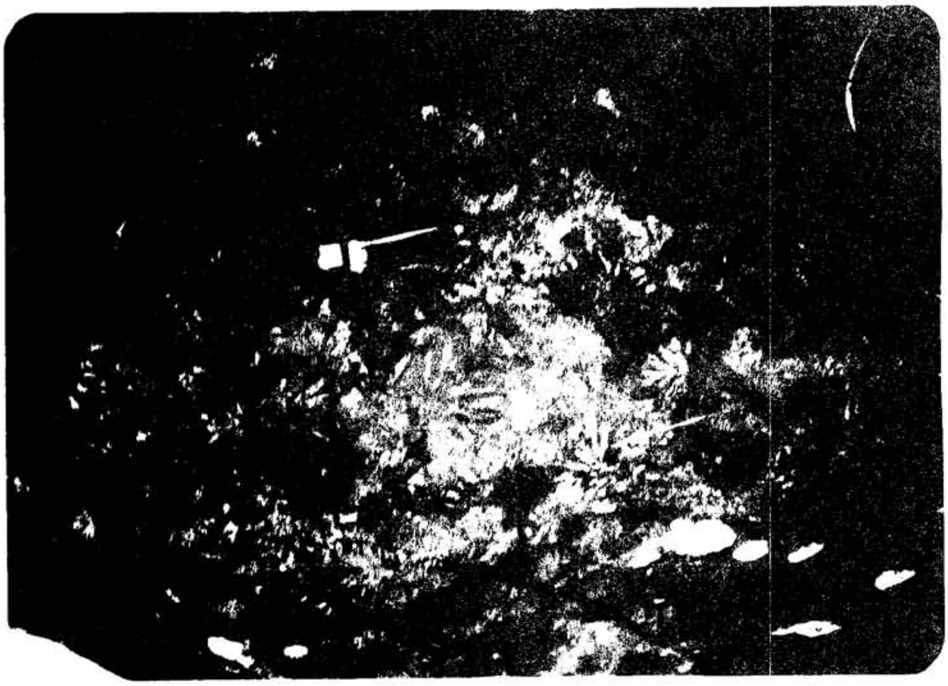

Plate 34. Radiating *Chondrites* on top of a sandstone block.
Locality MB 78l.

Plate 35. *Granularia* on top of a sandstone block. Locality MB 78.

Plate 36. Indeterminate big worm burrows in mudstone. Locality MB 38.

SECTION THREE - SOILS

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INTRODUCTION

The sedimentary parent materials of the Maliau Basin contribute to two Soil Associations, Maliau and Serudong, that make up the entire basin (Acres et al, 1975). The Maliau Association, which is the more extensive of the two, is composed extensively of soils derived from both mudstone and sandstone, while the Serudong Association comprises the soils of the dipslopes of the mountain cuestas, which are formed largely of sandstone with only minor interbedded mudstone. The Serudong Association extends in an arch form, capping the western and northern rims and extending inwards along ridges from the northeastern and eastern rims. Elsewhere in Sabah this Association is also found in the headwaters of river Serudong from which it takes its name, and coincides with similar massive bold topography and heath vegetation.

SOIL FORMATION

At any point on the relief, weathering and soil removal act in different degrees of intensity to promote the initiation of a soil profile. On level surfaces at a high elevation, for example in the heath forest zone, the presence of coarse-textured siliceous deposits and rapid accummulation of raw humus, favour podzolisation, while elsewhere at lower elevation on finer materials more weakly developed cambic horizons develop. Alluvial flats produce different profiles again.

The processes of eluviation and illuviation under conditions of hydration, hydrolysis and solution, eventually translocate and leach sesquioxides and clays into diagnostic horizons, such as the Fe, the organic matter-rich spodic, or the clay-rich cambic and argillic horizons. These are all common in Maliau Basin and form the basis of the technical classification that follows.

THE SOILS AND SOIL UNITS

Orthic Acrisols, Tanjong Lipat and Kapilit Families

These are derived from sandstone and mudstone and within the Maliau Association are found to occur on the scarpslopes. The two families are separated by the 25% clay content mark in their argillic horizons with the Tanjong Lipat having the higher content. Their argillic horizons range in colour from strong brown to yellowish brown. All depth phases occur. Fragments of weathered sandstones and mudstones are common in their profiles. Under undisturbed forest conditions, the level of plant nutrients, exchange capacities, base saturations and organic carbon for surface horizons are highest, and decrease with depth. The soil pHs are variable, but generally range from 4-5 and increase with depth.

Gleyic Acrisols, Gunung Alab Family

These are found on sandstone and mudstone on a range of slopes. They are imperfectly to poorly drained due mainly to surface water effects and the moist conditions at high altitudes. As a result there is the development of a gleyed horizon within 50 cm depth.

Occasionally, the upper argillic horizons below remain well drained indicating a perched water table situation. The textures of the upper argillic horizons range from moderately fine to coarse. The soils are moderately deep with stony subhorizons. Their upper horizons may contain concretions. At high altitudes only the surface horizons have reasonable nutrient level.

Dystric Cambisols, Antulai Family

Associated with actively eroding steep slopes are found these less fertile Cambisols. They are characterized by the weak horizonation and weak or moderate structural development of their profiles. The soil Family is identified on sandstone on steep hillsides and ridge crests. These soils are well or excessively drained and have a yellowish brown, medium textured Cambic horizon. Profiles are frequently stony and variable in depth.

Gleyic Podzols, Pa Sia Family

These are formed on sandstone and mudstone particularly on the moderate dipslopes of sandstone cuestas. They are generally imperfectly to poorly drained due mainly to surface water effects and as a result their E horizons are gleyed. The textures of the spodic horizons are moderately fine to coarse reflecting the different proportion of sandstone and mudstone in the regolith. The spodic horizon is coloured by the organic carbon, iron and aluminium. Generally, the spodics are not indurated. Profile depth varies.

Orthic Podzols, Sibuga Family

These soils are derived from sandstone on hills and mountains. The bleached E horizons are normally coarse textured while the spodic can vary from fine to coarse. There is often a clay increase in the horizons below the spodic. Indurated spodic and compact E horizons are rare. All profiles are well or excessively drained. The nutrient level is low except in the organic rich surface or clay rich horizons.

Humic Gleysols, Kidukarok Family

These are formed on sandstone which weathers to produce medium to coarse textured regolith. In these soils gleying is caused by surface water effects. The water is held by the thick organic O horizon which constantly saturates the underlying mineral soils. The soil profiles can be shallow to moderately deep, generally acid and have negligible levels of plant nutrients.

Dystric Histosols, Kaintano Family

These are peat soils formed on sandstone at high altitude under continuously moist conditions. They are diagnosed by the 40 cm or more of surface organic matter depth. The soil drainage, because of the extreme wetness is classed as poor. The good depth of organic matter may appear to indicate fertility, but its acidic environment impairs this.

Lithosols

These are shallow soils restricted in depth by rocky surfaces or rock outcrops and are frequently found together with the Antulai Family on steep slopes. They are formed on 10 cm of materials and are well or excessively drained.

THE SOIL MAPPING UNITS

On account of the size of Maliau Basin and the limited soil checks carried out, a broad grouping of soils is adopted, based on parent materials, soil-vegetation relationships, slopes and elevations (Map 7). One further mapping unit is defined by its association with soil mass movements. The soils that are expected to be found in each of these units are shown in Table 4. Dystric and Eutric Fluvisols are also likely to be found in the Alluvium Soil group.

TABLE 4

SOIL MAPPING UNITS

SOIL GROUP	MAPPING UNITS	SOIL UNIT							
		Acrisols		Dystric	Podzols		Humic	Dystric	Litho-
		Orthic	Gleyic	Cambisols	Gleyic	Orthic	Gleysols	Histosols	sols
Alluvium	Alluvial	P		P					
Above 900m a.s.l.	Under heath forest		P		P	P	P	P	
	Under montane forest	P	P	P	P	P	P	P	P
Below 900m a.s.l.	0-10° slopes	P	(P)	P					
	> 10° slopes	P		P					P
Affected by soil mass movement	Affected by land-slides,soil creep, etc	P		P					P

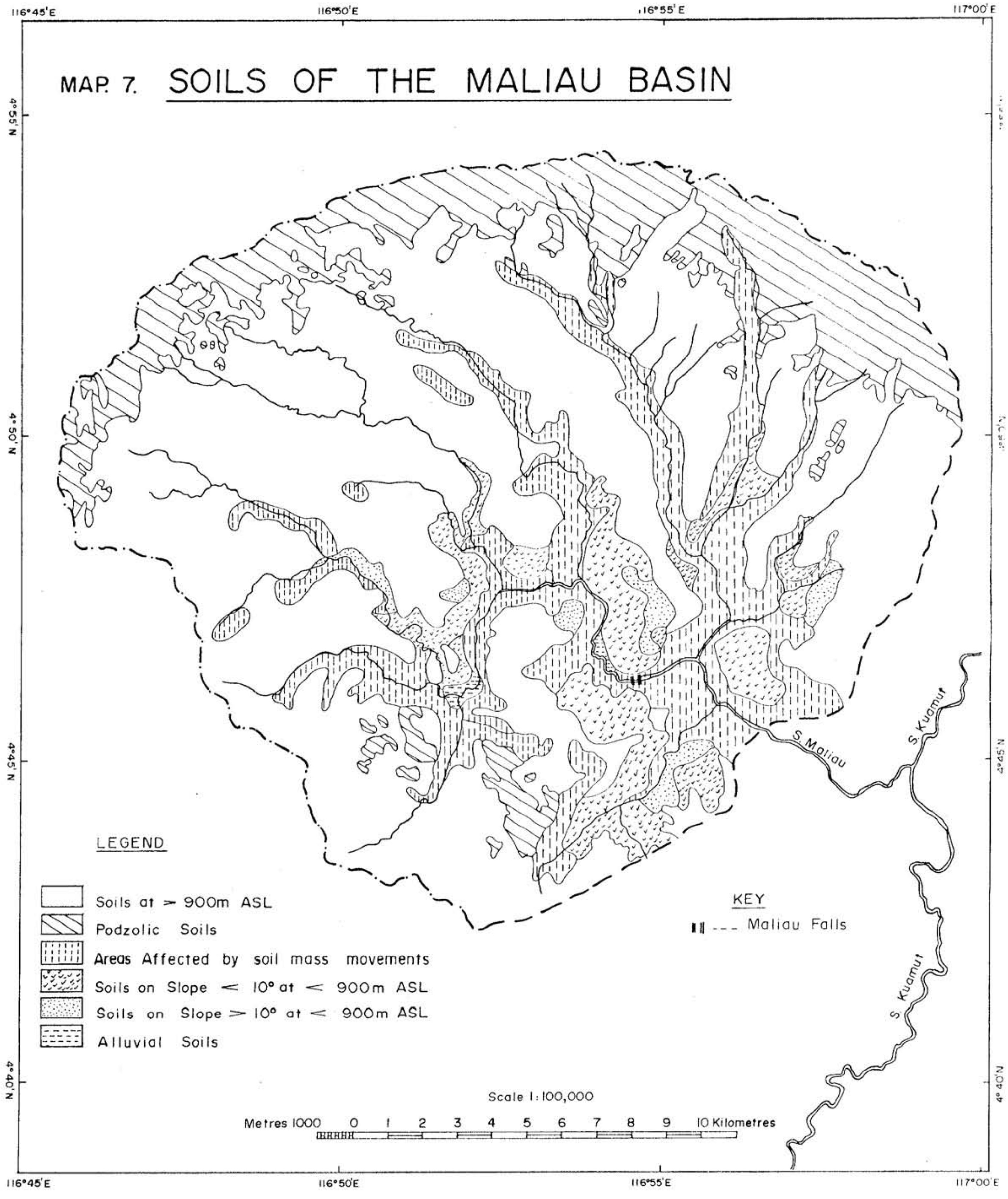
P = present (P) = may occur

Alluvial Soils

These are limited in extent and restricted to the meandering stretches downstream of rivers, forming narrow flats on both sides. The soils are weakly developed but their profiles may include contrasting textures representing different episodes of deposition. As fluvial deposits they are commonly quite fertile.

Soils Under Heath and Montane Forests Above 900 m a.s.l

The soils under these vegetations are very extensive particularly in the northern part. The soils under heath vegetation characteristically consists of coarse textured podzols, frequently with still weakly formed spodic horizons. Under (non-heath) montane forest both podzols and other soils like Cambisols and Acrisols are very common. Despite their coarse texture, localised water effects may still gley soil profiles. A deep accumulation of organic matter is a notable feature of these soils.



116°45'E
116°50'E
116°55'E
117°00'E
MAP 7. SOILS OF THE MALIAU BASIN
4°55'N
4°50'N
4°45'N
4°40'N
S. Maliau
S. Kuamut
LEGEND
Soils at > 900m ASL
Podzolic Soils
Areas Affected by soil mass movements
Soils on Slope < 10° at < 900m ASL
Soils on Slope > 10° at < 900m ASL
Alluvial Soils
KEY
--- Maliau Falls
Scale 1:100,000
Metres 1000 0 1 2 3 4 5 6 7 8 9 10 Kilometres

Soils Affected by Mass Movements Such as Landslides and Soil Creep

Evidences of soil mass movement is abundant on steep river banks where the soil is easily destablished by excess water seepage. Despite the instability of such sites vegetation regenerates quite rapidly and in some places vegetation has even established on cliff faces.

Soils Under Hill Dipterocarp Forest Below 900 m a.s.l

These soils are found scattered within the southern half of the Basin. Soil profile depth generally increases from steep to gentle gradients and typical soil units change from Lithosols to Cambisols and Acrisols. Also associated closely with this transition is the apparent change in forest species composition.

THE SOIL CATENA

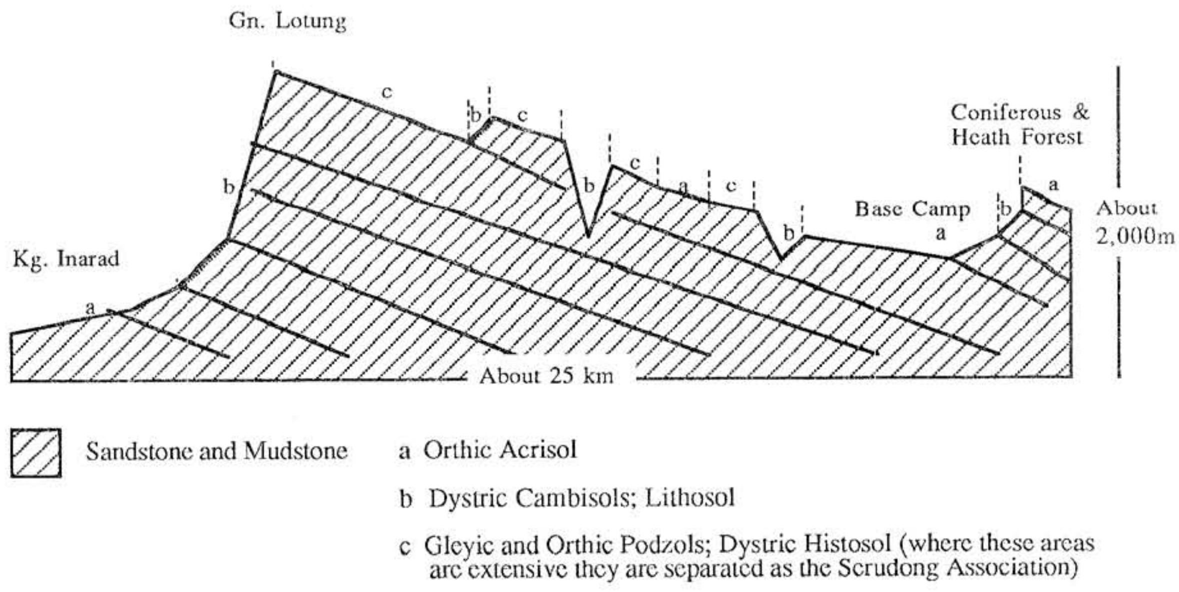
The Maliau Basin soils form a catena from lowland riverbank to montane cuestas at almost 2,000 m a.s.l. Soil profiles developed on alluvial deposits found at the lowest section of river courses are always deep. Nearest to the river bank, layers of boulders may restrict depth, but most of the soil profiles on the narrow strip of alluvium around Base Camp are at least a metre deep. On approaching the foothills, this good soil depth may persist, particularly if colluvial deposits have been formed. On ascending the slopes soil depth begins to vary. In sections where erosion is severe and slopes are unstable the soils are shallow or thin. On the ridges or in troughs where soil particles resist displacement good soil depths are developed. In the coniferous and heath forest zones the thick organic mat allows almost unimpeded development of profile depth, except in places where parent rocks outcrop.

Sandstones in the Maliau Basin are commonly fine grained and much more resistant to weathering than the mudstones and siltstones. At lower elevations, the narrow alluvial flats are built up by deposition of their weathering products. While the finer materials are carried by water to distant floor plains coarser sediments are deposited nearby which explains the tendency for most surface horizons to be coarser than underlying levels. On the plateau surfaces, where soil particle removal is minimal, the coarser particles are retained while the clays are leached or washed laterally. In the surface horizons and the spodic layer the organic matter also helps to hold together the coarser soil particles.

Under dipterocarp forest below 900 m, aerobic conditions ensures maximum decomposition of organic materials. These are quickly incorporated into the soil surface horizons so that only fresh litter remains on the surface. Above this elevation decomposition is slower in a frequently water logged and cool environment, leading in the heath forest zone to a thick organic layer overlying the substrate.

From the foregoing account, a generalized picture of soils distribution can be drawn. In the theoretical cross-section of the Maliau Association (after Acres and Folland, 1975) shown below, the different soil locations are indicated.

Fig. 15 Diagramatic cross-section of Maliau Association.



Soil Fertility and Potential

Steep slopes and coarse texturedness reflect generally low soil fertility value in the Maliau Basin. Only two soil profiles were analysed in detail (Table 5). The first was sited in the coniferous forest above Camp II and the other at 200 m northwest of Base Camp. Both appear to have very low values for all cations and for base saturation. The good level of organic carbon in the surface horizons raises the values for cation exchange capacities (the spodics of the podzol give values of at least 10 meq %) and even cations like Mg and K. It may be stated that in all respect the soils at the lowest elevation (second profile) least affected by slopes are better, although in both cases the extremely low pH impairs their potential.

TABLE 5

ANALYSIS OF TWO SOIL PROFILES

PROFILE NO.	DEPTH (cm)	pH in H_2O	ORG. C. (%)	TOTAL N (%)	C/N RATIO	EXCHANGEABLE CATIONS (me %) Ca	Mg	K	Na	CEC me (%)	BASES TOTAL me (%)	SAT'N BASE (%)	EASILY SOLUBLE P p.p.m
1.	0-6	3.4	18.77	1.014	19	0.31	1.29	2.07	0.23	53.30	3.90	7	21
	6-15	4.0	1.51	0.069	22	0.05	0.03	0.05	0.01	3.94	0.14	4	9
	15-32	4.1	0.49	0.035	14	0.08	0.02	0.03	0.01	4.85	0.14	3	6
	32-70	4.5	0.21	0.029	7	0.04	0.01	0.03	0.01	4.91	0.09	2	7
	70-100	4.5	0.15	0.030	5	0.18	0.01	0.05	0.04	5.29	0.28	5	6
2.	0-5	3.6	3.37	0.328	10	0.19	0.54	0.25	0.01	14.08	0.99	7	6
	5-27	4.2	0.54	0.091	6	0.09	0.10	0.11	0.03	6.52	0.33	5	15
	27-51	4.2	0.41	0.077	5	0.10	0.07	0.11	0.02	6.97	0.30	4	7
	51-120	4.4	0.25	0.066	4	0.12	0.13	0.11	0.02	8.65	0.38	4	7

From an agricultural standpoint, the Basin has little to offer. Most of the negotiable terrain contains poor, coarse textured soils with inherent nutrient deficiencies (Mapping Units I and II). Unstable slope conditions affect much of the rest (Unit III and IV). The remaining patches of alluvial and gentle lower slope soils (Units IV and VI) have at most marginal agricultural potential, but are small, scattered and inaccessible.

It is particularly important to mention the vulnerability of the soils in Mapping Unit III, which comprises almost sheer slopes of river gorges. Any removal of forest cover here would cause very severe soil erosion. Without doubt, the most logical use of the whole basin is its conservation.

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SECTION FOUR - HYDROLOGY, GEOMORPHOLOGY AND EROSION POTENTIAL

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INTRODUCTION

There has recently been a growing awareness of the severe environmental consequences of tropical rainforest clearance. Foremost among these effects are large-scale soil erosion and river siltation. However, Sternberg (1987) has pointed to the lamentable lack of hydrological and geomorphological base data on uncleared forests against which the effects of clearance may be gauged.

This study involves hydrological investigations of the environment of the Maliau Basin in its present equilibrium state, examining the river flow characteristics, water chemistry and suspended sediment loads. This information may be related to the geology, topography and vegetation of the catchment. Comparisons are made with the hydrological data presently being collected from the lowland rainforest catchment at the Danum Valley Field Centre by the "HydroGeoTrop" programme based at the University of Manchester. Studies of geomorphology and soil erosion are made, and the potential increase in erosion likely to be caused by land clearance is assessed.

The Sungai Maliau Drainage Basin

The Maliau Basin is a sedimentary plateau drained by the river Maliau, and its topography can broadly be divided into two categories; the upland areas of the Basin which are flat (eg. the heath forest south of Camp II) or gently dipping (eg. the southern flank of Gunong Lotung), and the river valleys which are steep sided and deeply incised, in places with sheer cliffs and knife-edge interfluves. Both headward and valley side erosion are very much in evidence, particularly in the headwater streams which are characterized by waterfalls, gorges, and undercutting of the valley sides resulting in landslips. The latter process is enhanced by the strength differentials between the geological strata, with the friable mudstones removed at a much faster rate than the harder sandstones. This also leads to the occurrence of natural bridges and subterranean river flow when sandstone strata remain intact after the underlying mudstone has been removed.

Drainage in the Maliau Basin is controlled by geological structure. The drainage pattern is dendritic but asymmetric with pronounced northern tributaries due to the higher relief of the northern part of the basin rim and to the asymmetry of the geological formation itself. The trough of the sedimentary syncline lies in the southerly part of the Basin in the "heath forest" area close to Camp II. The northern tributary rivers are related to the series of secondary escarpments in the north part of the Basin, the most pronounced of which forms the "long ridge". These features are elucidated by Tjia and Komoo (Section 2.1). The rivers generally follow the curve of these escarpments, flowing in a southeasterly and then a southerly direction along the base of the scarp slopes. The Sungai Maliau exits the Basin through a steep gorge to the south east where the rim is at its lowest.

Average drainage density is defined by Horton (1932) as "the total length of stream channels per unit area". Drainage density for the Maliau Basin is 1.573 km/km2. This figure was derived from the 1 : 50,000 scale map of the Basin using an opisometer or map-wheel. Comparable values derived from other areas are given in Table 6. The figure is considerably lower than that derived for comparable terrain in West Malaysia. This initially suggests a poorly developed network of incised channels on the upland plateau areas of the catchment. However, variations in techniques of measurement probably play a greater part in creating the disparity. Walsh (1982) extends the river network wherever contour crenulations on the map indicate that a valley, and hence arguably a stream channel, exists. Eyles (1966) demonstrated that for Peninsular Malaysia, drainage densities computed directly from air photographs were roughly double their map-derived values, giving densities of 7.5-9.3 km/km2. Field observations of the smaller tributaries of the Maliau suggest that there are numerous first and second order channels, gullies and ravines which do not appear on the map. It can therefore, be assumed that true drainage densities in the Maliau Basin are two to three times the map-derived figure given above, making it higher than average for a rainforest catchment.

TABLE 6

AVERAGE DRAINAGE DENSITY

DRAINAGE DENSITY (km/km2)	AREA	SOURCE
1.57	Maliau Basin	Author's data
1.34	Limestone, Mulu	Walsh, 1982
1.54	Shale, Mulu	Walsh, 1982
4.03	Granites, Peninsular Malaysia	Eyles, 1966

Figure 1 shows a long section through the Maliau Basin. It can be seen that there are two distinct "steps" in the profile. The upper of the two is a reach of steeper gradient approximately 3 km long which occurs where the Maliau crosses one of the secondary escarpment structures. The lower and larger of the two is the gorge through the rim through which the Maliau exits the Basin. The stream channels may be divided into four categories as follows:-

(1) The upland areas of the catchment are characterized by ephemeral channels. These may be deeply incised, and large boulders are often found in the channels indicating that flow is "flashy" and may reach very high levels during storms. For example, a stream on the eastern flank of the "Long Ridge" which drained a catchment of approximately 0.25 km2 was observed to rise from negligible flow to an estimated 0.8 cumecs in 15 minutes during intense rain.

(2) Upland permanent stream channels with baseflows of greater than zero to 0.25 cumecs, are frequently steep sided gullies or ravines, with downcutting, undercut/slump and headward erosion. Waterfalls of up to 15 m may be observed, forming due to the differing resistances of the geological strata.

(3) Rivers, with baseflows of 0.25 cumecs and above. Bank and bed erosion is active, with riffle and pool series interspersed with rapids and waterfalls of up to 20 m in height.

(4) At Base Camp the channel consists entirely of a series of riffles and pools and an alluvial flood plain is well developed. This channel form continues to the main Maliau Falls. The upper of these two waterfalls is 28 m in height, the lower is 15 m. Below the falls the channel character alters to rapid flow along a boulder and bedrock channel as the gradient increases towards the gorge through the southwestern rim. The Maliau Falls may be regarded as the local base level of erosion in the upper part of the Maliau Basin.

RAINFALL

Rainfall measurements were taken using a Casella tipping bucket recording raingauge, calibrated using a totalising check gauge. Rainfall records are shown in Table 7. Average annual rainfall is estimated as 3,800 mm.

TABLE 7

RAINFALL RECORDS AT BASE CAMP HELIPAD

DAY & DATE		DURATION (time on-off)	RAINFALL (mm)	MAX. INTENSITY (mm/hr)
Monday	25/04	2030-2120	29.58	54.34
Tuesday	26/04	1520-1525	1.94	7.76
Wednesday	27/04	1725-1740	9.66	29.10
Thursday	28/04	1310-1415	1.45	3.68
Monday	02/05	1730-1815	12.12	29.70
Tuesday	03/05	2125-0000	6.79	3.87

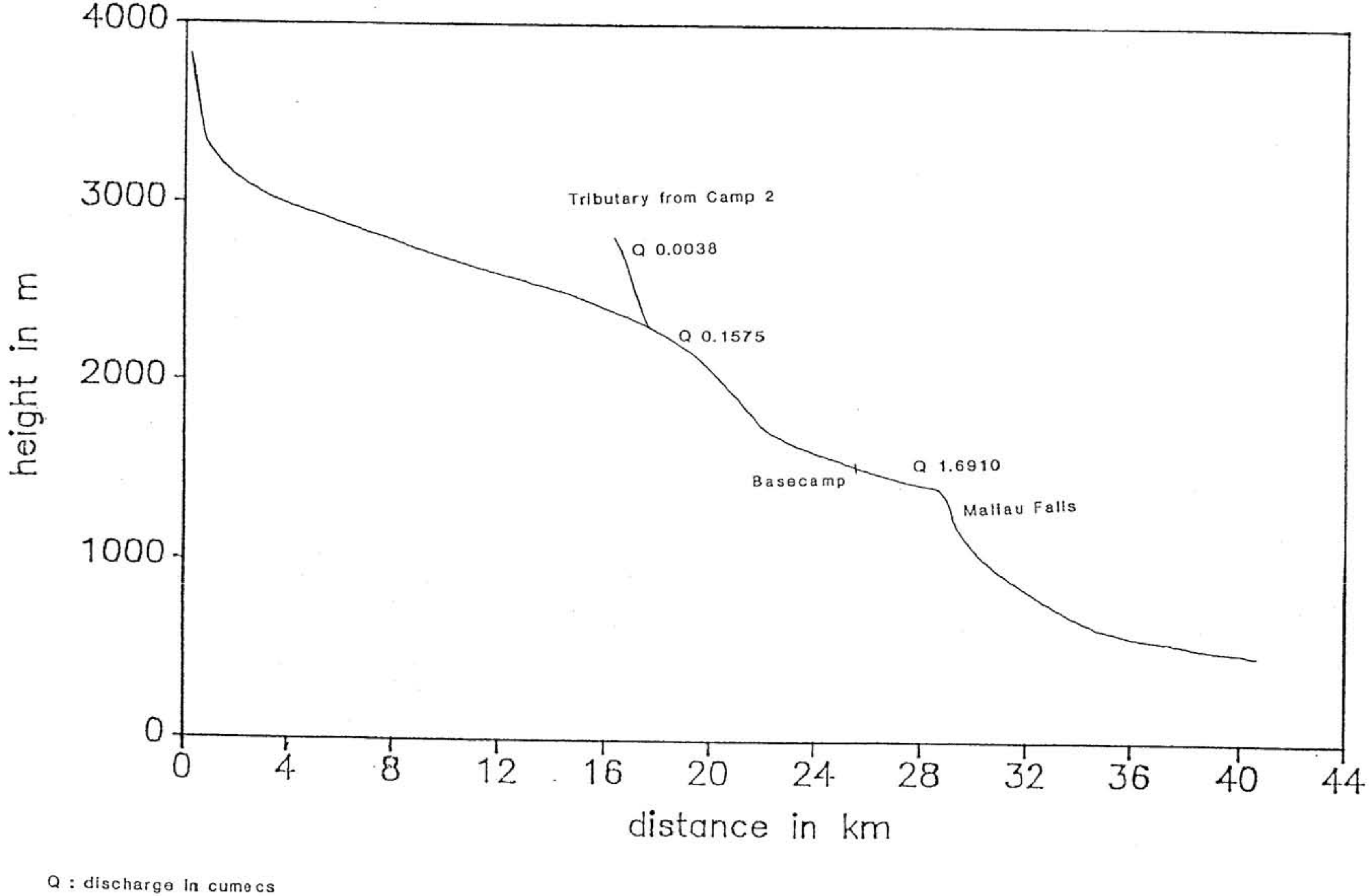
HYDROLOGY

The short-term nature of this study places limitations on the amount of information which can be gained from measurements of river flow. For example, measurements of the relationship between rainfall and runoff cannot be established without continuous records of rainfall and river discharge over a period of weeks or months. However, monitoring of baseflow and discharge variations for one storm can be coupled with observations of channel characteristics and ground evidence of recent floods to provide estimations of maximum flows. Clear "drift lines" of flood borne debris are visible at many points along the riverbank. In the plunge pool below the lower of the two Maliau Falls, a clearly defined drift line can be seen six metres above the present water level.

River discharge measurements were made at low flow at a number of points on the catchment. These are shown on the long section in Figure 16. A cross section of the Sungai Maliau channel was measured at a point approximately 1.5 km north of the Base Camp where a straight channel reach with a gradient of 3°, v-shaped cross section and well defined banks meant that bankfull channel area could be easily defined. The channel is 45 m wide and 5.5 m deep at maximum. Cross sectional area is calculated as 124 sq. m. If velocity is assumed to be 3 m s^{-1}, this gives an estimate of bankfull discharge as 321 cu. m. s^{-1} (cumecs).

More detailed monitoring of river flow on the Maliau was made at the Base Camp itself. Readings of stage (river height) were taken from a series of gauging poles which were installed in the pool immediately below the camp. These were wooden poles marked at 10 cm intervals, allowing for a rise of up to 4 m in water level. River discharge at each stage was approximated by surveying the cross section of the channel at its outflow from the pool. Velocities were estimated using a float. At high flows the error associated with velocity estimation increased, and this was exacerbated by the fact that the storm event on which the stage discharge rating curve was based took place at night, making accurate observations difficult.

Fig. 16 **Sungai Maliau Long Section**



Two distinct flood events occured on the Maliau during the period of the expedition. The first, on Monday, 25th - Tuesday, 26th April, reached an estimated discharge of 22 cumecs, and the second, on Tuesday, 4th - Wednesday, 5th May, reached an estimated 80 cumecs. Only the former event was monitored in detail, as during the second flood the author was away from Base Camp. The hydrograph is shown in Figure 17.

Suspended sediment measurements were made by Millipore filtration in Manchester of 60 ml water samples which were collected by hand at intervals through the storm. These are shown in Figure 17. Suspended sediment load at baseflow was found to be negligible. The maximum suspended sediment concentration recorded was 1,217 mg 1^{-1}. This figure was compared with presently unpublished data from the Danum Valley Field Centre (Greer, pers. comm.). Concentrations of this magnitude only occur in the undisturbed rainforest catchment at Danum during major storm events. As the monitored storm event on the Sungai Maliau represented only a small fraction of bankfull discharge, it can be assumed that suspended sediment concentrations on the Maliau during major floods will be considerably higher than those at Danum.

Much of the erosion in the catchment is event based and related to landslips (which are discussed more fully in the next section), and this will lead to variations in sediment load across the catchment due to landslips acting as point sources of sediment. Their importance is evident from the difference in river cross sections above and below a slip. Above, the riverbed is narrow and consists of large boulders and blocks with the river flowing around or beneath them; while below, the channel is wider and evenly graded with an abundance of sand and gravel sized particles.

The solute concentration of river water was measured in the field using a portable conductivity probe. Conductivity is a measure of the ability of water to conduct electricity. A strong and direct relationship exists between the "specific conductance" of a sample (its conductivity at a standard temperature of 25°) and the concentration of dissolved solids (Gregory and Walling 1973, 171). This is shown,

$$T = k C$$

where T = solute concentration (mg 1^{-1})
C = specific conductance (Ns cm^{-1})
k = a local constant depending on the particular solutes in the water

In general the values for the constant lie between 0.55 and 0.85. In this study, conductivity values are used unaltered as an expression of solute load. The waters of the catchment are very dilute. Values varied between 10 and 30 Ns. Conductivity readings were taken over a wide area of the catchment, and were found to be very uniform. The higher conductivities were observed in small streams where flow was almost zero, where standing water can remain for a considerable period in contact with the bed. These results compare with values of between 100 and 150 Ns for the lowland rainforest catchment at Danum Valley. The chemical composition of the solutes is determined using the technique of "inductively coupled atomic emmission plasma spectrophotometry" (ICP). Figure 18 shows a comparison of the Maliau and the undisturbed tributaries of the Sungai Segama at Danum. It can be seen that most of the difference in concentration is accounted for by the high quantities of Calcium and Silica at Danum.

The comparison between chemical composition of waters at high and low flow on the Maliau (Figure 19) shows that there is generally very little difference between the two. This finding is borne out by conductivity values, which are consistently 20 Ns throughout the flood event. This lack of change is attributable to the very low initial concentrations, although potassium, which is a less reactive element than calcium and magnesium and is slow to be taken up into solution, is not present at high flow.

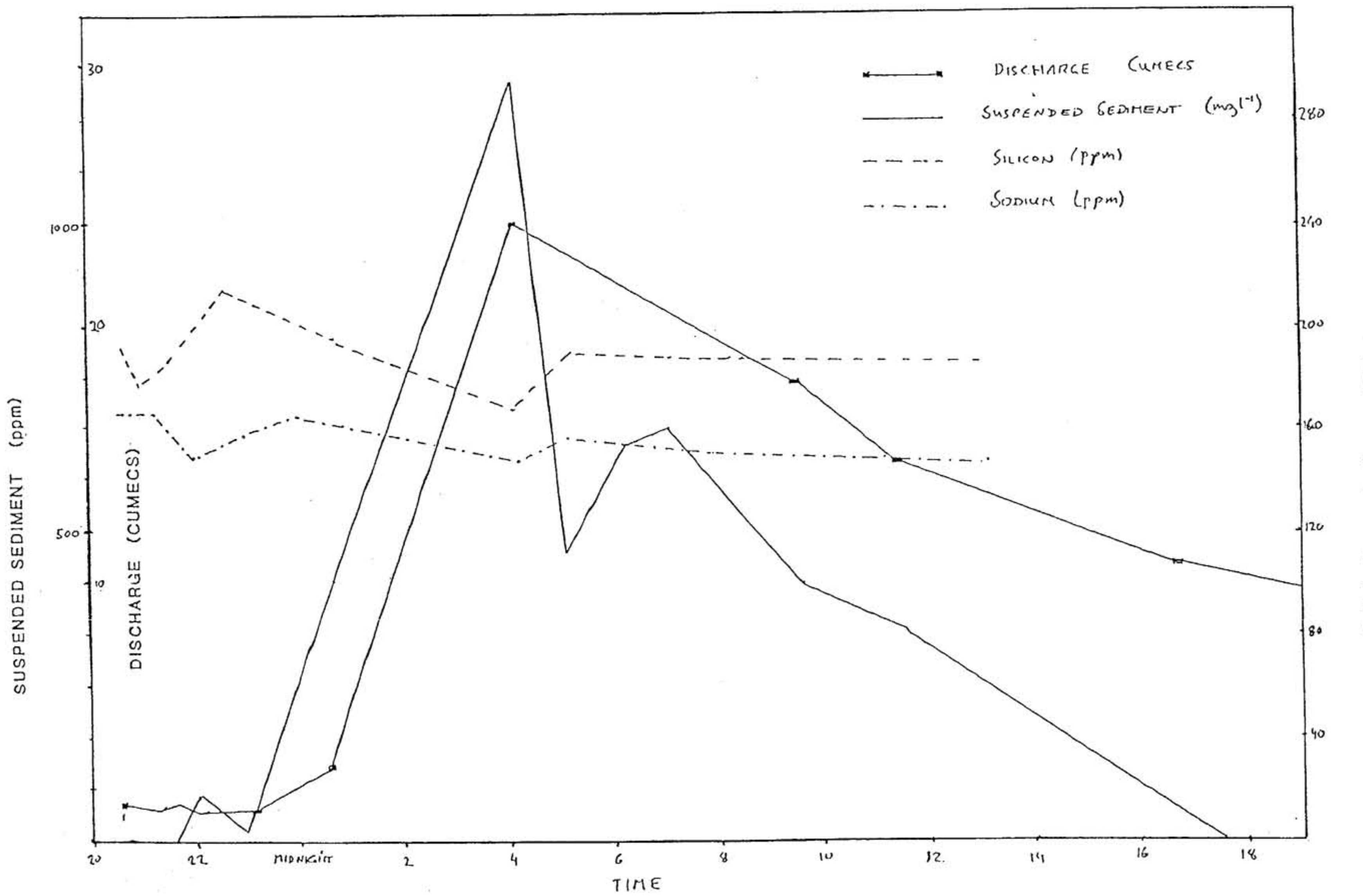


FIGURE 17 THROUGH – STORM VARIATION IN DISCHARGE, SUSPENDED SEDIMENT, AND SILICON AND SODIUM CONCENTRATION, FOR SUNGAI MALIAU WATERS AT BASE CAMP

Fig 18. Chemical Composition of River Water
Comparison of S. Maliau (G. Lotung) and Danum Valley waters at low flow.

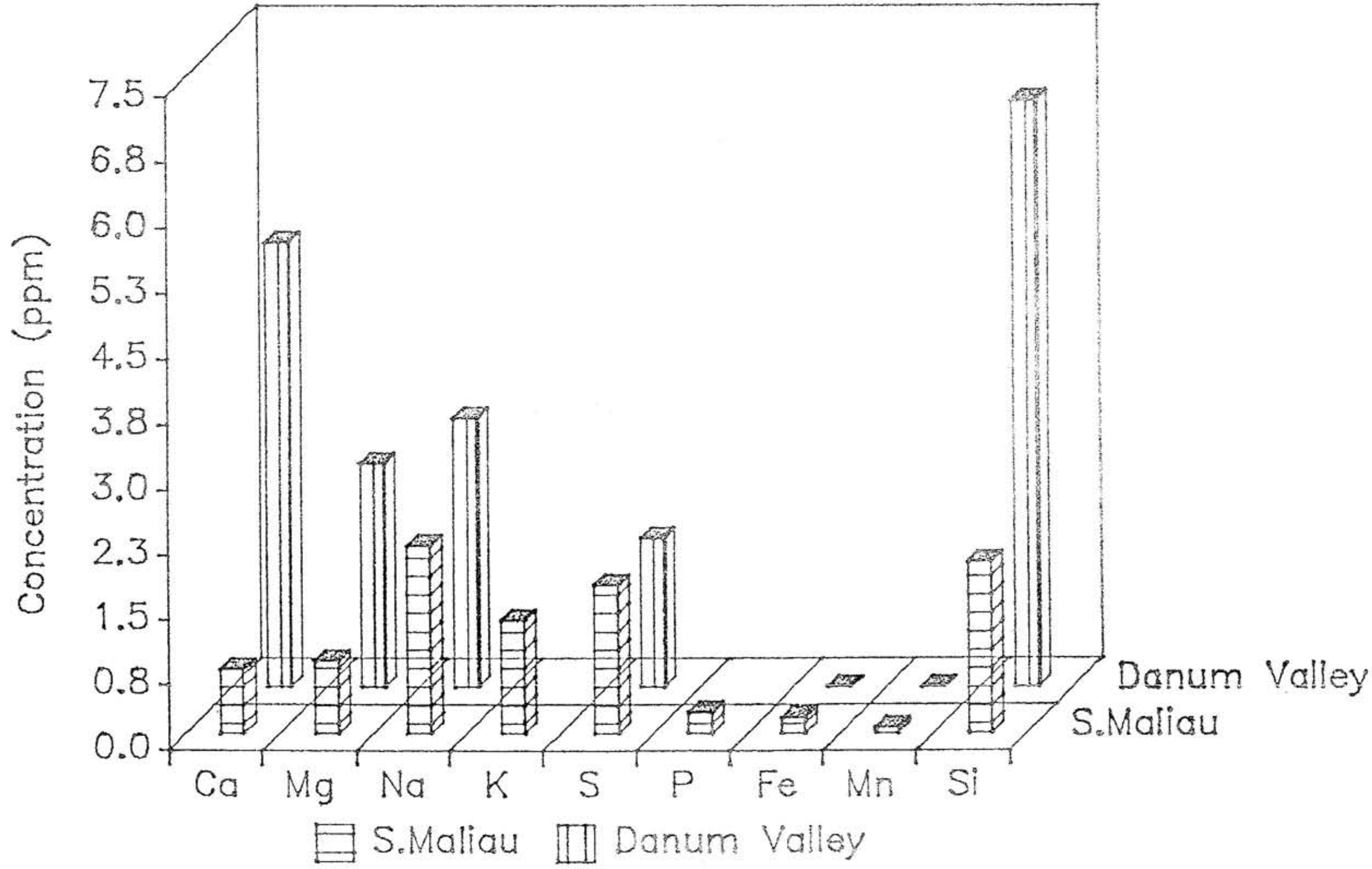
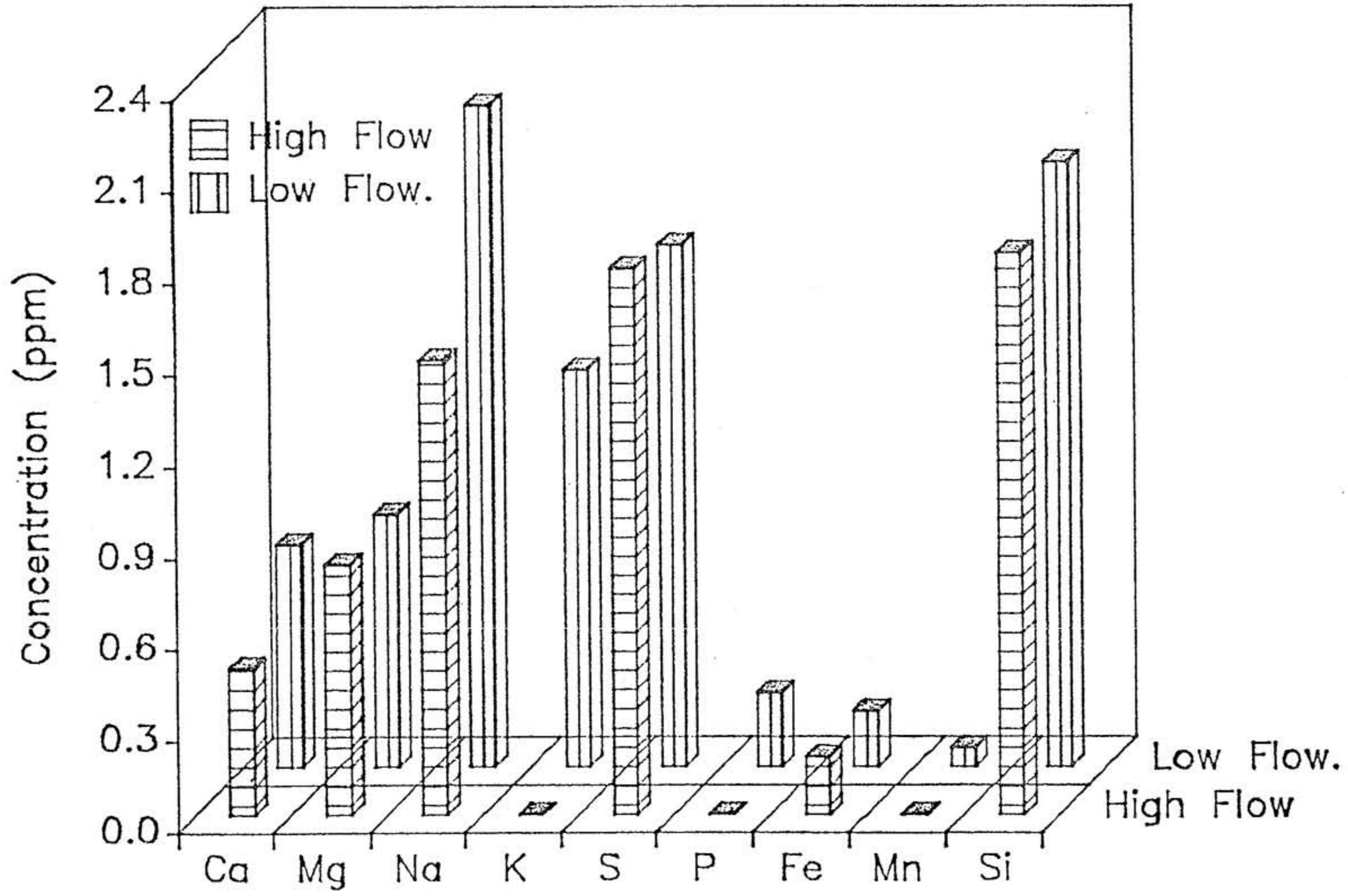


Fig 19. Chemical Composition of River Water
Comparison of high and low flow on Sungai Maliau



The pH of river water varies between 4.5 and 6.8, and is generally around 5.4. The streams draining upland areas are notably more acid than those draining the valley sides. For example, the stream at Camp II which drains upland dipterocarp and heath forest has a pH of 5, while the "corridor creek" which drains lowland forest opposite the Base Camp has a pH of 6.5. By comparison, baseflow in the lowland catchments at Danum is neutral or slightly basic. The spatial variations in pH and water chemistry are shown in Figure 20.

A characteristic of the Sungai Maliau at baseflow is the dark "tea-like" colour of the waters. This is a property found in many upland tropical rivers and also occasionally in lowland areas. The presence of this colouration is discussed by Brinkmann (1986), who makes a detailed examination of the "clearwater", "blackwater" and "whitewater" rivers of the Rio Negro basin of the Amazon. The so-called "whitewater" streams have higher concentrations of solutes and far higher suspended sediment loads than the other types. However, the "clearwater" and "blackwater" streams are both characterized by acidic waters with very low concentrations of dissolved solids independent of type. In these respects the Rio Negro waters can be regarded as extremely similar to the Sungai Maliau.

The difference in chemical composition between blackwaters and clearwaters is that blackwaters contain "small but nearly constant amounts of humic substances (humic acids, fulvic acids and humins) in the colloidal form" which account for the dark colour of the water (Brinkmann, 1986). It is argued that the lack of these blackwater constituents in clearwater streams is due to differences in rates of retention and recycling rather than variations in the amounts produced. However, rates of production do seem to be higher in areas of nutrient-poor soil, such as the sandstone soils of the Gunong Lotung basin which comprise quartz grains which have already been leached in one erosional-depositional cycle.

Percolating soil water is the key process; humic compounds are removed from the litter layer in the same way as solutes are leached from the mineral matrix of the soil. The ease with which they reach the streamwater is controlled by:

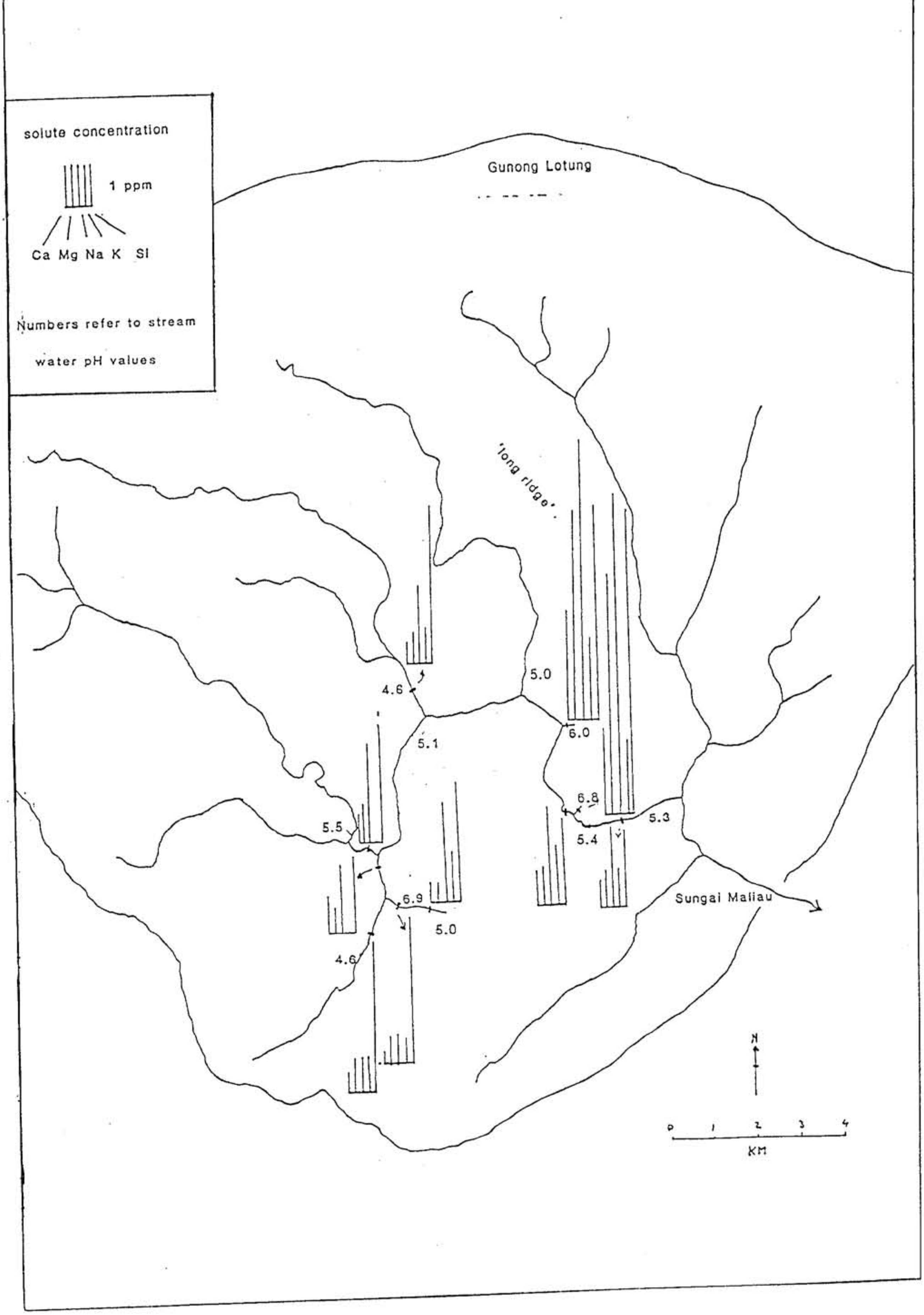
(1) The efficiency of the root mat of the rain forest in recycling plant nutrients into the living biomass.

(2) The ability of the soil matrix to retain organic colloids. Retention is particularly efficient in latosols, and especially those which are well structured and well drained and where the weathering profile is deep and well developed. Such conditions generally occur in areas of gentle relief.

In the Maliau Basin, plant nutrients and non-humic substances released from the litter layer will be rapidly recycled into the biomass, but residual humic substances will enter the groundwater and drain into the river system. The comparatively sparse heath forest vegetation of the plateau can be regarded as less efficient than the dipterocarp forest in trapping humic compounds, while the steep slopes and thin soils of the valley sides will allow rapid and unhindered drainage into the blackwater streams.

To test for humic compounds, the Ultra Violet absorbance of a water sample in the 230 nm waveband is used. However, the water samples from the Sungai Maliau could not be tested due to "blooming" of algal material in the sample bottles. Immediate refrigeration of samples after collection would be required to prevent this. Until such a test can be conducted, the above explanation of blackwater conditions in the Maliau must be regarded as speculative. However, the similarity of the environments of the Maliau and blackwater streams of the Rio Negro suggest that both are subject to similar physical processes.

Fig 20. pH VALUES AND SOLUTE CONCENTRATIONS IN THE SUNGAI MALIAU CATCHMENT



During flood flow the increased sediment loads of the Sungai Maliau alter the blackwater colouration to a turbid pale brown.

GEOMORPHOLOGICAL INVESTIGATIONS

Field observations of processes of erosion were made. Root steps, indicating soil creep, are widespread throughout the catchment, even on gentler slopes of around 10°. On the steep (20-40°) slopes of the valley sides there is abundant evidence of active erosion, much of which appears to take place as single high magnitude events such as landslips rather than as a continuing gradual process. The occurrence of talus and boulder deposits is widespread, particularly on the lower slopes. These occur due to landslips, and to differential weathering of the geological strata producing caves and overhangs which subsequently collapse. The material is held in position by vegetation. A single treefall can trigger movement over a considerable area. On the higher slopes where talus deposits occur less frequently, there is evidence in places of soil piping and subterranean drainage beneath a mantle of accumulated vegetation and debris. On the plateau areas (such as the heath forest south of Camp II) erosion features are less obvious due to the gentler gradients. Rainsplash processes appear to be important in this area, and soil pillars and elevated ground can be seen beneath roots and fallen branches which give protection from raindrop impact. The increased importance of rainsplash as an agent of erosion in this area can be accounted for by the fact that the tree canopy in the heath forest is sparser than in the dipterocarp zone, resulting in smaller amounts of rainfall interception and stemflow.

Areal reconnaisance of the catchment indicates that landslips are widespread. A landslip at grid reference 622254 which had been triggered by river bank undercutting was approximately 100 m in width and 220 m long. Four major landslip sites could be observed on the 10 km reach of the Sungai Maliau above the Maliau Falls. However, not one of these can be seen on the vertical air photograph series of 17/7/71, indicating that they have all occurred within the last 17 years. These observations suggest that the Maliau Basin is potentially very vulnerable to soil erosion, and that any widespread disturbance of vegetation (eg. logging) would have very severe geomorphological consequences.

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SECTION FIVE - PLANT STUDIES

5.1 : PHASE I BOTANICAL DIARY WITH PARTICULAR ATTENTION TO FRUIT TREES, ORCHIDS AND HERBACEOUS FLORA

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APRIL 19, 1988

This was our first day in the field. W.W. followed En. Donson Simin to the N.E. Ridge opposite Base Camp making a traverse from the riverbank at 045 degrees bearing. Several orchids were seen at the river bank including a Coelogyne sp. They also disturbed a large colony of flying foxes (Pteropus vampyrus natunae) 800 m from the river and located a tarap (Artocarpus odoratissimus) with a 2 m girth.

Meanwhile, A.L. accompanied the RTM crew, Puan Elaine Gasis and others to the Maliau Falls, collecting along the way. Among the small trees and shrubs found in flower or fruit were a species of Memecylon (Melastomaceae) and a shrub with small red fruits that was probably Syzygium chrysanthum. A pale pinkish white flowering Coelogyne orchid (Section Moniliformes) by the river was collected by Puan Gasis. At the falls, A.L. collected a hairy pink flowered Begonia sp. and a white flowered Marantaceae.

APRIL 20, 1988

It was decided to follow the Yayasan Sabah team cutting the trail up Main Trail Ridge (Plates 37 and 38). We left at 7.30 am crossing a small kuala near to Base Camp to a small river levee. Here two fruit trees, both sterile at the time, were discovered. One was a pulasan (Nephelium ramboutan-ake) and the other the small fruited Baccaurea stipulata. After a short distance the ridge ascended very steeply and on a low tree a small orchid was collected. This later flowered at the Tenom Orchid Centre and turned out to be Abdominea minimiflora (Sarcanthine. See Figure 21). On the ground an orange flowered ginger Globba cf. propinqua was observed.

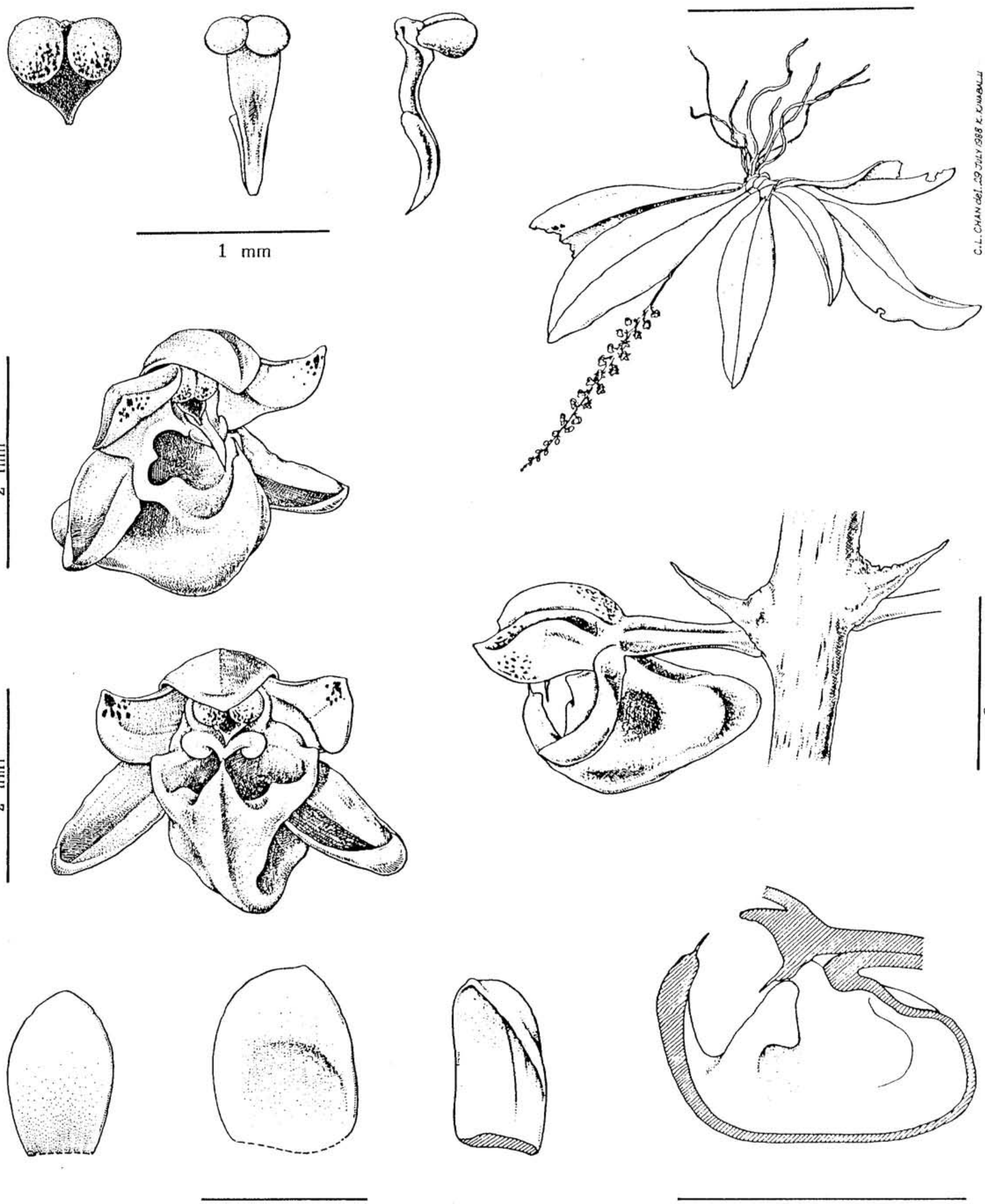
Then came a surprise at altitude 650 m a.s.l. when we discovered a freshly killed male proboscis monkey (Nasalis larvatus) (Plate 39) with one arm torn off and many bite marks. It appeared the path blazers had passed it by. While photographing it, we suddenly upset two others in the group that started calling and moved off. A little further up the ridge a commotion above brought us to a halt and a small Grey Leaf monkey (Presbytis hoseii) crashed to the ground in front of us and raced off being followed above by what appeared to be a large and angry male proboscis monkey. We surmized this male had killed the young proboscis monkey in a fight.

In this area, up to 750 m elevation, were a few Mountain Nibong palms (Oncosperma horridum), tarap (Artocarpus odoratissimus) and a large leaved Nyatoh Buluh (Palaquim becarrianum) in the Sapotaceae family. The most interesting find, however, was a wild mango with large leaves, the bole was 60 ft tall and girth about 2 m. However, it has no flowers or fruits. It is like no other mango species we have found, but with leaves similar to Mangifera pajang. It was subsequently identified by J. Bompard as M. bullata, which is a new record for Borneo. The species is also found in Sumatra.

CHAN: 159

ORCHIDS OF BORNEO
SABAH: G. Lotong
Maliau Basin
Coll. A. Lamb 1988.

~~Hodominea minimiflora~~ Fig. 21



On one steep section a large Garcinia sp. was found in flower. Most of the red flowers appeared to have aborted, due to the drought. The tree was over 10 m with a bole of 35 cm diameter. The latex of this species was white. Another small Garcinia tree with large leaves looked like the typical mangosteen, Garcinia mangostana. A few sterile orchids were seen on some trees, including a Pteroceras sp.

On the way up, a very large unusual termites nest with a mass of protruding "root-like" hollow tubes was examined (see Plate 40). A small Sterculia tree with open red seed pods and a lot of rotans were other features of this forest.

On the way down, a magnificent Phanera kockiana creeper covering a tree was in full flower – orange flowers. Up in the crowns of several trees a scarlet flowering parasitic Lauranthaceae was observed to be quite common. W.W. had to go slowly with knee trouble, and A.L., Puan Gasis and En. Leopold Madani went ahead collecting some of the oaks, many of which had been fruiting, though Bearded Pigs had eaten most of the acorns. There seemed to be several species, with leaves of one species appearing to be unknown.

APRIL 21, 1988

Due to his knee trouble, W.W. accompanied the RTM crew filming the activities of the Botanists and Entomologist along Corridor Creek.

A.L. and En. Andy Surat also went across the river to the same ridge area where a small shrub with orange/yellow fruits (Urophyllum collubrum) was found and collected.

A stream was reached where two rambutan trees, a Nephelium cuspidatum var, robustum and Nephelium spp. were found without flowers or fruits, and then some oaks (Quercus argentata?) in heavy fruit with a Kijang (Muntiacus muntjak) feeding on the acorns in the stream bed. The stream widened and straightened at a 5-10 degrees slope with the bed consisting of a continuous slab of sandstone forming a corridor through the forest. Hence it was named Corridor Creek.

A beautiful creeper with flattened red flowering stems hung over the stream – a species of Pterisanthes of the grape family, Vitaceae (Plate 42). Along this river and in the forest to the side there appeared a large number of wild fruit trees; particularly noted were three to four species of Artocarpus including tarap (Artocarpus odoratissimus), togop (Artocarpus elasticus) and two other species, however none were flowering or fruiting. The forest was also quite rich in dipterocarps. After leaving the stream, but following the valley, a further eight rambutan trees (Nephelium spp.) were recorded and some tampois including "Kunau-Kunau" (Baccaurea stipulata) and Limpaun (B. lanceolata). A seedling mango "Bachang" (Mangifera foetida) was found and also a durian, probably Durio kinabaluensis which A.L. had found in fruit in this area in 1982.

The headwaters of the creek by now had split into several small streams which were crossed. Very few orchids were encountered until this point, particularly ground orchids, but near these streams a Nephelaphyllum pulchrum with a yellow/green lip to the flower (usually a white lip) was collected, and on a small tree Taeniophyllum filiforne (leafless orchid). Proceeding back down the ridge on the western side of Corridor Creek, 3-4 very large pulasan trees (Nephelium ramboutan-ake) were found in a group. An area of forest was then reached which was dotted with recent Bearded Pigs nests (1 month old). In the area were several oaks, (Quercus argentata?) dropping acorns. The area under these trees had become completely bare earth with the trampling and clearing of the leaf litter by pigs and deer. The streams nearby were dotted with pig wallows but only one small Bearded Pig was seen departing

Moving to the edge of the ridge above the Maliau River a large 10 m Garcinia mangostana was found. A red flowering Dendrobium spp. was found flowering on fallen dipterocarp branches. In this area of the steep scarp slope other orchids found were Acriopsis spp., Pteroceras spp. and a Grosourdya spp., all infertile. The last fruit tree of the day was a large durian sukang tree (Durio oxleyanus) identified by its leaves.

Base Camp was reached in the late afternoon after a day in which the survey indicated that the ridge, subsequently, named Rambutan Ridge was extremely rich in wild fruit trees. The dry soils and leaf litter and aborted fruits apart from the oaks indicated a failed fruiting season. The presence of so many flying foxes, hornbills, monkeys and wild pigs indicated that they had migrated here in anticipation of the fruiting season (Plate 43).

That evening, En. Donson Simin brought in a flowering Malaxis punctata ground orchid with spotted leaves and small purple flowers.

APRIL 22, 1988

En. Andy Surat left early to carry camping equipment up to Camp II. A.L. spent the morning preparing equipment and notes, but, also collected a flowering orchid (Chelonestele spp.) on a branch of a tree over the river by the Base Camp. In the afternoon, he took a different route behind Base Camp following a very difficult stream with small waterfalls, landslides and fallen trees. Along the river were a lot of Begonias of one species. Leaving the stream, to climb the very steep ridge behind the camp, he found a seedling Durio acutifolius. Further up the ridge a 40 cm tall saprophytic orchid, Sterusandra savaniam, was found in full flower with purple tips to the petals (Plate 44).

W.W. with Cik Patricia Regis left camp at 8.30 am to go up the ridge behind the Base Camp. They found a wild mangosteen or Kandis seedling of 2.3 m identified by its habit and leaves as Garcinia parvifolia ? and also a pulasan tree.

En. Andy Surat arrived back at Base Camp in the evening having collected a Begonia sp. with white flower and the Necklace orchid, Coelogyne dayana, with a 60 cm long inflorescence of cream flowers with chocolate lips. The specimen was rather large so only flowers were collected in spirit.

APRIL 23, 1988

A.L. and En. Andy Surat made an early start for Camp II to study the flora in the heath forest. W.W. decided his knee could not take the strain and so continued surveys along the river. On the route up, A.L. and party watched a large Tufted Ground Squirrel (Rheithrosciurus macrotis) feeding on Canarium fruits in the crown of a large tree. Its huge, bushy, umbrella-like tail and long tufts of hair on its ears easily distinguished it. This particular animal was clearly seen and appeared to be pale grey-buff, with no brown upper parts as usually recorded.

After reaching Camp II, the party continued up a ridge dominated by large rengas trees, which when cut exuded a black sap. From a clearing here we could see across a deep valley to the edge of the plateau with the heath forest. From this point, we could also look into the canopy of several trees, and saw a large Lauranthaceae in full flower. At this point a very interesting Bulbophyllum spp., an orchid with medium-sized yellow flowers, was found (Plate 46) and remains unidentified as yet. Further up the ridge an interesting Eugenia with large leaves, and quite large cauliflorus fruits on the tree trunk was thought to be most unusual (Plate 41). A lot of Podochilus orchids were noted at the base of some of the trees.

Eventually, a small hill top was reached about 150 m above the camp (1,100 m) with a forest containing Casuarina sumatrana, Phyllocladus hypophyllus, the Celery Pine, Dacrydium beccarii, a Southern Pine, Agathis dammara or Bornean Kauri Pine, and a Podocarpus sp. was also noted, and so the forest could be described as lower montane mixed Casuarina and coniferous forest. On the forest floor a thick peaty leaf litter covered the ground, and several sprawling Nepenthes plants were noted. These were collected and later discovered to be Nepenthes hirsuta (Plate 47), probably the first record for Sabah. There are no reports in the literature, though specimens from other areas of Sabah could occur in herbaria, as this species is found in Brunei and Sarawak. It is very close to N. leptochila and N. macrovulgaris and could easily be confused with the former if it were not for its hairy tendrils.

A second interesting find in this forest was an epiphytic Coelogyne orchid with cinnamon and white coloured flowers on a pendulus inflorescence. This appears to be a very rare species close to C. odoardi J. J. Smith (after Beccari the Italian Explorer) but it does not quite fit so it could be new (Plate 51). As Dr. E. de Vogel is working on this orchid section at the Reikshebarium in Leiden, an identification in future should be confirmed.

The area appeared rich in orchids but as time was short the team proceeded down the hill into the stunted heath forest of the plateau. Here we met the Forestry Department team returning to Base Camp. A well worn fairly straight pig/animal trail, an obvious migration route into the Maliau Basin, was followed through most of the heath forest along which En. Donson Simin had taken soil augers and made profile pits. This trail was named "Jalan Babi".

Three Nepenthes spp. were identified. The most spectacular was N. veitchii which in some places climbs straight up tree trunks, the leaves clasping the tree trunk like straps, with the large golden pitchers hooked over each other down one side (Plate 49). The unusual habit, large golden peristomes of this pitcher plant make it one of the most striking. A more common mountain pitcher plant growing on the shrubs was N. stenophylla (Plate 50). A few plants of the widespread N. reinwardtiana were also found.

Amongst these plants was another very beautiful pitcher plant with pink, blotched pitchers that seemed intermediate. This appears to be a first record in Sabah of the natural hybrid N. veitchii x N. stenophylla (Plate 48). Subsequently, Bruce Sutton of the USA who is studying the taxonomy of the genus Nepenthes examined the specimens and thought it might be a species of the N. maxima complex, however, in the field the habit and distribution of the plants all pointed to it being a hybrid. Natural hybrids of Nepenthes in Sabah are quite a common occurrence.

APRIL 24, 1988

W.W. set off at 7.30 am from Base Camp with the Forestry group going up river along the Maliau River and spent some time collecting fish in various pools, succeeding in collecting about 20 catfish. They then joined up with Dr. C. Marsh to visit the site of a Rafflesia tengku-adlinii discovered by En. Leopold Madani and the Forestry group, to check the growth of the buds. This was on a ridge behind the Base Camp.

A.L. and En. Andy Surat, the RTM crew, Puan E. Gasis and Cik Patricia Regis rose quite early with the plan to help the RTM crew filming in the heath forest. They had only arrived late the previous afternoon with all the equipment. Whilst having breakfast by a camp fire on the edge of the stream, two Kijang (barking deer) suddenly appeared, jumping over the camp fire and rushed past Cik Patricia Regis and A.L. missing them by a foot. They appeared to be the common species. After breakfast the group headed up Rengas Ridge past an old camp site made in 1986 by a previous expedition (see p.18).

Progress was slow as filming took place as we went. On reaching the mixed Casuarina-coniferous forest, En. Andy Surat and En. A. Lamb searched for orchids, particularly a small Helmet orchid seen the previous day. Finally, a flowering plant in moss around the base of tree was discovered and identified as Corybas piliferus (Plate 54). This relatively newly discovered species was only previously known from a few individuals in podsol forest at 450 m near Nabawan also growing in moss at the base of a conifer (Dacrydium pectinatum). So besides being a second locality record for this species at twice the elevation of Nabawan the fact that over a hundred plants were found at this site is significant to its conservation.

In the same area growing in the peaty leaf litter layer was a Dendrobium spp. (see Figure 22) with wiry stems having yellow flowers with a white lip belonging to the Section Conostalix in this one of the largest genus of orchids in Sabah. A terrestrial saprophytic orchid was also found, growing in the deep leaf mould. Flowers were borne on blackish wiry stems to 30 cm tall, and had wide spreading ocher petals and a yellow hairy lip which did not appear to be reflexed. At present it is only identified at the genus level as Lecanorchis.

The RTM crew moved into the heath forest spending several hours filming Nepenthes and the two Rhododendron species that could be found in flower, R. longiflorum var. subcaudatum (Plate 14b) with orange flowers and R. durionifolium spp. sabahense with pinkish purple flowers. A rare Dendrobium pachyanthum (Figure 23, Plate 45) was discovered during the filming. This species has only been found in Sabah before by A.L. on Mt. Kinabalu.

The cameraman of the RTM crew was quite ill with a gastric problem and so filming was confined to one area of the heath forest. Little flowering material could be found apart from one Chelonistele amplissima. In the podsol forest, Dacrydium beccarii and Tristania spp. were common but Casuarina sumatrana was not. The latter only became predominant on the better drained soils usually on slopes. Shorea coriacea was also noted in the heath forest as distinct from the Shorea platycarpa found in the mixed Casuarina-coniferous forest. The change to heath forest was quite sharp as the land became flat.

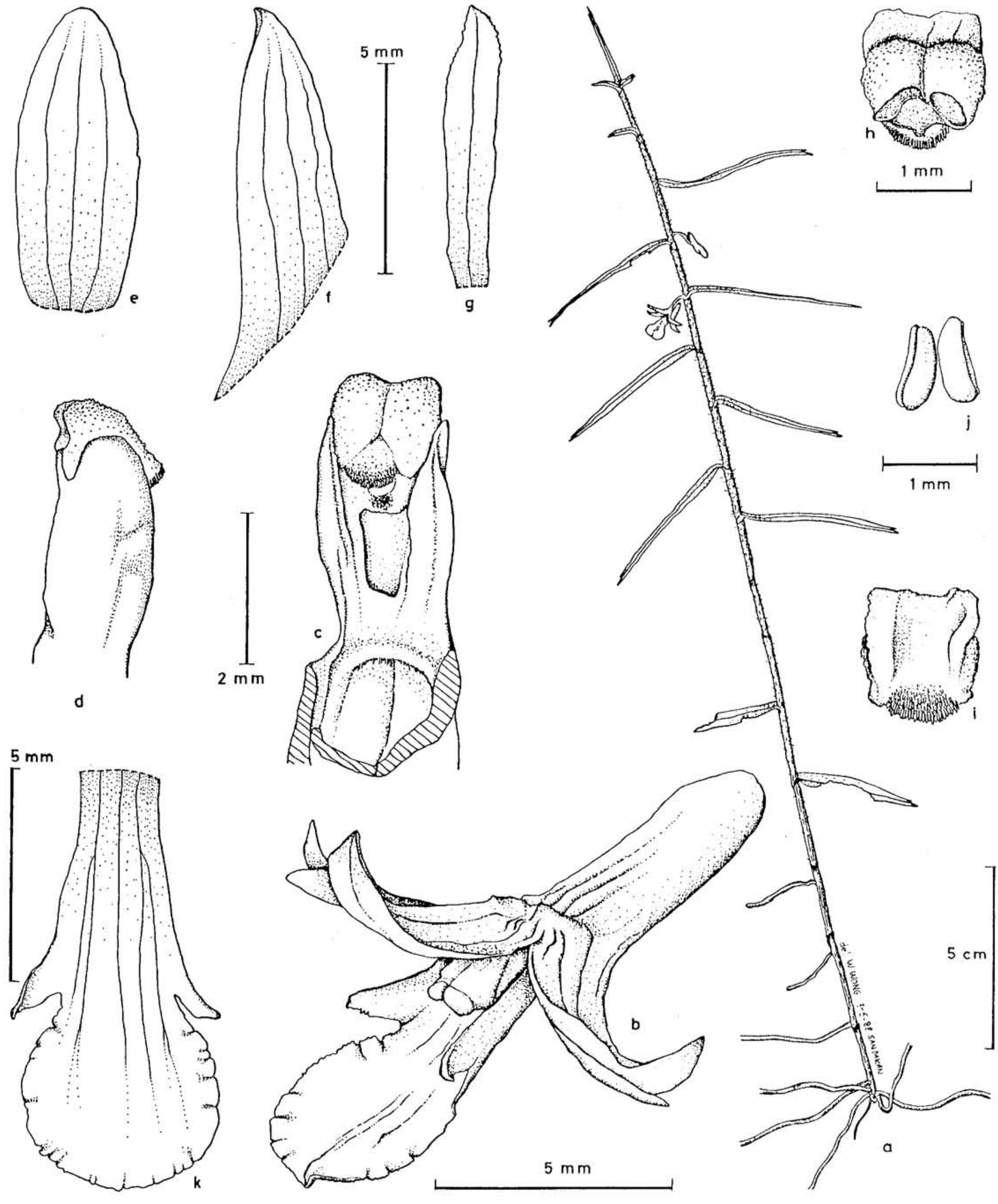
Leaving the RTM crew after they had finished filming plants of interest, A.L. and En. Andy Surat joined Puan E. Gasis in general collecting in the South Plateau heath forest. After 2 km, Jalan Babi dropped down a slope through predominently Casuarina forest to a small stream where En. J. Gasis and Puan E. Gasis were joined for a snack lunch. Then a search of a small hill on the other side of the stream with mixed Casuarina-conifer forest, yielded a very beautiful large pink-flowered orchid Dendrobium sanguinea (Figure 24, Plate 55) and a purple-pink flowered Bulbophyllum acuminatum. On the trail a large pile of rhinoceros droppings were found. Again in the moss at the base of the trees, Corybas were found, and since it was not in flower, it was assumed to be C. piliferus.

APRIL 25, 1988

W.W. joined the Forestry group following a trail up Rambutan Ridge following north-east of Corridor Creek generally to the eastern side of this wide ridge. Along the lower slopes they first located a Pulasan in fruit with immature fruits (Nephelium ramboutan-ake). A little further up the ridge they located more non-fruiting Nephelium spp. and Artocarpus spp. They then met a steep 30-40 m cliff. Above this the ridge leveled off and here they collected an Aglaia spp. in flower (Meliaceae family) followed by a Durio spp. at 650 m a.s.l. The trail led upto a steep ridge and here they found a tree with profuse pink flowers around the base of the trunk which was identified as Goniothalamus ridleyi of the family Annonaceae (see Plate 57). After 2 hours the group started to return to Base Camp.

W. WONG No. 8

Fig.22 Dendrobium sp.



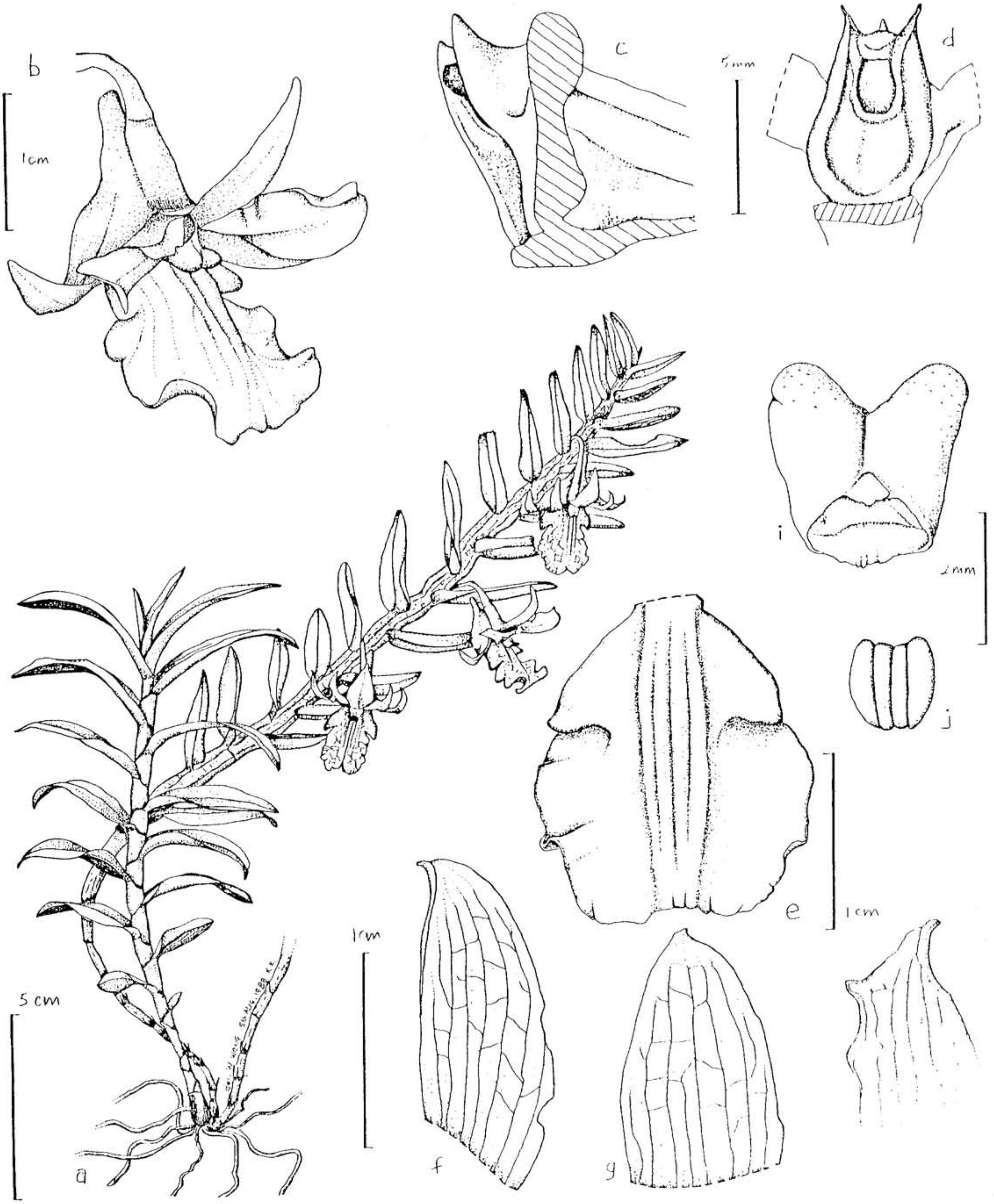
W. WONG NO 7

Fig. 23

Dendrobium pachyanthum

Gunung Lotung (Maliau Basin)

a) habit
b) flower
c) column (side)
d) column (ventral)
e) lip
f) Lat. sepal
g) Dorsal sepal
h) Petal
i) Anther cap
j) Pollinia



W. WONG No. 6

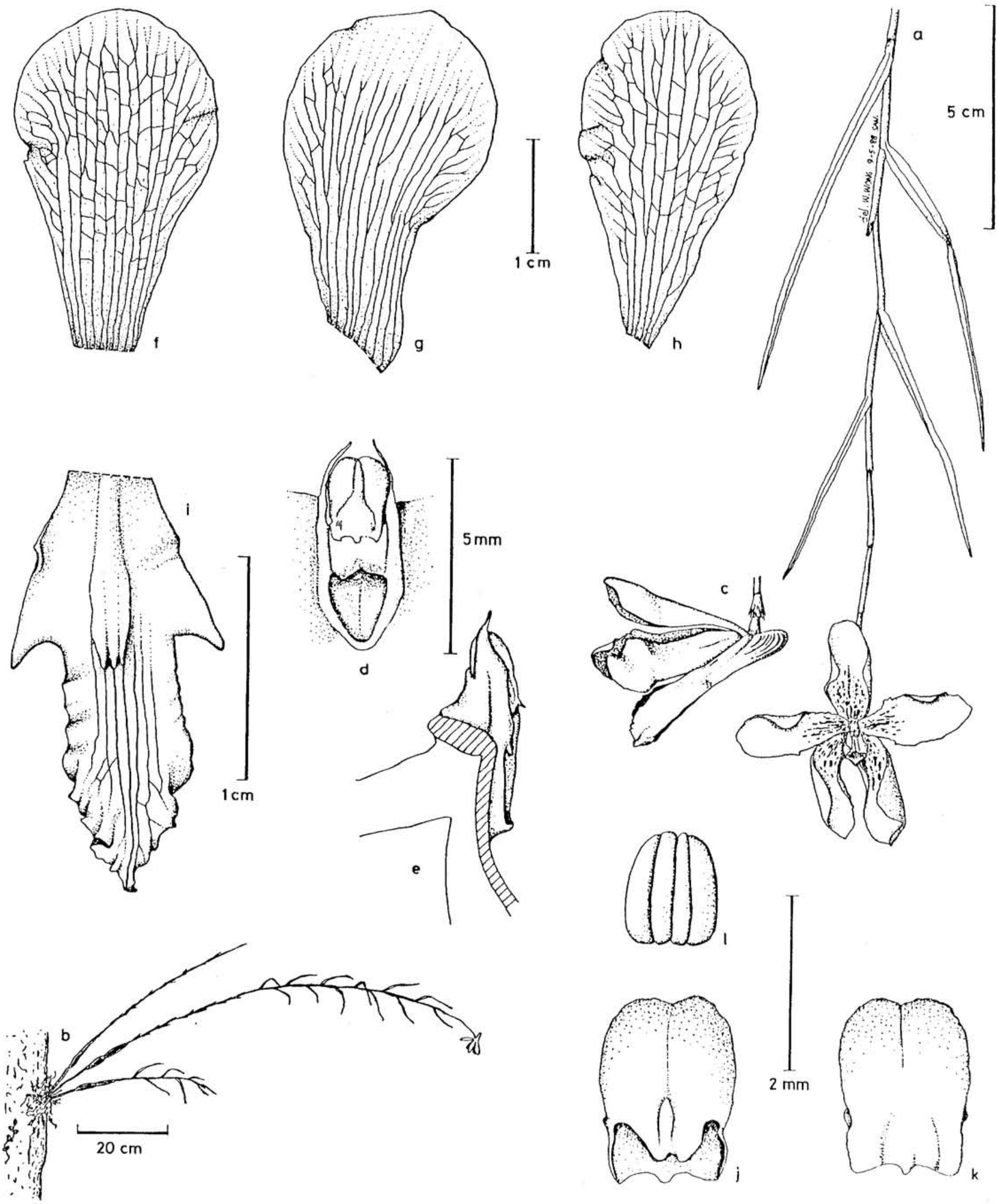
- Coll.: A. Lamb
- Kerangas forest, 3,000' asl
- Maliau Basin, G. Lotung

Colour notes:
- lip: golden yellowish with purplish-brown towards end of lip, white at base
- Sepals and petals, white at base, with darkish purple spots, gradual pink colour towards ½ of the sepals & petals

Spur - white ... stripes
Habitat - Epiphytic on trees

Fig. 24 Dendrobium sanguinea

b) habit ...
c) flowers side view
d) column ventral view
e) column side view
f) dorsal sepal
g) lateral sepal
i) lip
j) pollen cap
k) pollen cap
l) pollinia



A.L. and En. Andy Surat at the sub-camp rose early and returned up Rengas Ridge to the heath forest. They located a plant of Dimorphorchis lowii, but it was not in flower. This highland form had shorter, narrower and thinner textured leaves, another plant having also been found by the river at Camp II.

On reaching the Casuarina-Coniferous forest, the green-flowered orchid Coelogyne pandurata was found in flower, several plants climbing up the base of small shrubs; at over 1,000 m this was quite a record for this species which is normally found in the lowlands.

On top of the ridge another exciting orchid discovery was made, this time a ground orchid with attractive pink flowers. The small heart-shaped leaves has dark-purple undersides and brownish top surfaces with greenish veins. It has been identified as a very rare orchid, Nephelaphyllum trapoides J. J. Smith (Plate 53), and is a new record for Sabah.

One of the main aims of the visit to the heath forest that day was to take more photographs of the Nepenthes and after this was done, a short traverse was made to the edge of the heath forest to the east and down a slope which was dominated by Casuarina and Conifers. Here Rhododendron longiflorum and R. durionifolium were common. Several orchids were flowering, among those collected was the large pink-flowered Coelogyne cuprea and two Eria spp., and a very showy flowered, hairy-leaved Trichotosia spp. which seemed unusual, the flowers being borne on a very short inflorescence as a cluster.

On the ground, plants of Nepenthes tentaculata with clusters of small purplish pink pitchers were found. As the Casuarina-Conifer forest had yielded the most flowering orchids a return was made to the hill of Casuarina-Conifer forest where the Corybas had been found previously. A careful search through the shrubs underneath the trees yielded two more Bulbophyllum orchids : Bulbophyllum cf. limbatum, probably a new record for Sabah and a species that looked close to B. nigro-maculatum. Also found was Acriopsis gracilis, an orchid species previously described and recorded only from the Sook Plain and Nabawan at 450 m.

DISCUSSION AND CONCLUSIONS

The team set out to undertake three projects during the course of the week available. The accident to Puan Anthea Lamb meant that her work on the herbaceous flora could only be partly covered by others. The surveys of the orchid flora and wild fruit trees projects were completely upset by the unexpected drought that had affected the area for an estimated two months before the expedition. Lists of the species collected in the three projects are given in Appendices I to III.

The visual observations of what little was in flower and of the non-flowering of fruiting plants in the groups studied indicated a very rich diversity of fruit trees in the lower parts of the Basin near the Maliau River and to a lesser extent in the higher ridge forests. These areas were generally poor in orchids but the presence of Rafflessia tengku-adlini and some other rare trees and herbs indicated an unusual and diverse flora in the area. A mango species discovered is a new record for Borneo.

For orchids the small area covered revealed many important new records, with the Casuarina-conifer forest being particularly interesting. This type of forest does not appear to have been recorded from any other parts of Sabah so far. It indicates that strict conservation of these particular areas would preserve not just a few but many species of the orchid family, some probably unique to the area. The heath forest flora was most notable for its orchid and pitcher plant flora, particularly when compared to similar habitats at 450 m at Nabawan and at the same (1,000 m) altitudes at Long Pasia, in southern Sabah, and at Bario in Sarawak. In all four localities the forest is developed over flat or gently sloping terrain of leached podsolic soils, poor in nutrients, that become very dry in drought but waterlogged in rainy seasons due to the poor run-off from the flat terrain. Patches of heath forest at even higher altitude in the northern part of the Maliau Basin, which was traversed during the 1982 expedition can also be compared. These were generally at an altitude of over 1,300 m.

At Nabawan the dominant trees are Dacrydium pectinatum and at least two species of Tristania, probably T. obovata? and one with a very reddish trunk (T. clementis?). The understorey layer in particular contains two common Rhododendrons, R. longiflorum and coppices or patches of R. malayanum. Two species of pitcher plants and sometimes three in certain wetter patches are common. These are the common lowland species, Nepenthes rafflesiana, N. ampullaria, and less commonly N. gracilis. The hybrid, N. hookeriana, (N. ampullaria x N. rafflesiana) was also commonly found here. The forest floor had patches of Sphagnum moss in shallow hollows. This forest varied from very open stunted forest on the poorest sandy podsols, usually flat areas, to taller more shaded forest where there were slopes and better drainage. The area was rich in orchids with many Bulbophyllum species, Epigenium, Dendrobiums and the unusual Porphyroglottis maxwelliae, as well as all five known species of Acriopsis, including A. gracilis. All the Acriopsis have strong associations with ants common in heath or kerengas forest. In the taller more shaded forest Corybas piliferus was rarely found at the base of the trees. Certain Coelogyne orchids were also typical of this forest, namely the green-flowered C. zurowetzii, C. testacea in the taller shadier forest and C. cummingii, and C. distans in the more open scrub forest together with the related Gaesinkorchis alati callosa. Dilochia spp. and Bromheadia finlaysoniana were common as well as several species of Eria. In general the orchid flora was very rich both in numbers as well as diversity and too large to cover in detail here.

By comparison, the habitat of the Maliau Basin heath forest above Camp II was similar, but for each group of typical plants, species replacement occurred although with one or two interesting exceptions. Hence Dacrydium beccarrii replaced D. pectinatum, the Tristania (a genus that is difficult to sort out) appeared to be a different species with paler grey trunks. Rhododendron longiflorum was the same but R. durionifolium ssp. sabahense had replaced R. malayanum. For Nepenthes there was a marked replacement in species with N. veitchii and N. stenophylla and the hybrid N. veitchii x N. stenophylla being present with N. reinwardtiana and N. hirsuta in the shadier forest where Casuarina trees became more common.

For the orchids there were three or more species common to both Nabawan and Maliau, these being Bulbophyllum acuminatum and Corybas piliferus, the latter being more common, and Acriopsis gracilis. For many genera such as Eria, Dendrobium and Epigenium there seems to be this same pattern of species replacement. This was particularly true in the Coelogyne orchids and their relatives, Dendrochilum. Coelogyne testacea was replaced by a similar thick leaved species which could be new (close to C. odoardi); the green C. zurowetzii by C. pandurata. However, there were enough striking similarities to consider that a further detailed enumeration of the flora at the site would make a fascinating comparative study. Similarly for Dendrobium and Eria each forest had its distinctive species. For Dendrobium, D. pachyanthum stood out at 1,000 m whereas at higher elevations in the Maliau there was D. sculptum, and different species at Bario and Nabawan. For Bario the orchid Gaesinkorchis alata was reported, as in Nabawan. In Bario and also in Long Pasia, the Nepenthes replacements were mainly N. reinwardtiana and N. stenophylla with N. veitchii also occurring in some areas of heath forest in the Long Pasia area. For Rhododendrons, R. durionifolium ssp. sabahense replaced R. malayanum in both areas while R. longiflorum was replaced by R. lanceolatum and R. pneumonanthum. At the higher elevation podsol forest in Maliau more species of

Rhododendron occurred but R. longiflorum and R. durionifolium were still there, together with other species such as R. crassifolium and R. nervulosum. Here Nepenthes reinwardtiana and N. stenophylla were still present with N. tentaculata also becoming more common.

At Bario, Long Pasia and the Maliau area at 1,000 m Sphagnum moss was much more common than at Nabawan and for Bario and Long Pasia the Corybas, though not common, seemed to be C. pictus (based on leaf characters and flowers of specimens seen). Finally in comparing Bario, Long Pasia and Maliau the flora had a high proportion of Sarawak species, some of whose distribution disappears further north in Sabah. Comparison of other floral groups would make a rewarding study of species replacement at different altitudes in these interesting "kerengas" or heath forests.

FRUIT TREE COLLECTIONS

* Also Spirit Collection

Status in Sabah
N = New Spp?
NR = New Record
R = Rare
QR = Quite Rare
UC = Uncommon
C = Common

FAMILY	SPECIES	COMMON NAME	ALTITUDE	DOA NO.*	STATUS
Bombacaceae	Durio cf. acutifolius	-	400 M	00501 *	C
Anacardiaceae	Mangifer bullata	-	600 M	00503	NR
Guttiferae	Garcinia sp.	-	600 M	00504 *	QR?
Moraceae	Artocarpus odoratissimus	Tarap	1000 M	00505	C
Moraceae	Artocarpus elasticus ?	Togop	400 M	00506	C
Moraceae	Artocarpus sp.	Tankalingan	400 M	00507	UC
Euphorbiaceae	Baccaurea lanceolatus	Limpaun	400 M	00508	C
Bombacaceae	Durio oxleyanus	Sukang	450 M?	00509	C
Bombacaceae	Durio sp. (cf. kinabaluensis)	-	500 M?	00510	UC
Sapindaceae	Nephelium sp.	-	450 M?	00511	?
Anacardiaceae	Mangifera rigida?	-	500 M?	00513	QR
Bombacaceae	Durio kutejensis	Durian Lai	400 M	00514	UC
Rutaceae	?	? 400 M	00515	?	
Bombacaceae	Durio acutifolius	-	500 M	00516	C
Sapindaceae	Nephelium ramboutan-ake	Pulasan	400 M	00517 *	C
Meliaceeae	Aglia sp.	-	500 M	00518 *	?
Guttiferae	Garcinia sp.	-	1300 M	00519	?
Bombacaceae	Durio graveolens	Durian Merah	400 M	00520	C

ORCHID COLLECTIONS

* Type E = Epiphyte, S = Saprophyte, T = Terrestial

\+ Vegetative Zone
MD = Mixed Dipterocarp
C = Casuarina/Conifer Forest
H = Podsolic Heath Forest
MOC = Mixed Oak/Chestnut
R = Riverine

Status in Sabah
N = New Sp?
NR = New Record for Sabah?
R = Rare
QR = Quite Rare
UC = Uncommon
C = Common

A.L. Collection No. 1988	Name	Section	Type *	Vegetative Zone +	Approx. Altitude Metres	Herbarium Specim. H Spirit Collection C Sighting S	Established in T.O.C X	Status in Sabah
926	Abdominea minimiflora (Hk.f.) J.J.Sm.		E	MD	500	C	X	UC
915	Acriopsis gracilis Mind & de Vogel		E	H	1000	H & C	X	QR
910	Bulbophyllum acuminatum Ridl.	Cirrhopetalum	E	H	1000	H	-	C
917	B. cf. nigromaculatum Holtt.	Micromonanthe	E	H	1000	C	X	UC
925	B. cf. limbatum Lindl.	Racemosae	E	H	1000	H & C	X	NR?
931	B. Vaginatum (Lindl.) Rohb.cf.	Cirrhopetalum	E	MD & R	450	H	-	C
905	Bulbophyllum sp.	?	E	MOC	950	H & C	-	N?
923	Bulbophyllum sp.	-	E	H	900	C	X	UC
911	Bulbophyllum sp.	?	E	H	900	H	-	UC
907	Chelonistele amplissima Carr.	-	E	H	900	H	-	C
901	Chelonistele cf. lurida ? Pfitz.	-	E	R	400	H	-	C
927	Cleisostoma subulatus (Bl.) Rchb.f.	-	E	R	400	S	X	C
906	Coelogyne cf. Cuprea Wendl. & Krzl.	Longifoliae	E	C	900	H	-	C
903	Coelogyne dayana Rchb.f.	Tomentosae	E	MOC	850	C	-	C
906	Coelogyne sp. (cf. odoardi Schltr.)	Tomentosae	E	C	1000	H & C	-	N?
914	Coelogyne pandurata Lindl.	Verrucosae	E/T	C	1000	H & C	X	UC
909	Corybas piliferus J. Dransf.	Corybas	T	C	1000	C	-	R
912	Dendrobium sanguinea Carr	Rhopalanthe?	E	C	900	H & C	-	R

A.L. Collection No. 1988	Name	Section	Type *	Vegetative Zone +	Approx. Altitude Metres	Herbarium Specim. H Spirit Collection C Sighting S	Established in T.O.C X	Status in Sabah
913	Dendrobium pachyanthum Schltr.	Distichophyllus?	E	H	950	H & C	X	R
933	Dendrobium rosellum Ridl.	Aporum	E	MD	450	H & C	X	C
899	Dendrobium sp.	Oxystophyllum	E	MD	500	H	-	C
922	Dendrobium sp.	Oxystophyllum	E	C	1000	H & C	-	?
904	Dendrobium sp.	Conostalix?	T	C	1000	H & C	-	C
	Dimorphorchis lowii var.? (Ldl.) Rolfe	-	E	MOC/R	900	S	X	QR
919	Eria cf. melaleuca ?	-	T	C	950	H	-	UC
921	Eria sp.	-	E	C	950	H & C	?	-
908	Lecanorchis sp.	-	S	C	1000	H & C	-	R
900	Malaxis cf. punctata J.J. Wood	-	T	MOC	700?	H & C	-	UC
928	Maleola cf. dentifera J.J.Sm.	-	E	MD	500	H & C	X	C
930	Nephelaphyllum pulchrum Bl.	-	T	MD	500	H & C	X	C
916	Nephelaphyllum trapoides J.J.Sm.	-	T	C	1000	C	X	NR
920	Podochilus cf. tenuis (Bl) Lindl.	-	E	MOC	900	H	-	C
929	Pomatocalpa spicata Breda	-	E	MD/R	400	C	X	C
902	Stereosandra javanica Bl.	-	S	MD	450	H & C	-	QR
934	Taeniophyllum filiforme J.J.Sm.	Rhynchanthera	E	MD/R	450	-	X	C
924	Trichotosia sp.	-	E	C	1000	H & C	X	?
932	Trichotosia sp.	-	E	MD	400	H & C	X	?

APPENDIX III

HERBS, SHRUBS AND CREEPERS

Type of Plant S = Shrub
C = Creeper
H = Herb

Collection or Sightings H = Herbarium specimen
C = Spirit Collection

Vegetative Zone MD = Mixed Dipterocarp
C = Casuarina/Conifer Forest
H = Heath Forest
MOC = Mixed Oak/Chestnut Forest

R = Riverine
* = New Record for Sabah

COLLECTION NO.	NAME	TYPE OF PLANT	VEGETATION ZONE	APPROX. ALTITUDE M	COLLECTIION
DOA 00502	Melastomacea	S	MD/R	400	H & C
DOA 00512	Ixora sp. (Rubiaceae)	S	MD	400	H
ALFB 122	Globba c.f. Propinqua (Zingiberaceae)	H	MD	420	H & C
ALFB 123	(Zingiberaceae) sp.	H	MOC	800	H
ALFB 120	Begonia sp. (Begoniaceae)	H	MD/R	390	H
ALFB 121	Begonia sp. (Begoniaceae)	H	MD	500	H
ALFB 124	Begonia sp. (Begoniaceae)	H	MOC	700	H & C
ALFB 130	Begonia sp. (Begoniaceae)	H	MOC	600	H & C
ALFB 131	Begonia sp. (Begoniaceae)	H	MD/R	460	H & C
ALFB 125	Pterisanthes (Vitaceae)	C	MD/R	500	H
ALFB 138	Nepenthes veitchi (Nepenthaceae)	C	C/H	1000	H
ALFB 144	N. veitchii x N. senophylla *	C	H	1000	H
ALFB 143	Nepenthes hirsuta *	C	C	1000	H
ALFB 142	Nepenthes tentaculata	C	C	1000	H
ALFB 135	Nepenthes stenophylla	C	H	1000	H
ALFB 134	Nepenthes reinwardtiana	C	H	1000	H
ALFB 133	Rhododendron durionifolium var. sabahense (Ericaceae)	S	H	1000	H
ALFB 139	Rhododendron longiflorum var. subcaudatum	S	H	1000	H
ALFB 140	Rhododendron borneense	S	H	1000	H
ALFB 132	Aeschynanthus sp. (Gesneriaceae)	C	C/R	900	H & C
ALFB 129	(Acanthaceae)	H	MD/R	400	H & C

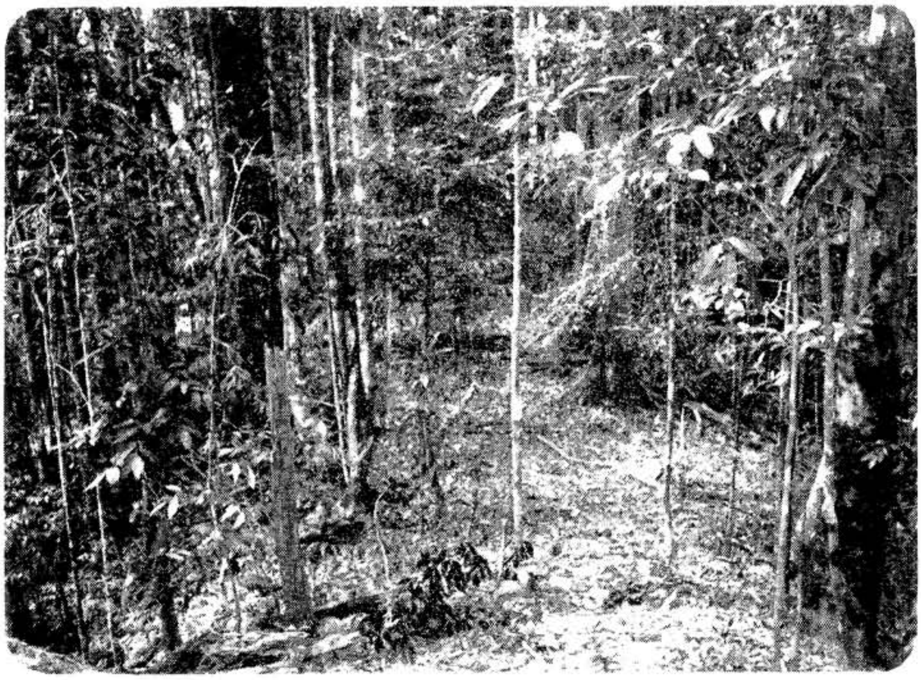


Plate 37. Main Trail at 1,000 m a.s.l. Notice the very dry leaf litter on the forest floor

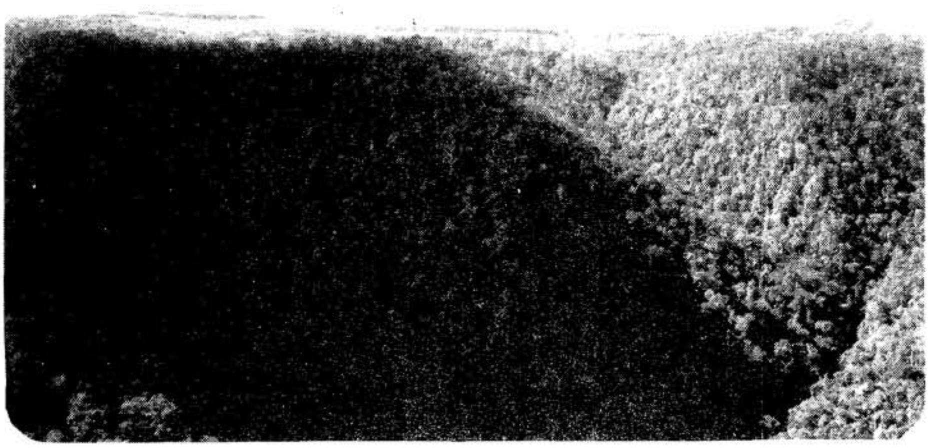


Plate 38. A view of the heath forest on South Plateau with a steep scarp descending from it.

Plate 39. A freshly killed juvenile male proboscis monkey, probably the result of a fight.

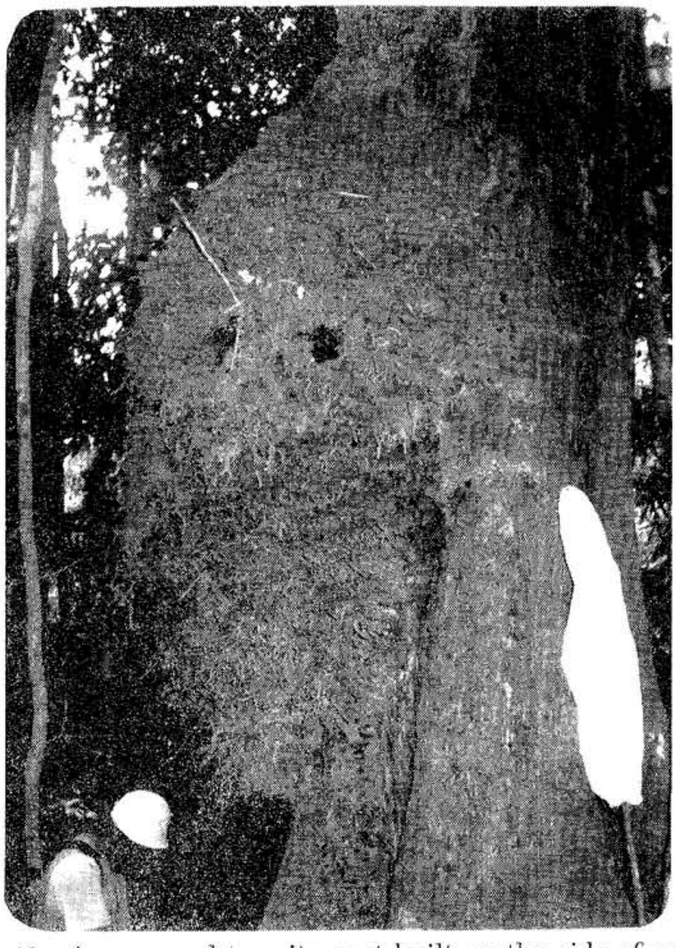


Plate 40. An unusual termite nest built on the side of a tree trunk. Note the root-like projections of the tunnels.

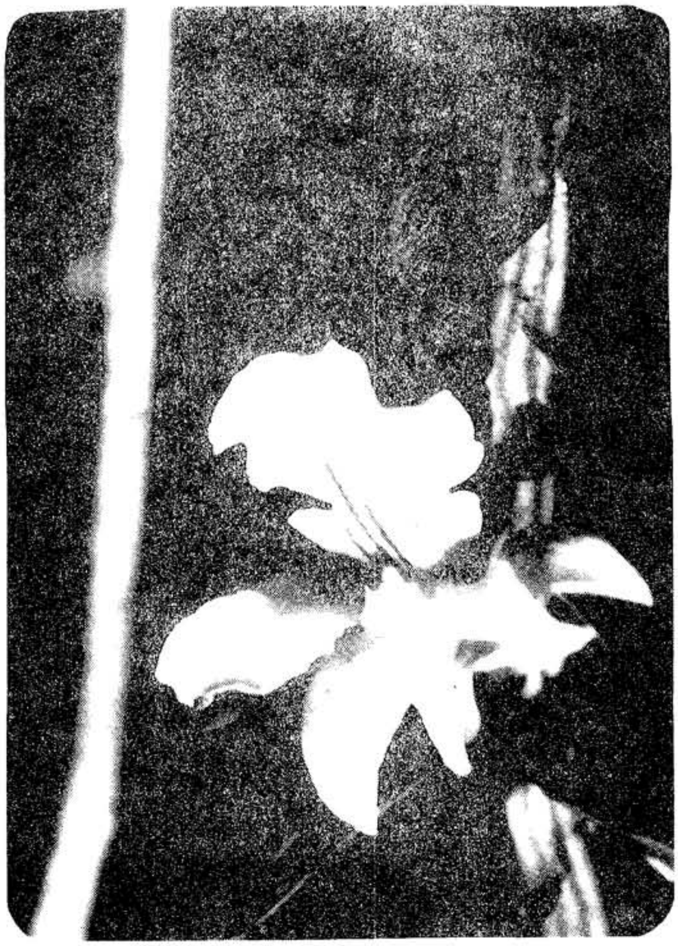
Plate 41. This cauliflorous tree is a <u>Eugenia</u> sp. found on "Rengas Ridge" at about 950 m a.s.l.

Plate 42. <u>Pterisanthes</u> sp.: a creeper with unusual inflorescences found along "Corridor Creek". The small flowers arise from a flattened, red, bract-like pod.

Plate 43. Flying Foxes over Base Camp

Plate 44. A saprophytic orchid, Stereosandra javanicum

Plate 45. Dendrobium pachyanthum : an epiphytic orchid found in heath forest on South Plateau.



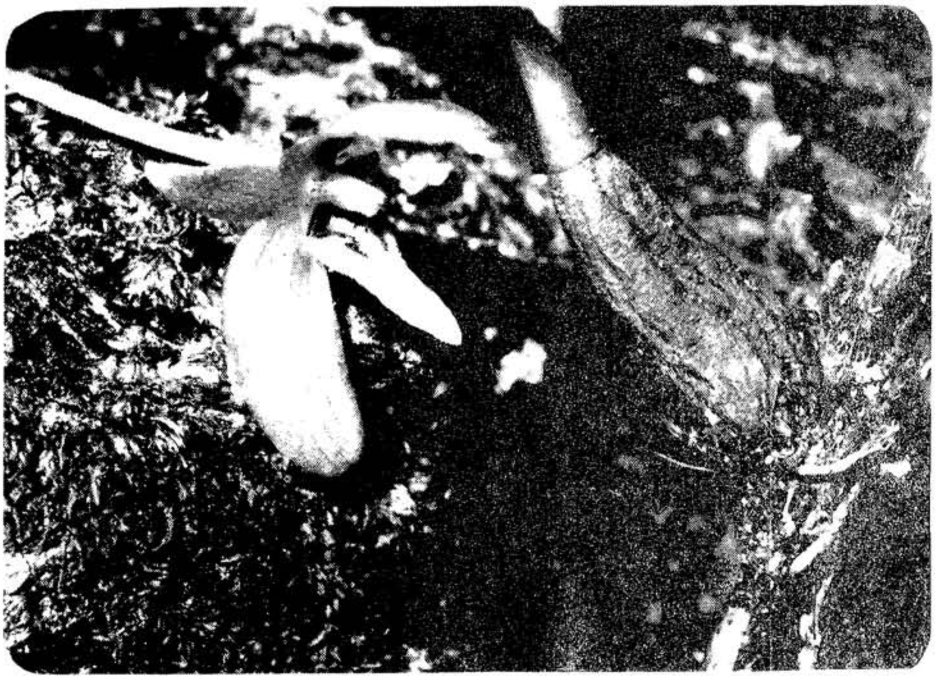


Plate 46. An unknown Bulbophyllym sp. epiphytic on trees in coniferous/Casuarina forest.

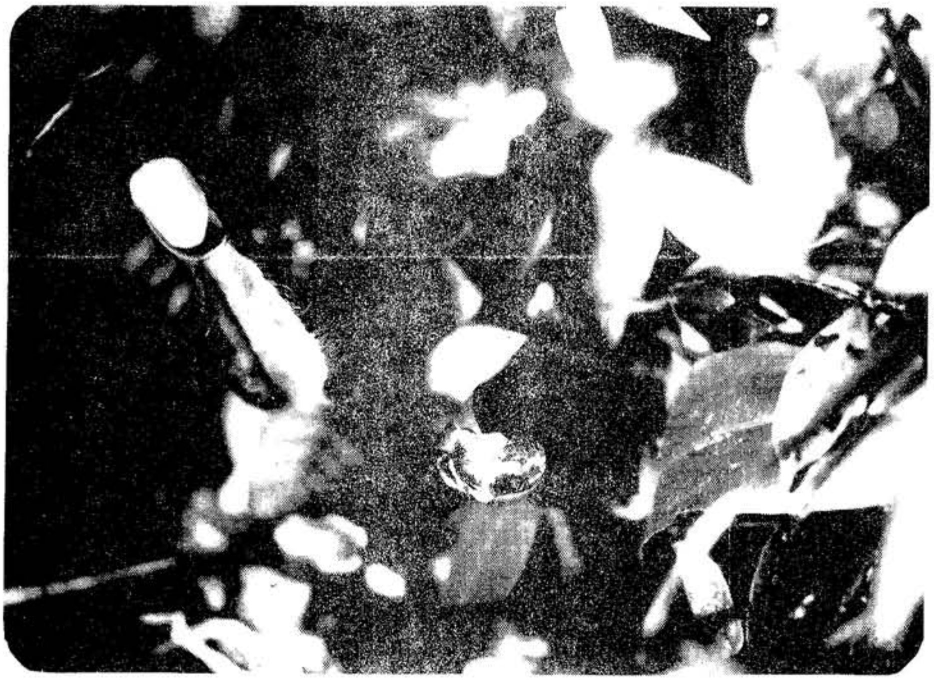


Plate 47. Nepenthes hirsuta, the first confirmed record in Sabah. Plants were scrambling over the forest floor of thick peaty top soil under Dacrydium trees.

Plate 48. Nepenthes veitchii x stenophylla. A beautiful natural hybrid found in heath forest at 3,000 ft. A first record for Sabah.

Plate 49. Nepenthes veitchii. Several vines of this spectacular pitcher-plant were found with leaves clasping the trunks of the trees and with the pitchers hooked over each other on the other side.

Plate 50. Nepenthes stenophylla Another upland Nepenthes commonly found on South Plateau

Plate 51. A rare Coelogyne sp. was discovered at 1,000 m as an epiphyte in coniferous/Casuarina forest

Plate 52. Another rare orchid, Bulbophyllum limbatum Lindl. that has rarely been found in flower in Sabah, was discovered in heath forest on South Plateau.

Plate 53. In forest rich in Podocarpus, Phyllocladus, dacrydium and Casuarina trees, occurred a small-leaved terrestrial orchid Nephelaphyllum trapiodes. This is probably the first record for Sabah, for this very rare orchid.

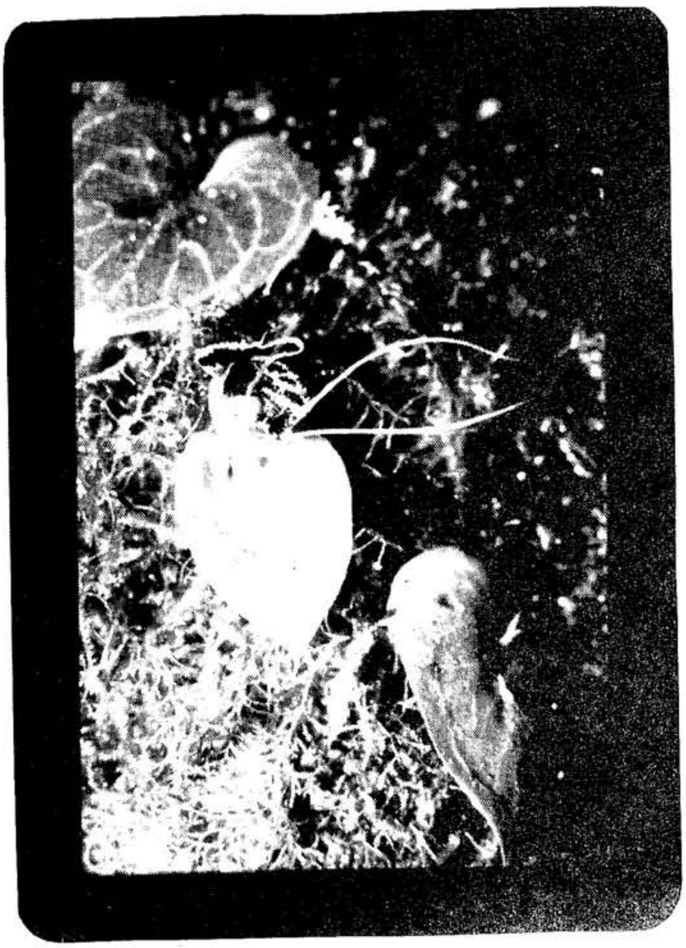


Plate 54. Also in ridge forest at the base of Dacrydium and Casuarina trees were found small colonies of the Helmet orchid, Corybas piliferus.

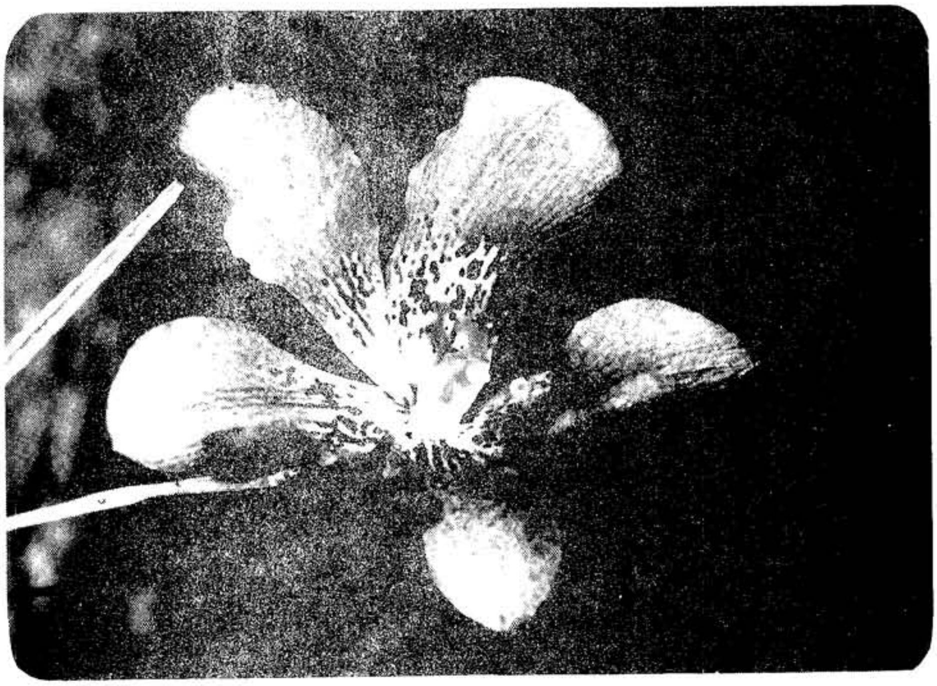


Plate 55. Dendrobium sanguinea - a species with several varieties. This one was found in mixed coniferous/Casuarina forest.

Plate 56. Rhododendron longiflorum from the Sabah Plateau heath forest.

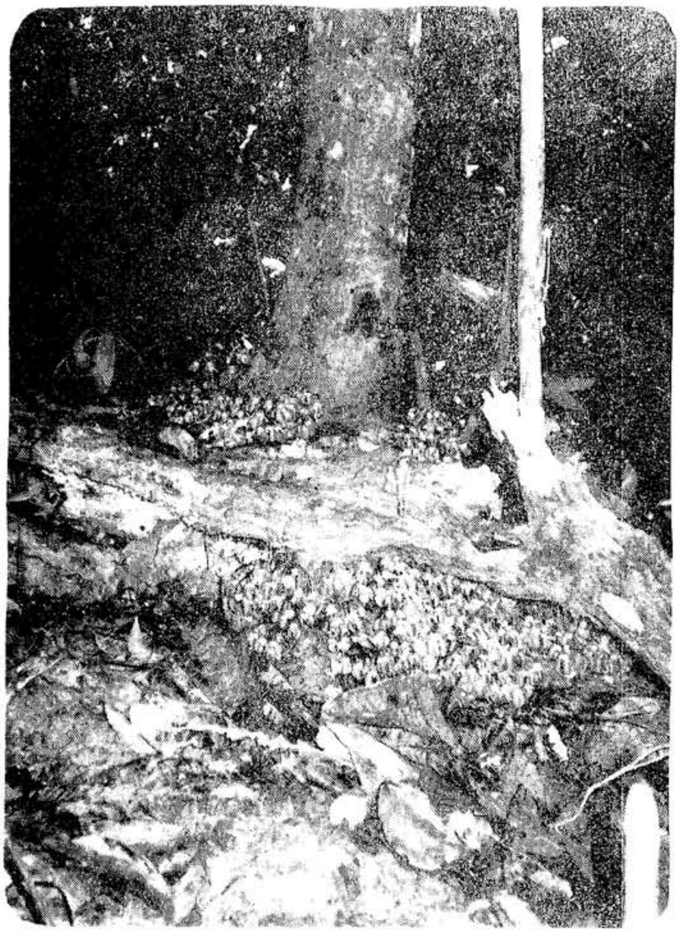


Plate 57. A flowering Anonaceae, located on the Rambutan Ridge

Plate 58. Along the Maliau River on a sandy bank, a young Natrix? snake was found sunning itself.

Plate 59. Fruits of Durio lanceolatus near the 1982 camp on the Sg. Maliau

Plate 60. Dried leaves and immature fruits of Durio acutifolius, a medium-sized tree that was felled at the Base Came helipad

5.2 : PHASE II BOTANICAL DIARY, WITH NOTES ON PLANTS WITH TRADITIONAL USES

J. Guntavid
Sabah Museum

APRIL 26, 1988

On landing at the Base Camp site, we organized our camping arrangements and equipment. Just at the edge of the Base Camp, I encountered several specimens of the much sought after Eurycoma longifolia Jack[1] growing beside the stream, competing with the numerous species of other herbaceous undergrowth including Praravinia suberosa[2], and a flowering reddish scarlet Globba propinqua[3].

The canopy is dominated by large timber trees, such as Shorea pauciflora and draped in giant lianas such as Gnetum gnemon[4]. We were sometimes halted by the grappling thorns of the rattans Calamus caesius[5] and Korthalsia echinometra[6].

APRIL 27, 1988

At 0730 hours, after breakfast, we started out for Camp II. Along the trail, we saw a specimen of Achasma spp.[7] easily identified by its variegated leaves, and a sterile Melastoma cf. polyanthum (leaves similar to the Kinabalu's M. polyanthum).

I was hot and as usual the Aphis aphis[8] started licking my sweat. Could they be collecting my body salt for their honey mixture?! While resting, I looked around at the undergrowth and could see numerous Calamus caesius, Korthalsia echinometra, Licuala longipes[9], mountain Pandanus, Frecyntia, Hanguana spp. Pinanga cf. fistulosa, Iguanura cf. polimorpha and the giant leguminous lianas Bauhinia diptera Bl.[10].

When we reached the top of the ridge, we stumbled on a rare sight of Sumatran Rhinoceros[11] footprints. I also encountered several Cyathea latebrosa, Sonerila spp., Costus speciosus Koeing[12], and the white flowered Didymocarpus cf. hispida, Hedyotis spp.[13].

In the coniferous forest, we observed Shorea leptocladus (an unexpected encounter) and Agathis dammara[14], Podocarpus polystachys R. Brev. and Phyllocladus hypophyllus Hk. f. The undergrowth comprised of miniature shrubs and herbs like Iguanura spp., Pinanga spp., Nepethes tentaculata[15]. At about 980 m a.s.l. we spotted a fruiting Myristica spp. tree (fruit ovoid globose, 6.5 cm x 4 cm with longitudinal suture around fruit, fruit reddish brown).

APRIL 28, 1988

On a second visit to the heath forest from Camp II, we encountered Scaphium spp., Praravinia suberosa, and Gnetum gnemon which grew lushly along the trail, but we had missed the previous day. We at times tried to avoid grabbing rotans, such as Licuala longipes, Korthalsia echinometra, Calamus caesius and Calamus pogonacanthus Becc.[16]. At 940 m a.s.l. I was very much surprised to learn that Artocarpus odoratissimus[17] could still strive in this type of habitat. In the undergrowth were a few Curculigo cf. latifolia and a fruiting Wikstroemia tenuiramis[18] We also encountered a few clumps of

Dianella cf. ensifolia growing on the rocky cliffs at 950 m a.s.l., including the common fern, Gleichenia linearis[19]. Nothing new could be sighted in the kerengas forest, so we returned to Camp II, collected our kit and returned to Base Camp.

APRIL 29, 1988

En. Saw Leng Guan, En. Ahmad Zuhaidi and myself set off along the Sg. Maliau. Along the riverside were lushly fruiting Leea indica L.[20] together with fruiting Guioa pleuropteris Lmk.[21], Mallotus laekeyi[22] climbing and creeping Dinochloa scandens[23], Callicarpa longifolia, Melastoma spp. (cf. malabathricum[24]) and Dissochaeta spp. Other collections were made of Rubus mollacanus L.[25], Lindernia spp., Glochidion spp., Eugenia spp., Uncaria spp.[26] and Milletia cf. vastata. Up a ravine a solitary majestic Arenga undulatifolia[27] could be seen.

On a new sand bar a small patch of Imperata cilinderica L[28] had to some extend prevented erosion. Older bars support a good population of Parkia cf. jiringa and Caesalphinia sappan L[29]. I also saw hundreds of flying foxes roosting on the Caesalphinia sappan tree.

APRIL 30, 1988

A group of us made our way down river to the Maliau Waterfall. The shallowest river crossing on the way was up to the thigh but a couple reached my chest and one even cost me my camera, which became soaked and jammed! Around the river banks apart from the dominating dipterocarps, we sighted an interesting fruiting Glochidion spp. (fruit red and ovoid globose and almost resembled the Sauroupus androgynous except the former is larger). Next to it protruded a fruiting fagaceous sapling of Lithocarpus spp. (growth stunted due to the rock beds substrate) and a conspicuous fruiting Schefflera spp. Overhanging the dipterocarp saplings at the river banks sprouted fruiting (red globose fruit) Cissus hastata[30] and Elastostoma spp. Ficus fistulosa Reinw[31], Nauclea subdita (a very beautiful ornamental). Shrub and climbing Tetracera akarii[32], Homalomena spp. are also quite common vegetation.

On the way back from the falls, a very rare view of Schizostachyum cf. longispiculatum Kurz[33] just across the river was obtained at 430 m a.s.l., together with the rare Susum cf. malayanum Hook. Other plants which interested me included the Hoya latifolia G. Don[34] (a rare outgrowth in its original habitat) and Callicarpa candicans (Burm.) Hochr.[35]. We reached the Base Camp at 1430 hours wet and exhausted. It was at this time that I realised that several tent cords had been tied to a renghas sapling, Melanorrhoea wallichi Hook. f.[36]. No wonder, one or two expedition members complained of rashes!

MAY 1, 1988

It was Sunday so I decided that En. Jarius and myself would go out surveying only half of the day. So we went to the Rafflessia site which the Forest Department staff discovered several days ago, an hour's walk above camp. When we reached the site, the Rafflesia[37] cf. borneensis had just bloomed. The bloom measured 13 cm across and was brick red all over with darker stains. On the inside were present about twenty-four protruding processes. There were another two unopened buds clamping themselves onto the host plant Tetrastigma cf. lanceolarium[38]. Judging from scars on this vine, I believed there had been six blooms prior to the present one. On the way back we also sighted a fruiting Diospyros spp. and a clump of solitary Caryota mitis[39], a good population of Eurycoma longifolia Jack and of course the maranraceous outgrowths that covered the forest floors.

MAY 2, 1988

Set off for Rambutan Ridge and Sapindaceous trees indeed seemed to dominate the area in places thus justifying the name. Creeping and climbing allies of Calamus could also be sighted. Dinochloa scandens still existed even at 620 m a.s.l. on the ridge. But what interested us were the flowering specimens. Thriving quite lushly on the ridge were the Mallotus wrayi (inflorescence yellowish-white), Actinodaphne cf. oleifolia (fruit ovoid-oblong-globose), conspicuous flowering Ixora javanicum[40], fruiting Susum cf. malayanum, Lasianthus spp. (fruit hairy, globose, yellowish, orange), Pavetta spp. (fruit globose) and Eugenia spp. Other interesting species included Ardisia cf. elliptica, Gnetum gnemon (can be found almost every locality), Bauhinia diptera Bl., Polyalthia sumatrana, Polyalthia cf. tapis, Fagraea racemosa[41], fruiting "gangulang" or Blumeadendron tokbrai (Bl.) Kruz[42] Pentace spp., Chisocheton spp. and Mallotus Wrayi. We turned around at 750 m a.s.l. and returned to Base Camp by 1430 hours.

That afternoon while we were talking, a lesser mousedeer, Tragulus javanicum wandered into camp and was promptly caught and put into captivity in a small pen.

MAY 3, 1988

Visited Long Ridge where I stumbled on a flowering Globba propinqua. It seemed that the locality here accommodated about the same vegetation as on the Rambutan Ridge except that Nephelium cf. mutabile was less common here. Other than what were found the day before we also spotted a fruiting Baccaurea stipulata J.J. Smith[43] (reddish globose fruit), Dillenia borneensis Hoogl.[44] and epiphitic Asplenium nidus[45] and Platycerium coronarium (quite rare). While we were on our way back at 1200 hours a terrified kijang stumbled on us. Nearby the incoming corridor creek a cautious sambar deer sensed our presence and fled. We arrived at camp at about 1330 hours.

At 1430 hours, Dr. Clive Marsh, En. Jarius Titin and myself went up to the Rafflesia site to pluck the flower while it was still fresh and blooming. I cut the bloom cautiously at its joint or pedicel in order not to cut the host plant lest the 2 existing buds would be affected and drop off. When we reached camp, I immersed the specimen with Kew Spirits.

MAY 4, 1988

After breakfast all participants helped to clear up camp in preparation for the expected visit of our Chief Minister, YAB Datuk Joseph Pairin Kitingan together with YS Deputy Director, Tengku D. Z. Adlin. These honoured guests duly arrived at 0930 hours and were introduced to all the members of the expedition. Dr. Marsh gave a briefing and showed the CM specimens of Nepenthes veitchii, N. leptochila, N. reinwartiana and the recently plucked (two days ago) Rafflesia tengku-adlini bloom submerged in the Kew Spirits. Then Dr. Ibrahim Komoo talked on the geology of the Maliau Basin and I gave an account of the vegetation. En. Joseph Gasis (YS, Field Manager for Danum Valley) likewise gave a short account of his faunal survey of the area and at the same time producing a ceramic[46] fragment he found in the forest. The Chief Minister was also shown the unfortunate captive mousedeer, which he recommended be let free to its own world again. It was a pregnant female.

After the briefing we accompanied the CM to the Rafflesia site. After a brief break for light drinks the visitors departed at 1300 hours. It had been a memorable day for us all.

MAY 5, 1988

As I woke up at 0730 hours, I sighted a pair of rhinoceros hornbill (Buceros rhinoceros borneensis[47]) or "sungang".

To remind myself of what had been done the last eight days, I went around the camp site and helipad once again. I encountered Scorodocarpus borneensis[48], Salacca cf. affinis[49], and numerous Dinochloa scandens. On the northern part of the helipad, I could still see the gliding and hanging flying foxes Pteropus vampyrus[50] but the numbers had diminished as compared to the previous population. It was time for us to leave too.

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FOOTNOTES

1 Eurycoma longifolia Jack of the family Simaroubaceae is also known as "tongkat Ali" (Bahasa Malaysia), "tombuid" or "wonod mondou" (Dusun/Kadazan), "Lodus di asing" (Tangala Murut). Almost all the different ethnic groups of Sabah called all species of Eurycoma spp. by the same name. This plant is used in different forms for curing various ailments like malarial, coughs, gastritis, loss of appetite, skin complaints, hypertension, headache. It is also used as an aphrodisiac and in post-partum treatment.

2 Praravinia suberosa from the Rubiaceous family is also known as "kingkimut" (Tangala Murut; Dusun/Kadazan). It is used for deep cuts in humans and wounded pets like dogs and cats.

3 Globba propinqua of the ginger Family Zingiberaceae also known as "banglai" (Dusun Sungei) is employed in post-partum treatment.

4 Gnetum gnemon L. an existing ancient plant of the Gnetaceae family is also known as "hokos" or "golokos" (Dusun/Kadazan) and is employed for chronic chest complaints and in "sikat" (medicinal and traditional drink preparation employed in lung complaints).

5 Calamus caesius L. is the main rattan species of commerce. "Soho" (Murut) or "sogo" (Dusun/Kadazan) or "rotan saga" (Bahasa Malaysia) is utilised by all the ethnic groups of Sabah for tying fences, dwellings, artifacts and even for making household implements. The bitter young stem-apices may be consumed as a vegetable and crude preparations are employed in lung complaints.

6 Korthalsia echinometra is also considered a commercial rattan.

7 This species of unidentified taxa Achasma spp. is known as "tolidus nu palanuk" (Tangala Murut) and traditionally identified by village folk through its variegated leaves. It is employed in treating intermittent headache.

8 Aphis aphis or "pemesuen" or "pomosuon" (Dusun/Kadazan) is sometimes cultured in hollow tree trunks and hung on outside walls of dwellings. According to tradition a good harvest of this insect's honey means good luck and tidings.

9 Licuala longipes Bl. or "palas" (Bahasa Malaysia) or "silar" or "silad" (Dusun/Kadazan) was long ago used for thatching roofs or "atap". The main rachis may be used as a weapon (when cut to its edge it is sharp as a razor). Nowadays it is used as an ornamental.

10 Bauhinia diptera Bl. (Leguminosae) also known as "lumapak" (Tangala Murut) is employed as an expectorant for whooping coughs. The tough bark is also used for making strong cords and ropes among the Dusuns/Kadazans and the Tangala Muruts.

11 Dicerorhinus sumatrensis or "badak sumbu" (Dusun/Kadazan) or "badak sumbu sumatra" (Bahasa Malaysia) is a dying species. This poor friend is poached for its valuable horn, bones, flesh and stools for treatment against various ailments.

12 Costus speciosus Smith of the Zingiberaceae family is also known as "insasabu" (Murut) or "tangkar-tangkar" (Dusun/Kadazan) and is used in traditional medicine for curing of painful enlargement of the spleen, coughs, influenza and conjuntivities.

13 Hedyotis spp. also known as "piluyum" (Tagel Murut) is used by the Muruts as a main ingredient of charms: also known as "pugai" or "paramanis".

14 In Dusun/Kadazan "salong" or "damar" (Bahasa Malaysia) is a resinous product of Agathis dammara (Lambert) Richard. The resin is used as fuel and incense in homes. It is also used to mend leaking holes of boats and sampan among the Muruts. The tree is an excellent firewoods and can even used directly after felling. Its timber is of excellent quality wood.

15 All species of Nepenthes are known as "kukuanga" (Dusun/Kadazan), and "periok kera" (Bahasa Malaysia, Brunei). And all species are used among the Dusun/Kadazan to promote vigorous growth of hairs of the head and the bigger pitcher are used to cook rice to stimulate appetite.

16 Calamus pogonacanthus Becc. (Palmae) or "sambunil" (Tangala Muruts), is antihelmintic and sometimes employed for gastritis. The cane is also used in the making of artifacts and casual tying.

17 "Timadang" (Dusun/Kadazan) or "terap" (Bahasa Malaysia, Brunei) is the term applied to Artocarpus odoratissimus Blanco (Moraceae). The fruit is consumed and the dried scabrid leaves are used as sandpapers. The young leaves are also used to wrap cooked rice.

18 Wikstroemia tenuiramis Miq. (Thymelaeceae) or "tindot" (Dusun/Kadazan) is used as an antipyretic agent. It is sometimes used for tying. The young plant or its matured bark is very durable.

19 "Salingkawang" (Rungus, Bajau, Irranun, Brunei) or Gleichenia linearis (Gleicheniaceae) is used in the making of artifacts.

20 "Ruvow" (Rungus) or Leea indica L. (Leguminosae) is employed for coughs, stomachache and diarrhoea.

21 "Tinggir manuk" (Dusun/Kadazan, Bajau) or "medang putih" (Bahasa Malaysia) or Guioa pleuropteris Lmk. (Sapindaceae) is employed for neuralgia in children and boils.

22 Mallotus laekeyi Elmer (Euphorbiaceae) is also known as "bolontos" among the Rungus. It is aromatic and is used for treating chronic stomachache.

23 Dinochloa scandens or "wadan" (Dusun/Kadazan) is used in the treatment of deep cuts and sometimes the leaves are used for wrapping festive cake.

24 Melastoma malabathricum L. (Melastomaceae) or "gosing" (Dusun/Kadazan), "uduk-uduk" (Brunei) or "senduduk" (Bahasa Malaysia) is widely used. It is employed in the treatment of athsma, bloody sputtum and cuts.

25 Rubus mollacanus L. or "kalatagu" (Rungus) is used for treating acute diarrhoea.

26 Uncaria spp. (Rubiaceae) or "langkait" (Dusun/Kadazan; Rungus) is employed in chest complaints.

27 Arenga undulatifolia (Palmae) or "polod" (Dusun/Kadazan) young stem-apices are consumed as vegetable. Sago is also sometimes extracted from its stem. On the other hand the leaves in ancient times were used to make roof thatchings in dwellings. The fine scrapped fibres are used to catch frictional splinters in the making of fire. The sweet juice extract from this plant is sometimes used to prepare traditional alcoholic drinks.

28 "Lalang" (Bahasa Malaysia), "paka" (Dusun/Kadazan) or "kutad" (Rungus), or Imperata cylinderica L. is employed in the treatment of acute diarrhoea, fever and measles (?). Also known in Murut as "alab"; used apparently the same.

29 Caesalphinia sappan L. or "sapang" (Dusun/Kadazan, Brunei, Murut, Bahasa Malaysia) is used in the preparation of the traditional Dusun/Kadazan "sikat" drink. It is also employed in the treatment of chest complaints, kidney and blood trouble and lumbago.

30 Cissus hastata Miq. or "roloi-roloi" (Dusun/Kadazan) is believed to cure whooping coughs, fever and influenza. Sometimes the young apical stems are consumed as half cooked salads "ulam" (Bahasa Malaysia).

31 Ficus fistulosa Reinw. or "lintotobou topurak" (Dusun/Kadazan) is used as alternative of Ficus lepicarpa "lintotobou taragang" (Dusun/Kadazan) in post-partum treatment.

32 Tetracera akarii (Dilleniaceae), "bambad" or "mempelas" (Bahasa Malaysia, Brunei), "mampalas" (Dusun/Kadazan) is an alternative of Tetracera scandens sandpapers. "Bambad" (Tangala Murut) is also used to remedy fevers.

33 "Sumbiling" (Dusun/Kadazan) or Schizostachyum cf. longispiculatum (Bambusoidae) was long ago used for making weapons, artifacts and mattresses. The calcium oxalate extraction of the culm is sometimes used in treatment against diarrhoea.

34 Hoya latifolia G. don. or "weeda" (Dusun/Kadazan) or "setebal akar" (Bahasa Malaysia) is used for the treatment of painful enlargement of the spleen and open wounds in children.

35 Callicarpa candicans (Bum.) Hochr. (Verbenaceae) or "liwu-liwu" (Dusun/Kadazan) or "tampang besi" (Bahasa Malaysia) is employed in the treatment of stomachache, acute diarrhoea, boils and cuts. It is also a mouth gargle and an excellent contraceptive.

36 Melanorrhoca wallichi Hook. f. (Anacardiaceae) or "rangas" (Dusun/Kadazan) or "renghas" (Bahasa Malaysia) is a poisonous plant which produces acrid smoke when burned as firewood. The milky sap when come into contact with the human skin can cause acute allergic reactions.

37 All species of Rafflesia (Rafflesiaceae) or "romus" or "bunga gamut" or "Kukuanga" (Dusun/Kadazan) or "Bunga patma" (Bahasa Malaysia) are used as post-partum preparation and in charm philtre.

38 Tetrastigma lanceolarium Wall. (Vitaceae) is also known as "pupus" (Dusun/Kadazan) or "akar cabang lima" (Bahasa Malaysia) is used for venomous snake bite.

39 Caryota mitis Lour, (Palmae) or "botu" (Dusun/Kadazan), or "ararae" (Murut) or "beredin" (Bahasa Malaysia) young stem-apices are consumed as a vegetable during post-partum treatment. On the other hand the ripe fruits are poisonous and may cause allergic reactions on the skin.

40 Ixora Javaicum is a conspicuous ornamental.

41 Fagraea racemosa, Jack (Loganiaceae), also known as "todopon puok" (Dusun/Kadazan), is a handsome ornamental and in time immemorial the Dusun/Kadazan used it as ritual plant.

42 Blumeodendron tokbrai (Bl.) Kurz or "gangulang" (Dusun/Kadazan) fruits are edible.

43 Baccaurea stipulata J.J. Smith (Euphorbiaceae) or "kunau-kunau" (Bahasa Malaysia) fruits maybe consumed.

44 Dillenia borneensis Hoogl. (Dilleniaceae) or "simpoh gajah" (Bahasa Malaysia) is a handsome tree and ornamental.

45 Asplenium nidus L. (Polypodiaceae) or "tapako" (Murut, Dusun/Kadazan) is considered sacred or otherwise used in the treatment against deafness due to acts of witchcraft and sometimes employed in fever and post-partum treatment.

46 This particular debris could have been brought and lost or abandoned by hunters as the artifact was not found under the earth surface. Found by Joseph Gasis on May 2, 1988 at corridor creek and had been given to the Sabah Museum for further identification.

47 "Sungang" (Dusun/Kadazan) is a legendary cure for act of witchcraft, black magic and ordeal poison indicator.

48 Scorodocarpus borneensis (Baill.) Becc. (Olacaceae) or "bawang hutan" (Bahasa Malaysia, Brunei) or "bawang talun" (Dusun/Kadazan) is a popular seasoning and condiment. It is also used to blackened the hair. It is also used as an antidote to the blowpipe's darts poison (mainly of Antaris toxicaria (Pers.) Lesch. preparation.

49 "Sunsum" (Rungus, Dusun/Kadazan) or Salacca affinis leaves were long ago used to make steps whereas the fruit is either consumed or made into a traditional sour beverage.

50 "Mangkawot", "gawir" (Dusun/Kadazan) or "kelawar" or Pteropus vampyrus is consumed to erase or eliminate asthsma. According to belief its flesh is hot.

5.3 : ALTITUDINAL DISTRIBUTION OF DIPTEROCARPS

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METHODS

Dipterocarps were collected opportunistically throughout the expedition (LM) and also sampled more systematically (NB) to assess their altitudinal distribution. A 20 m wide, 3.5 km long transect, from Base Camp at an altitude of 490 m, to the heath forest zone at 1,050 m, was surveyed by measuring the gradient over 20 m sections. All dipterocarp seedlings, saplings, and large adult trees within the transect were recorded on a presence/absence basis. Every 200 m along the slope, a quantitative survey of all dipterocarp seedlings was made in a 400 m2 plot.

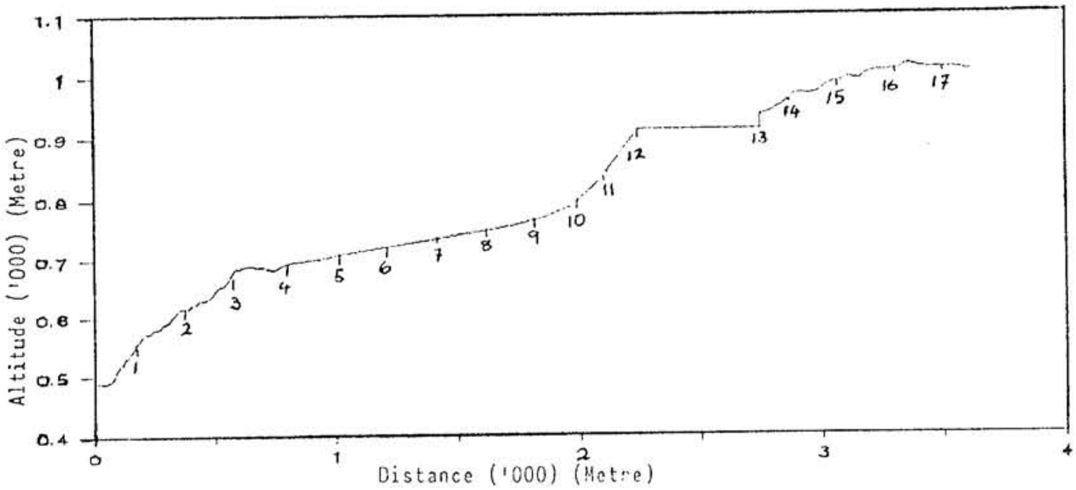
Measurements of maximum and minimum shade air temperature at 1.3 m above the ground were made at altitudes of 625 m, 690 m, 900 m and 1,000 m (the transition between coniferous and heath forest zones). Pichemeters were used to measure cumulative, relative, atmospheric water demand (a measure of the evaporative capacity of the air) at 625 m, 690 m, 900 m, 980 m (the transition between hill dipterocarp and coniferous forest) and 1,000 m.

RESULTS

Meteorology

The transect can be divided into three topographic sections (Figure 25) : a) the stepped slope from Base Camp up Main Trail Ridge to 680 m. b) the smooth ascent of Main Trail Ridge to the top at 900 m. c) the rugged ascent of Rengas Ridge above Camp II grading into the plateau of the coniferous and heath forest zones. The shallow valley between Main Trail Ridge and Rengas Ridge was omitted from the survey.

Fig.25 Profile from Base Camp to Heath Forest, Maliau Basin. (Positions of numbered plots shown).



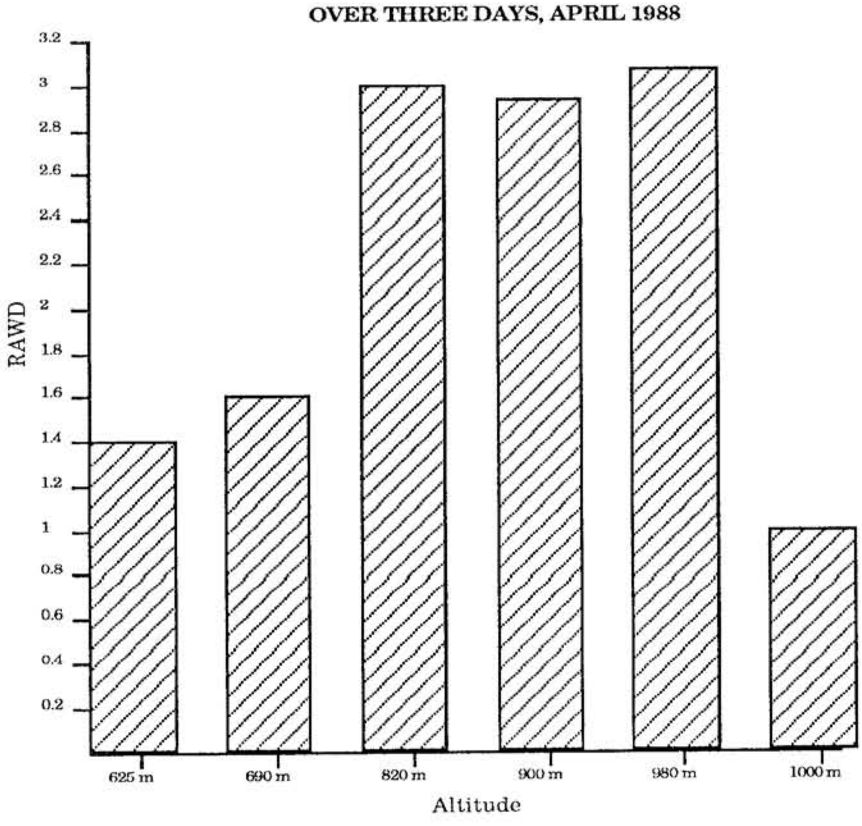
Mean minimum temperature falls with altitude at a lapse rate of 0.32°C/100 m. Unpublished measurements in lowland forest at Danum Valley Conservation Area, Sabah, show that forest structure has little influence on mean minimum temperature. This fall in temperature with altitude may be attributed to adiabatic cooling alone.

Mean maximum temperature falls with altitude too, up to 900 m, at a lapse rate of 1.27°C/100 m. However, the highest maximum temperature of 30.6°C was recorded in the heath forest at 1,000 m. It is suggested that the open, stunted structure of this forest allows strong solar heating of the ground and vegetation with radiation to the still air.

Relative atmospheric water demand (RAWD) is considerably greater on the exposed ridges at 820 m, 900 m, and 980 m (Figure 26) where wind constantly removes saturated air from above an evaporating surface. The less exposed plateau at 1,000 m shows a typical suppression of RAWD due to increasing relative humidity with altitude.

Fig. 26

RELATIVE ATMOSPHERIC WATER DEMAND RECORDED OVER THREE DAYS, APRIL 1988



Dipterocarp Flora

In all, 38 species of dipterocarp were collected in the Maliau Basin (see main checklist), which comprises about 21% of the dipterocarp flora of Sabah. Only three species were collected in flower: Parashorea malaanonan, Dipterocarpus caudiferus and Hopea nervosa. One species is a notable distribution record : Shorea cariacea (seraya tankai panjang) was collected in the heath forest but is otherwise known only from Malaman, Sipitang. Meijer and Wood (1964) consider it one of the least known serayas in Sabah, although it is common on kerangas soils in Sarawak.

Dipterocarp Distribution

Tables 8 and 9 show the distribution of adults and of seedlings and saplings by 50 m altitudinal steps. Table 10 shows the number and species of dipterocarp seedlings in each of the 17 sample plots.

TABLE 8

ADULT DIPTEROCARP DISTRIBUTION BY ALTITUDE

	SPECIES												
ALTITUDE	Sj	Hn	So	Sov	Dl	Dc	Sf	Sm	Sa	Sp	Spl	A	B
< 500 m	x	x	x	x	x								
500-550 m		x											
550-600 m		x	x		x								
600-650 m	x		x		x	x		x					
650-700 m	x		x		x		x		x	x			
700-750 m		x	x			x	x			x		x	x
750-800 m										x		x	x
800-850 m						x							
850-900 m							x						
900-950 m							x						x
950-1000 m							x						x
1000 m-Heath											x		
Heath													

TABLE 9

DIPTEROCARP SEEDLING AND SAPLING DISTRIBUTION BY ALTITUDE

	SPECIES													
ALTITUDE	Hn	So	Sj	Pt	Dl	Sp	Sl	Sa	Sb	V?	Hb	Spl	Sov	Sv
< 500 m	x	x	x	x	x		x		x	x				
500-550 m	x	x	x	x	x	x				x				
550-600 m	x	x			x	x	x		x	x			x	
600-650 m	x	x	x		x	x	x	x	x	x				
650-700 m	x	x	x	x	x	x		x		x	x		x	
700-750 m	x	x		x		x	x	x		x	x			
750-800 m	x			x			x			x				
800- 850 m						x					x			
850-900 m											x			
900-950 m								x	x					
950-1000 m		x				x	x		x	x		x		
1000-Heath											x	x		x
Heath														x

TABLE 10

SEEDLING AND SAPLING FREQUENCY IN 400 M2 SAMPLE PLOTS

		SPECIES												
PLOT	ALTITUDE	Hn	Sj	Pt	Dl	Sp	Sl	Sa	Sb	V?	Hb	Spl	Sv	So
1	558 m	7			23	1			1	1				
2	625 m	58	2			1			9					49
3	675 m					2		3		7				17
4	690 m	7			2	1								29
5	700 m	19		3	7	4				1				31
6	712 m	10		2		2				2				
7	724 m	42		2		4	4			1				
8	736 m	25				10	3				2			1
9	750 m	8		7		7	4	1		2				2
10	800 m	2		1		2				2				
11	855 m					3								
12	900 m							1			7			
13	920 m								1	4		2		
14	950 m						10		1	5		7		4
15	1000 m					1					1			
16	1020 m										8	1		
17	1010 m												4	

Key to species name abbreviations, Tables 8, 9 and 10.

Hn	Hopea nervosa	Dl	Dryanobalanops lanceolata	Sl	Shorea leprosula
Sj	Shorea johorensis	Dc	Dipterocarpus caudiferous	Sb	Shorea bracteolata
Sa	Shorea argentifolia	Pt	Parashorea tomentella	Sv	Shorea venulosa
Spl	Shorea platyclados	V?	Unidentified Vatica species	Sov	Shorea ovalis
So	Shorea fallax	A	Unidentified adult red seraya	Sp	Shorea parvifolia
Sm	Shorea macroptera	B	Unidentified adult yellow seraya		
Sf	Shorea faguetiana	Hb	Hopea beccariana		

Both adults and seedlings/saplings show similar distribution patterns. Differences in adult and seedling distributions may be due to, a) much greater numbers of seedlings within the 20 m wide transect giving a larger sample and possibly a more accurate reflection of ecological preferences, or b) conditions towards the margins of a species range permitting the establishment of seedlings but not favouring further development.

Some species are only present as either adults or seedlings. Where only seedlings are present this may be due to the very small sample of adult trees included in the transect. Three species are present as adults only, Dipterocarpus caudiferous Merr., Shorea faguetiana Heim, and Shorea macroptera Dyer. This may reflect poor regeneration or lack of seedling persistence. Meijer and Wood (1964) report that regeneration of S. faguetiana is not normally abundant.

Five species appear to have an altitudinal restriction. Shorea johorensis Sym., Shorea ovalis (Korth.) Bl. and Dryanobalanops lanceolata Burck. are not found above 700 m. Hopea nervosa King and Parashorea tomentella Meijer do not occur above 800 m. Meijer and Wood (op cit) describe all five as lowland species or species of low hills.

By contrast Shorea argentifolia Sym., Hopea beccariana Burck. and Shorea platyclados Van Slotten occur only above 650 m, 700 m and 1,000 m respectively. Wyatt-Smith (1963) describes H. beccariana as a common ridge forest species and S. platyclados as characteristic of upper dipterocarp forest.

Shorea venulosa Wood ex Meijer is restricted to the heath forest above 1,010 m, where it is the only dipterocarp species found. Its vernacular name of seraya kerangas suggests it may be typically tolerant of these conditons.

Shorea fallax Ashton and Shorea bracteolata Dyer are found as high as 1,000 m but both species are absent from ridges, occuring only on the slopes below Rengas ridge and where the knife ridge grades into the high level plateau.

Vatica species, Shorea parvifolia Dyer, and Shorea leprosula Miq. appear to be more or less ubiquitous.

CONCLUSIONS

Meteorological observations and dipterocarp distribution data permit a preliminary classification of forest types :

a) **Lowland hill dipterocarp forest.** In valley bottoms and slopes upto 700 m. Characterised by abundant adult H. nervosa, S. fallax, S. johorensis and D. lanceolata and dense regeneration of H. nervosa and S. fallax.

b) **Ridge forest.** On upper slopes and ridge crests upto 950 m. Characterised by fewer emergent dipterocarps co-dominating with large Fagaceae. Dipterocarp flora characterised by H. beccariana, or by S. platyclados. Regeneration sparse.

The division between ridge and lowland forest is not principally altitudinal, for there does not appear to be any significant difference in the range of air temperatures. Topography, however, may play an important part in increasing exposure, thereby increasing atmospheric water demand, and steep slopes allow strong side lighting between tree canopies, increasing under-canopy light levels.

c) **Coniferous forest.** A lower stature forest above 950 m with a sparse, species poor dipterocarp flora. Regeneration rare and dominated by H. beccariana and S. platyclados. This can be considered a lower montane formation.

d) **Heath forest.** Low, exposed forest at lower montane elevations with high humidity and extremes of temperature. Dipterocarpacae reduced to a single species, S. venulosa, with adult trees very rare.

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5.4 : VEGETATION CLASSIFICATION AND MAPPING

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INTRODUCTION

The purpose of this report is to make a preliminary identification of the major forest types of the Maliau Basin based on ground observations, and to compare this with a classification based on the interpretation of aerial photographs.

As discussed by various authors, a number of forest formations and types are recognised in the moist tropical rainforest (Burtt-Day 1938, Symington 1943, Wyatt-Smith 1963, Burgess 1969, Whitmore & Burnham 1969, Whitmore 1984). Forests are first divided into formation types, based on their structure and physiognomy without any consideration of floristic composition. The formation types can be further defined and sub-divided for specific regions according to the floristic composition, for example, the forest types of Malaya, as depicted by Symington (1943).

The Maliau Basin has four forest formations. These have been categorised here according to two base origins, viz. the Climatic Climax Forests, ie. the Lowland Rain Forest Formation, the Lower Montane Rain Forest Formation and the Upper Montane Rain Forest Formation (as defined by Burgess, 1969); and secondly, the Edaphic Climax Forests, ie. the Heath Forest.

LOWLAND RAIN FOREST FORMATION TYPE

Lowland Dipterocarp Forest

Burgess (1969) merged Symington's (1943) proposed division of the Lowland Dipterocarp Forest and the Hill Dipterocarp Forest into this type and he termed this forest type as the Lowland Dipterocarp Forest. This forest type includes most of the inland dry forest from the coast to about 830 m (2,500 ft) a.s.l.

In the Maliau Basin, this forest type is confined mainly along the slope draining the Sg. Maliau, including the forest around Base Camp. The forest is dense and multi-layered. Emergents exceeding 30 m in height and with diameters over 100 cm were noted on the ridges of Main Trail and Long Ridge.

Floristically, Lowland Dipterocarp Forest is the most diverse forest type in the Maliau Basin. Dominant emergents observed included the family Dipterocarpaceae (Dipterocarpus, Parashorea, Shorea and Dryobalanops), Burseraceae (Dacryodes), and Leguminosae (Parkia, Koompassia and Sindora). Shorea appeared to be exceptionally diverse here. Of the 65-70 Shorea species recorded in Sabah (Wood & Meijer, 1964), 30 species have been recorded in the Maliau Basin (Section 5.5). The other larger genera of this family, however, are less represented in diversity (Dipterocarpus, 6 out of 24; Hopea, 3 out of 40 and Vatica, 3 out of 13).

Riverine Forests and Riverbank Communities

Lowland forest adjacent to the rivers and larger streams can be considered a specialised sub-type conditioned by more exposed light, more rocky soils and the periodic inundation of the riverbanks. Plants of this community, termed rheophytes, have one or more of the following characteristics :

(i) they are firmly anchored to the bank, rocks or rapids;

(ii) their leaves are either small or substantially dissected, or narrow to linear in shape;

(iii) they produce basal shoots easily and often have a tufted or many-stemmed shrubby habit;

(iv) they survive flooding and torrential flow.

Floristically, this community is not well developed in this Basin as compared to some other river systems eg. Sg. Endau (Wong et al., 1987) and Sg. Tahan (Saw L. G., personal observations) in Malaya. The common trees observed wree Eugenia claviflora var. riparis, E. perpuncticulata, E. rejangense and Tristania cf. grandifolia. Of particular interest is Eugenia claviflora var. riparia. Until now it has only ben recorded as a rare endemic of the Tahan river of Pen. Malaysia. Tristania cf. grandifolia which was seen mainly in the Heath Forest, is also common here. Such disjunct distribution of Tristania between the Heath Forest community and the Riverine Forest community was also observed in Sg. Endau river system (Wong et al., 1987).

Other tree species found mainly on riverbanks with alluvial soils included Callicarpa longfolia, Mallotus penangensis, Guioa pleuroptris, Cinnamomum racemosa, Dysoxylum cf. acutangula and Rhodamnia cinerea. An interesting fig, Ficus uncinata, was collected a short distance downstream of the Base Camp. This tree produces earth figs, ie. the fig is produced on long runners along the ground.

Shrubs and low growing plants growing mainly on rocky banks and sandbanks included Melastoma polyanthum, Clausena excavata, Glochidion wallichianum, a Pandanus sp. (very common) and a number of grasses and sedges (Cyperaceae). Of interest, was a small population of Osmoxylon borneensis (Araliaceae), an endemic shrub of Borneo, found near the water falls.

Other species of plants of this community included some climbers noteably, Milletia spp., Dissochaeta spp., Rubus moluccanus (very common), Tetracera korthalsii (common) and Poikilospermum suaveolens. The climbing bamboo, Dinochloa? scandens was also extremely common along the riverbanks, forming dense thickets in places.

LOWER MONTANE RAIN FOREST FORMATION TYPE

Upper Dipterocarp Forest

This forest type is characterised by the presence of Shorea platyclados and the absence of a large number of species characteristic of the Lowland Dipterocarp Forest. Structurally, it is similar to the Lowland dipterocarp Forest but it tends to lack the numerous pole-sized straight-growing trees of the latter. The altitudinal limits are between c. 830 m (2,500 ft) to c. 1,300 m (4,000 ft). In the Maliau Basin the upper limit appears to about 1,000 m.

Floristically, in the Maliau Basin the families Fagaceae, Lauraceae, Myrtaceae and Guttiferae predominate in this forest type. Dipterocarpaceae tend to concentrate on the ridges and begin to disappear at altitudes above 1,000 m where the oaks and laurels replace them (see Section 5.3). It is in this forest type at higher elevaions that the mountain ferns Dipteris conjugata and Matonia pectinata appear on exposed ridges.

Agathis-Shorea Platyclados/Oak-Laurel Forest

This forest type is found above the Upper Dipterocarp Forest and seems to correspond to Brown and Madani's "coniferous forest" (Section 5.3) and Lamb and Wong's Casuarina/coniferous forest (Section 5.4). In the Maliau Basin this develops above 1,000 m to c. 1,200 m elevation. The apparent narrow range and depression of elevation of this forest type in the Maliau Basin could be due to the influence of the geology of the area. Wyatt-Smith (1963) placed the altitudinal limits of this forest type as between c. 1,200 m to c. 1,600 m. Structurally, it is a two layered forest, with tree heights usually between 20 to 25 m tall. Humus accumulation increases and epiphytes become more common with increasing altitude.

Just below the South Plateau and on parts of the Long Ridge at about 1,000 m elevation a distinct local dominance of Agathis borneensis and Shorea platyclados occurs. Trees were mainly without buttresses, climbers scarce and soils peaty. The fern Taenitis blechnoides carpetted most of the forest floor especially on the South Plateau.

Other prominent trees observed here were Shorea venulosa and S. coriaceae (these species in both Montane and Heath forests), Pyrenaria sp., Eugenia spp., Calophyllum sp., and various Lauraceae (Actinodaphne sp., Litsea sp., etc.), oaks, Casuarina sumatrana, Podocarpus polystachyus, Phyllocladus hypophyllus etc. Of the palms, Iguanura and Pinaga were observed, and a few species of Calamus. The fern Oleandra pistillaris was also common on mossy ground especially at bases of tree trunks. An interesting narrow-stemmed rattan, Calamus javensis, was very abundant on the Long Ridge. This proved to be a new record for Sabah for this extreme montane form (Dransfield, per. comm.). This elevation also appeared to be the upper altitudinal limit of the climbing bamboo Dinochloa? scandens. Another species of small-stemmed bamboo (?Bambusa) was observed to be quite common on Long Ridge. Other notable common species were a Pandanus sp., a number of Nepenthes spp., Dianella ensifolia, and a Didymocarpus spp.

UPPER MONTANE RAIN FOREST FORMATION TYPE

Montane Ericaceous Forest

Burgess (1969) observed that this forest type develops in Malaya at elevations above 1,600 m on the Main Range but can be much lower on isolated peaks. In Sabah, Corner (1978) observed this forest type to develop above 1,300 m to c. 2,000 on Gn. Kinabalu. Burgess (1969) described the Montane Ericaceous Forest as :

"typically stunted, rarely reaching more than 17 m, often less than 4 m, the trees are crooked and somtimes prostrate, with a thick covering of moss and other epiphytes on stems and branches. The leaves are all markedly smaller than those in the forest of the Lower Montane Formation, macrophylls being entirely lacking, and microphylls being as numerous as mesophylls. Almost all leaves are xeromorphic. A thick layer of peat covers the ground, and the roots of the trees are so matted with semi-decomposed plant residues that one frequently plunges one's leg to knee depth in humus and roots when walking in this forest."

In the Maliau Basin, it was seen only at the northwest end of Long Ridge near the north rim, mainly above c. 1,200 m altitude. Trees close to the cliff edge were short, generally less than 4 m tall, gnarled, stunted and shrubby. There was a gradual decrease in tree heights from the start of the rim to the highest points at the cliff edge.

Whitmore (1984, pg. 252) has noted that both the Upper Montane and the Heath Forest have many similar features of structure and physiognomy. The rim at this elevation, however, is typed as a Montane Ericaceous Forest because a number of species found here are not known in the Lowland Heath Forest. These include Dacrydium falciforme, Phylloclados hypophyllus, Podocarpus imbricatus, (as noted by Whitmore, 1986; pg. 253), Eugenia cf. stapfiana, E. kinabaluensis, E. cf. ampullaria (checked from past records at KEP).

Other common Rim flora consisted mainly of species from the families Ericaceae (Rhododendron spp., Vaccinium spp., Diplycosia spp.), Myrtaceae (Eugenia spp., Tristania spp.), Lauraceae (Actinodaphne spp., Litsea spp., Cinnamomum spp.), Guttiferae (Calophyllum spp.), Casuarinaceae (Casuarina sumatrana and C. nobilis), conifers (Podocarpus spp., Dacrydium spp.) and others (Timonius spp., Nepenthes spp., Calamus spp., Fagraea spp., Weinmannia blumei, Tetractomia tetrandra, Embelia minutifolia, Elaeocarpus aff. palembanicus, etc.).

EDAPHIC CLIMAX FOREST

Heath Forest

Heath forests are developed on soils derived from siliceous parent materials which are inherently poor in bases, highly acidic, and are also commonly coarsely textured (Whitmore 1986). The forest structure has already been described above.

In the Maliau Baisn, Heath Forest was well developed on the South Plateau at an elevation of c. 1,000 m. As a result, species of the Upper Montane Forest were also recorded here (eg. the family Ericaceae, some Eugenias, etc). The Heath Forest differs from Montane Ericaceous Forest in having drier soils, less moss on the ground and trunks of trees, and a greater abundance of species with specialized means of obtaining nutrients (Nepenthes spp., Hydnophytum spp., Myrmecodia spp., Dischidia spp., etc.).

Common species recorded on the South Plateau included Tristania cf. grandifolia (very common), Parastemon urophyllus, Medinella crassifolia, Prunus arborea var. densa, Rhododendron (at least 3 spp.), Vaccinium clementis, Ilex cymosa, Elaeocarpus pendula var. Hirtistylis, Pandanus? monotheca (very common), Diplycosia barbigera (very common epiphytic climber). Shorea coriacea and S. venulosa were the only dipterocarps seen in the heath forest.

On the South Plateau, the Agathis-Shorea platyclados forest borders the heath forest. Within the transitional zone, Casuarina sumatrana, Phyllocladus hypophyllus and Dacrydium elatum were rather common but not seen in the heath forest proper.

VEGETATION CLASSIFICATION FROM AERIAL PHOTOGRAPHS

An aerial photographic interpretation and mapping of the vegetation in Maliau Basin was undertaken in 1970 by the Forest Department, as part of the FAO-sponsored Forest Inventory Study of Sabah. Mapping was further checked by Mr. Peter Cockburn, who was then Forest Botanist at Sepilok Forest Research Centre. From stereo photographs at a scale of approximately 1 : 50,000, a rather detailed map was produced at a scale of 100,000 (Map 8). Map 9 is a simplified version of the same, while habitat areas are given in Table 11. In the original work the forest was classified by four criteria each with two or three classes – altitude, crown size, crown closure and topography.

TABLE 11

CLASSIFICATION OF FOREST TYPES IN MALIAU BASIN BASED ON ANALYSES OF AERIAL PHOTOGRAPHS

	ELEVATION	CROWN-SIZE	SLOPE	AREA (ha)	NOTES
Total Area of Barn 39,000 (100%)	LOWLAND FOREST (<762m, 2500 ft) 4,576 ha (11.7%)	Large-crowned 2,708 ha (6.9%0	Undulating	212	Lower Rambutan Ridge Dipterocarp/ Sapindaceae
			Hilly	1,476	
			Steep	1,020	Upper Rambutan Ridge
		Medium-crowned 1,868 (4.8%)	Hilly	392	Valley slopes of Sg. Maliau and tributaries eg. Main Trail behind Base Camp
			Steep	1,476	
	MONTANE FOREST (>762m, 2,500 ft) 34,136 ha (20.5%)	Large crowned 1,860 (4.8%)	Hilly	1,860	Upper forest
		Medium-crowned 24,300 (62.3%)	Undulating	488	Inner rim Coniferous/ Casuarina forest and oak-dominated areas eg. Long Ridge and most of Main Trail
			Hilly	16,896	
			Steep	6,916	
		Small-crowned 7,976 (88.3%)	Undulating	996	South rim heath forest eg. Jalan Babi
			Hilly	5,942	North rim heath forest (Montane ericaceous)
			Steep	1,028	Heath on scarp slopes
		Exposed rock 288 (0.7%)		228	Padang vegetation on N. W. rim

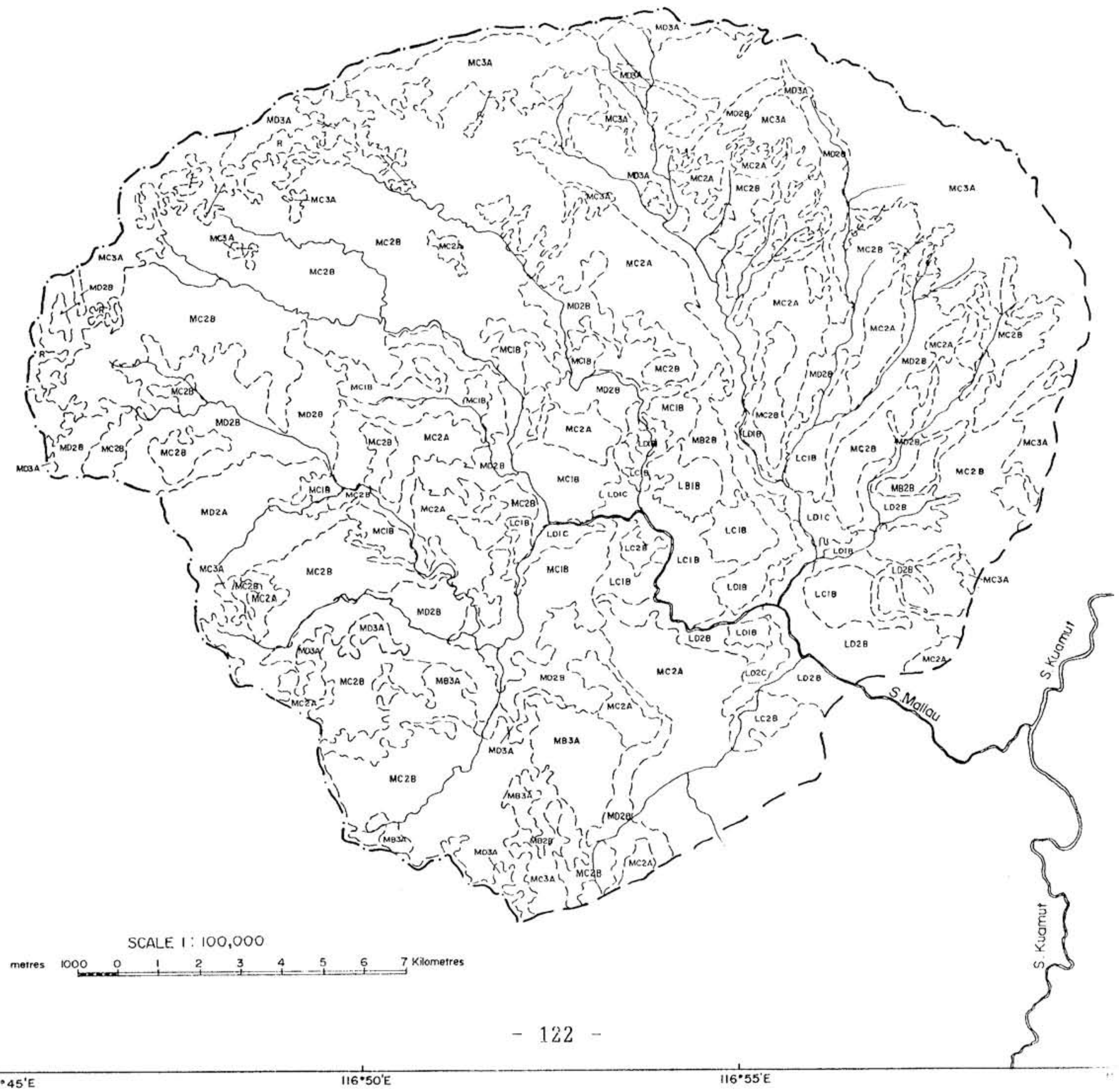
MAP NO. 8

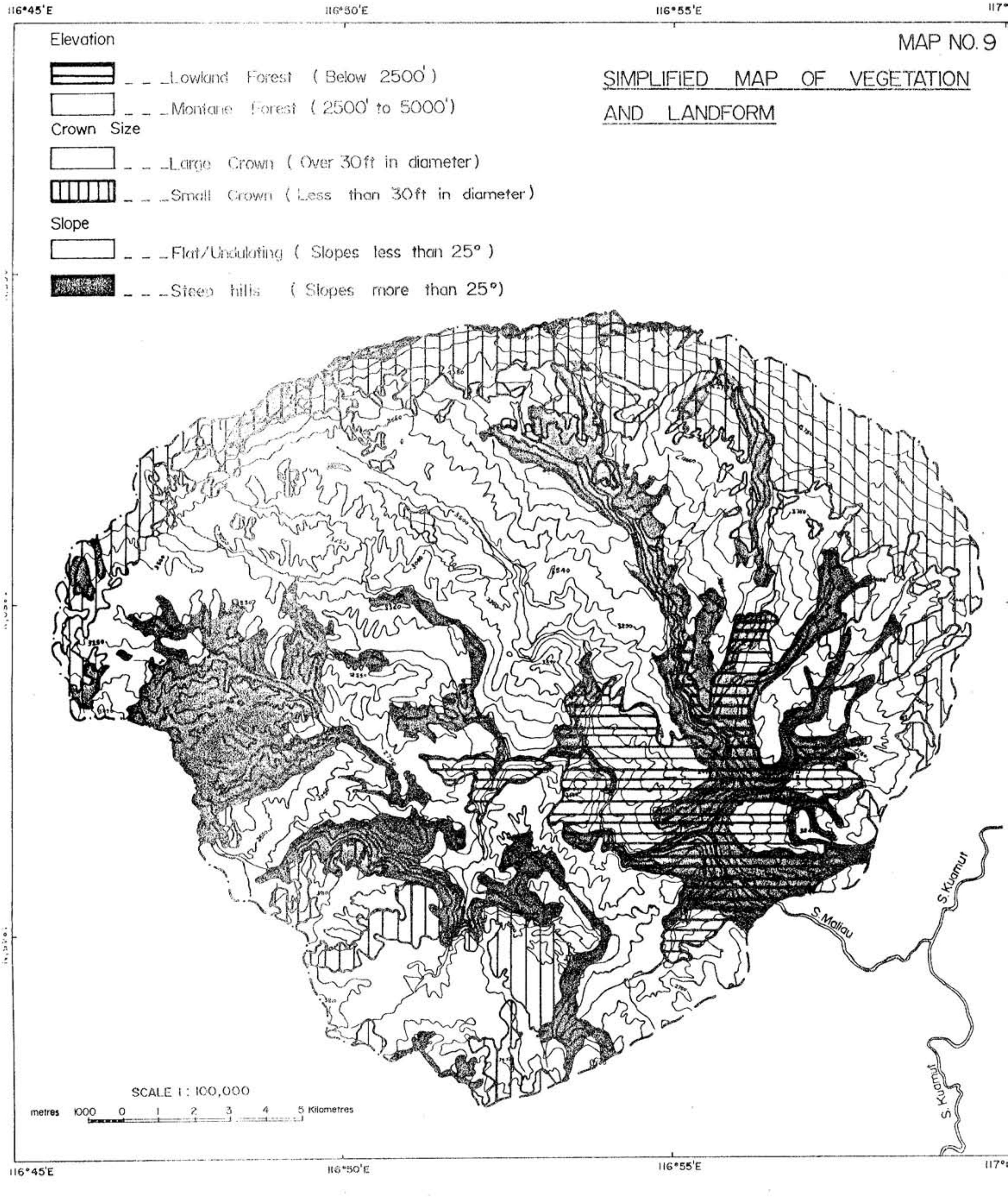
DETAILED VEGETATION MAP

Mapping units based on analysis of aerial photographs, supplemented by ground observations. Note that the altitudinal limit for lowland forest is taken to be 2500 ft. A.S.L

LEGEND

STRATA	FOREST TYPE	CROWN SIZE	CROWN CLOSURE	TOPOGRAPHY
LB1B	Lowland	Large	dense 60 – 90 %	undulating
LC1A	Lowland	Large	very dense 90%	hilly, slope < 25°
LC1B	Lowland	Large	dense 60 – 90%	hilly, slope < 25°
LC2B	Lowland	Medium	dense 60 – 90%	hilly, slope < 25°
LD1B	Lowland	Large	dense 60 – 90%	steep, dissected slope > 25°
LD1C	Lowland	Large	medium dense 30 – 60%	steep, dissected slope > 25°
LD2B	Lowland	Medium	dense 60 – 90%	steep, dissected slope > 25°
LD2C	Lowland	Medium	medium dense 30 – 60%	steep, dissected slope > 25°
MB2B	Montane	Medium	dense 60 – 90%	undulating
MB3A	Montane	Small	very dense 90%	undulating
MC1B	Montane	Large	dense 60 – 90%	hilly, slope < 25°
MC2A	Montane	Medium	very dense 90%	hilly, slope < 25°
MC2B	Montane	Medium	dense 60 – 90%	hilly, slope < 25°
MC3A	Montane	Small	very dense 90%	hilly, slope < 25°
MD2A	Montane	Medium	very dense 90%	steep, dissected slope > 25°
MD2B	Montane	Medium	dense 60 – 90%	steep, dissected slope > 25°
MD3A	Montane	Small	very dense 90%	steep, dissected slope > 25°
MD3B	Montane	Small	dense 60 – 90%	steep, dissected slope > 25°
R	Rock	—	—	cliffs




MAP NO. 9
SIMPLIFIED MAP OF VEGETATION AND LANDFORM
Elevation
Lowland Forest (Below 2500')
Montane Forest (2500' to 5000')
Crown Size
Large Crown (Over 30ft in diameter)
Small Crown (Less than 30ft in diameter)
Slope
Flat/Undulating (Slopes less than 25°)
Steep hills (Slopes more than 25°)
SCALE 1 : 100,000
metres 1000 0 1 2 3 4 5 Kilometres
116°45'E
116°50'E
116°55'E
S. Kuamut
S. Maliau

The first separation is between lowland and montane forest, for which the 2,500 ft (672 m) contour was taken as a rather arbitrary dividing line. On this basis, 88.3% of the Basin is montane while lowland forest makes up only 11.7% of the area, confined to the lower riverine region. Note that some authorities would describe this more precisely as **hill** lowland dipterocarp forest to distinguish it from a structurally similar but floristically distinct habitat confined to lower elevations than those found anywhere in the Maliau Basin (eg. Burgess, 1969). In Sabah, "truly" lowland forest also supports a rather different fauna (Davies and Payne, 1982).

A second classification character from aerial photographs is tree crown size - large, medium or small. When compared with observations on the ground, this separates three quite different forest types. Large-crowned areas are invariably dominated by dipterocarps, together with abundant fruit tree genera at lower canopy levels (eg. Rambutan Ridge). These comprise 2,708 ha (6.7%) in the lowland division and another 1,860 ha (4.8%) above the 2,500 ft contour. The nominally montane mapping units in question here are the middle valley slopes of Sg. Maliau tributaries upstream of Base Camp. In such sheltered locations, hill dipterocarp forest reaches to about 3,000 ft.

While all large-crowned forest seems to be dominated by dipterocarps, the converse is not true. Significant areas of lowland dipterocarp forest are classed as medium-crowned. These are mostly on steep lower valley slopes. From his transect studies, Brown also distinguishes slope and ridge faces of hill lowland forest (Section 5.3).

In the montane division, medium-crowned forest covers no less than 24,300 ha or 62% of the entire Basin, and includes both oak-dominated areas (eg. Long Ridge and along part of Main Trail) and coniferous/Casuarina forest, which probably covers a large expanse of the northern dip slopes of the Basin. When a third factor, canopy density, is considered, most of the "very dense" areas seem to be at lower elevation than merely "dense" areas, and this may indicate some separation of these two floristically distinct associations. However, the differentiation is not very strong - the coniferous forest belt above Camp II, for example, is not segregated on aerial photos from the oak forest below it along Main Trail.

Forest classed as "small-crowned" from photos coincides closely with heath and/or upper montane forest on the ground and comprises 7,976 ha, or 20.5% of the Basin. A useful further distinction from the aerial photographs can be made between small-crowned forest on "undulating" slopes (996 ha), which includes almost all the South Plateau heath forest, and similar-crowned forest on hilly or steep land (6,980 ha) which is concentrated along the outer northern rim of the Basin. As noted above, these latter areas are really upper montane ericaceous forest, dominated by stunted trees and strewn with moss. A few areas (788 ha) in the far northwest are classed as Bare Rock, representing an extremely stunted heath forest or "padang" vegetation.

DISCUSSION

On the whole, crown size and altitude are the most important photographic classification factors, with slope providing a useful guide to subtler habitat characters. Differences in canopy closure, on the other hand, do not seem to correspond closely to structural or floristic differences in the field. This measure is probably of more use in estimating timber volumes in lowland forest. In the Maliau Basin, potentially loggable forest can be taken as the large crowned areas, both lowland and montane, on undulating or hilly terrain, steep land being excluded for both environmental and practical reasons. Defined in this way, only 3,548 ha or 9.1% of the Basin can be considered potentially commercial dipterocarp forest. Almost all of this land lies at the southern end of Long Ridge and its horseshoe-shaped extensions onto Rambutan Ridge, and in parts of the main river valley upstream of Base Camp. Even some of these "workable" areas are in fact inaccessible because they are isolated by surrounding steep slopes. 26.7% of the Basin has slopes in excess of 25°.

To conclude, vegetation mapping indicates that the Basin includes 11.7% lowland hill dipterocarp forest, and 20.5% heath forest, most of which is at upper montane elevation along the north rim, but with about 10 sq. km. on flattish land near the south rim. Most of the remainder of the Basin (62%) is lower montane forest dominated according to site either by oaks and laurels or by conifers and Casuarina. Unfortunately, this botanically interesting division remains undifferentiated as it does not show up well on aerial photos. Also omitted are the subtler variants of lowland forest, as described in this and the previous section viz. riverine and ridge top forest. Thus, while aerial photos can provide a good guide to the proportional representation of forest types with differing crown size, more refined distinctions can be made only from ground observations.

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5.5 : CHECKLIST OF PLANTS SEEN AND COLLECTED

Compiled by A. Phillipps and E. Gasis

The attached master list was prepared by combining the records of all the expedition's botanists and foresters, namely: N. Brown, A. Garcia, E. Gasis, F. Goh, J. Guntavid, A. Lamb, L. Madani, L. G. Saw, W. W. Wong and A. Zuhaidi. The list comprises 460 species as follows:-

Ferns	:	11 families, 14 genera and 15 species
Gymnosperms	:	3 families, 5 genera and 9 species
Angiosperms	:	85 families, 329 genera, 436 species

TAXOM		NOTES

PTERIDOPHYTA (Ferns and their allies)

Adiantaceae	Taenitis blechnoides	
Aspleniaceae	Asplenium nidus	
Cyatheaceae	Cyathea latebrosa	
Dipteridaceae	Dipteris conjugata	
Gleicheniaceae	Gleichenia linearis	
Lindsaeaceae	Lindsaea sp.	
Lycopodiaceae	Lycopodium cernuum	
Oleandraceae	Oleandra pistillaris	
Polypodiaceae	Drynaria sparsisora Lecanopteris carnosa var. pumila Lecanopteris sinuosa Playtcerium coronarium P. ridleyi	
Selaginellaceae	Selaginella conferta	
Vittariaceae	Antrophyum callifolium	

GYMNOSPERMS (Conifers, etc.)

Araucariaceae	Agathis dammara	
Gnetaceae	Gnetum gnemon var. brunonianum	

TAXOM		NOTES
Podocarpaceae	Dacrydium beccarii	
	D. elatum	New record for Sabah (comparison with KLU 899, Pahang)
	D. falciforme	
	D. pectinatum	
	Phyllocladus hypophyllus	
	Podocarpus imbricatus	
	P. neriifolius	
	P. polystachyus	

ANGIOSPERMS (Flowering plants)

Acanthaceae	Acanthus sp.	
Agavacea	Pleomele angustifolia	
Alangiaceae	Alangium ebenaceum	
Anacardiaceae	Buchanania arborescens	
	Gluta sabahana	
	Koordersiodendron pinnatum	
	Mangifera foetida	
	M. rigida	
	M. bullata	New record for Borneo
	Melanorrhoea wallichii	
	Parishia insignis	
Annocaceae	Artabotrys roseus	
	Desmos sp.	
	Fissistigma sp.	
	Goniothalamus ridleyi	
	G. roseus	
	Polyalthia bullata	
	P. insignis	
	P. sumatrana	
	P. odoardoi	
	P. pisocarpa	
	Uvaria sp.	
Apocynaceae	Alstonia angustiloba	
	Alyxia? pilosa	
	Taebernaemontana pauciflora	
Aquifoliaceae	Ilex trifoliata	
	I. cymosa	
Araceae	Alocasia sp.	
	Pothos sp.	
	Scindapus sp.	

TAXOM		NOTES
Araliaceae	*Osmoxylon borneensis*	
	Schefflera sp.	
Asclepiadaceae	*Hoya latifolia*	
Begoniaceae	*Begonia* sp. I	
	B. sp. II	
	B. sp. III	
	B. pp. IV	
	B. sp. V	
Bombacaceae	*Durio* cf. *acutifolius*	
	D. graveolens	
	D. cf. *kinabaluensis*	
	D. kutejensis	
	D. oxleyanus	
Burseraceae	*Canarium denticulatum*	
	Dacryodes rugosa	
Casuarinaceae	*Casuarina sumatrana*	
	C. nobilis	
Celastraceae	*Cassine kochinchinensis*	
Connaraceae	*Agelaea borneensis*	
Cunoniaceae	*Weinmannia blumei*	
Cyperaceae	*Carex* sp.	
	Mapania urceolata	
	Scleria motleyi	
	Trichophorum sp.	
Datiscaceae	*Octomeles sumatrana*	
Dilleniaceae	*Dillenia borneensis*	
	D. excelsa	
	Tetracera akarii	
	T. korthalsii	
Dioscoreaceae	*Dioscorea* sp.	
Dipterocarpaceae	*Dipterocarpus acutangulus*	
	D. caudiferus	
	D. confertus	
	D. crinitus	
	D. gracilis	
	D. stellatus	
	Dryobalanops lanceolata	
	Hopea beccariana	
	H. nervosa	
	H. sangel	

TAXOM		NOTES
	Parashorea malaanonan	
	P. tomentella	
	Shorea acuminatissima	
	S. almon	
	S. angustifolia	
	S. argentifolia	
	S. asahii	
	S. bracteolata	
	S. coriacea	
	S. faguetiana	
	S. fallax	
	S. cf. flemmichii	
	S. foxworthyi	
	S. gibbosa	
	S. glaucescens	
	S. johorensis	
	S. laevis	
	S. leprosula	
	S. leptoclados	
	S. macroptera	
	S. mecistopteryx	
	S. obscura	
	S. ovalis	
	S. parvifolia	
	S. pauciflora	
	S. pilosa	
	S. platycarpa	
	S. platyclados	
	S. smithiana	
	S. superba	
	S. venulosa	
	S. waltoni	
	Vatica albiramis	
	V. dulitensis	
	V. oblongifolia	
Ebenaceae	Diospyros cauliflora	
	D. ? elliptifolia	
	D. cf. macrophylla	
	D. penibukanensis	
Eleocarpaceae	Eleocarpus hullettii	
	E. aff. palembanicus	
	E. obtusifolius	
Ericaceae	Diplycosia barbigera	
	D. chrysothrix	
	D. heterophylla var. latifolia	
	Rhododendron borneanse	
	R. durionifolium var. sabahense	
	R. longiflorum var. subcordatum	
	R. malayanum?	
	Vaccinium clementis	

TAXOM	NOTES
	V. sp.
Euphorbiaceae	Agrostistachys leptostachys
	Antidesma grandistipulata
	A. neurocarpum
	A. venenosum
	Aporusa grandistipula
	A. lucida
	Baccaurea javanica
	B. lanceolata
	B. macrocarpa
	B. stipulata
	Blumeodendron tokbrai
	Cleistanthus sp.
	Croton sp.
	Glochidion hypoleucum
	G. wallichianum
	Macaranga gigantea
	M. hypoleuca
	M. laekeyi
	M. macrostachys
	M. penangensis
	M. wrayi
	Mallotus muticus
	M. penangensis
	Omphalea sp.
	Sauropus sp.
Fagaceae	Castanopsis sp.
	Lithocarpus ewyckii
	L. nieuwenhuisii
	Quercus argentata?
Flacourtiaceae	Casearia sp.
	Homalium sp.
	Hydnocarpus woodii
	Ryparosa hullettii
Gesneriaceae	Aeschynanthus sp.
	Didymocarpus aff. amoenus
	D. crocea
	D. cf. hispida
Graminae (including Poaceae)	
	Bambusa sp.
	Dinochloa scandens
	Imperata cylindrica
	Joinvillea sp.
	Schizostachyum cf. longispiculatum

TAXOM		NOTES
Guttiferae (including Clusiaceae)		
	Calophyllum bursicolum	New record for Sabah (comparison) with Sarawak iso-type S 17230)
	C. gracilipes	
	C. nodosum	
	C. wallichianum var. incrassatum	
	Garcinia mangostana	
	G. parvifolia	
Hanguanaceae	Susum cf. malayanum	
Hypoxidaceae	Curculigo cf. latifolia	
Illiciaceae	Illicium sp.	
Juncaceae	Juncus sp.	
Lauraceae	Actinodaphne cf. oleifolia	
	Alseodaphne sp.	
	Beilschmiedia micrantha	
	Cinnamomum javanicum	
	C. racemosa	
	Cryptocarya sp.	
	Dehaasia caesia	
	Litsea elliptica	
	L. fulva	
	Notaphoebe spp.	
	Phoebe sp.	
Lecythidaceae	Barringtonia sarcostachys	
Leguminosae (including Fabaceae)		
	Albizia singularis	
	Bauhinia diptera	
	Caesalpinia sappan	
	Cynometra sp.	
	Dialium indum	
	Entada sp.	
	Koompassia excelsa	
	K. malaccensis	
	Millettia cf. vasta	
	Mucuna sp.	
	Parkia speciosa	
	P. jiringa	
	Phanera kockiana	
	Sindora sp.	
	Spatholobus macropterus	
Liliaceaae	Dianella ensifolia	
Linaceae	Ixonanthes reticulata	

TAXOM		NOTES
Longaniaceae	Fagraea blumii	
	F. involucrata	
	F. racemosa	
	Mitrasacme sp.	
	Strychnos ignatii	
Loranthaceae	Dendropthoe varians	
	Helixanthera sp.	
	Loranthus sp.	
	Macrosolen cochinchinensis	
Magnoliaceae	Talauma gitingensis	
	Magnolia sp.	
Marantaceae	Donax sp.	
	Phacelophrynum sp.	
Melastomataceae	Allomorphia sp.	
	Creaghiella setosa	
	Diplectria glabra	
	Dissochaeta beccariana	
	D. sp.	
	Driessenia sp.	
	Kibessia galeata	
	Medinella crassifolia	
	M. sp.	
	Melastoma malabathricum	
	M. polyanthum	
	Memecylon edule	
	M. paniculatum	
	Pternandra coerulescens	
	Sonerila sp.	
Meliaceae	Aglaia affinis	
	A. dubia	
	A. oligophylla	
	A. polyantha	
	A. trichostemon	
	Amoora sp.	
	Chisocheton beccarianum	
	C. sarawakensis	
	Dysoxylum cf. acutangula	
	D. rugulosum	
	Walsura sp.	
Moraceae	Artocarpus odoratissimus	
	A. anisophyllus	
	A. elasticus	
	Ficus cuspida	
	F. fistulosa	
	F. uncinata	
Musaceae	Musa sp.	

TAXOM		NOTES
Myristicaceae	Horsfieldia sp.	
	Knema cenerea	
	K. latericia var. albifolia	
	Myristica cinnamomea	
Myrsinaceae	Ardisia cf. elliptica	
	A. oxyphylla	
	Embelia minutifolia	
	Labisia sp.	
	Maesa macrothyrsa	
Myrtaceae	Eugenia cf. ampullaris	
	E. bankense	
	E. barringtoniodes	
	E. chrysantha	
	E. claviflora v. riparia	
	E. kinabaluensis	
	E. perpuncticulata	
	E. rajangense	
	E. rugosa	
	E. ? stapfiana	
	Rhodamnia cinerea	
	Sysygium sp.	
	Tristania cf. grandifolia	
Nepenthaceae	Nepenthes hirsuta	New record for Sabah. Recorded from Brunei and Sarawak.
	N. reinwardtiana	
	N. stenophylla	
	N. tentaculata	
	N. veitchii	
	N. veitchii x stenophylla (hybrid)	
Ochnaceae	Euthemis leucocarpa	
	E. minor	
	Gomphia borneensis	
	G. serrata	
Olacaceae	Ochanostachys amentacea	
	Scorodocarpus borneensis	
Oleaceae	Chionanthus beccarianus	
	Jasminum sp.	
Orchidaceae	Abdominea minimiflora	
	Acriopsis gracilis	
	Bulbophyllum acuminatum	
	B. cf. limbatum	
	B. cf. nigromaculatum	
	B. vaginatum	
	B. sp. I	
	B. sp. II	
	B. sp. III	
	Chelonistele amplissima	

TAXOM		NOTES
	C. cf. lurida?	
	Cleisostoma subulatus	
	Coelogyne cf. cuprea	
	C. dayana	
	C. cf. odoardi	
	C. pandurata	
	Corybas piliferus	
	Dendrobium cinnabarinum	
	D. pachyanthum	
	D. rosellum	
	D. sp. I	
	D. sp. II	
	D. sp. III	
	Dimorphorchis lowii	
	Eria cf. melaleuca?	
	E. sp.	
	Lecanorchis spp.	
	Malaxis cf. punctata	
	Maleola cf. dentifera	
	Nephelaphyllum pulchrum	
	N. trapoides	
	Podochilus cf. tenuis	
	Pomatocalpa spicata	
	Stereosandra javanica	
	Spathoglottis confusa	
	Taeniophyllum filiforme	
	Trichotosia sp.I	
	T. sp. II	
	Vanilla sp.	
Oxalidaceae	Sarcotheca diversifolia	
Palmae (including Arecaceae)		
	Areca sp.	
	Arenga undulatifolia	
	Calamus caesius	
	C. javensis	
	C. pogocanthus	
	Caryota mitis	
	Daemonorops sp.	
	Iguanura cf. polimorpha	
	Korthalsia echinometra	
	Licuala longipes	
	Oncosperma horridum	
	Pinanga sp.	
	Salacca cf. affinis	
Pandanaceae	Freycinetia sp.	
	Pandanus sp.	
Piperaceae	Peperomia sp.	
	Piper sp.	

TAXOM		NOTES
Polygalaceae	Polygala sp.	
	Xanthophyllum affine	
Proteaceae	Helicia robusta	
Rafflesiaceae	Rafflesia tengku-adlinii	Recently described from Gn. Trus Madi
Rhamnaceae	Ventilago sp.	
	Zizyphus sp.	
Rhizophoraceae	Carallia brachiata	
Rosaceae	Angelesia cf. splendens	
	Parastemon urophyllus	
	Parinari sp.	
	Prunus arborea var. densa	
	Rubus mollucanus	
Rubiaceae	Acranthera sp.	
	Anthocephalus chinensis	
	Argostemma sp.	
	Chassalia sp.	
	Gaertnera borneensis	
	Hedyotis sp.	
	Hydnophytum sp.	
	Ixora congesia	
	I. grandifolia	
	I.javanicum	
	Lasianthus cf. borneensis	
	L. inaequalis	
	Lucinaea sp.	
	Nauclea subdita	
	Paederia sp.	
	Pavetta sp.	
	Praravinia sericotricha	
	P. suberosa	
	Prismatomeris beccariana	
	Streblosa sp.	
	Timonius eskerianus	
	T. cf. flavescens	
	Uncaria sp.	
	Urophyllum glabrum	
	U. hirsutum	
	Zeuxantha moultonii	
Rutaceae	Clausena excavata	
	Luvunga sp.	
	Tetractomia tetrandra	
Sapindaceae	Guioa pleuropteris	
	Nephelium cuspidatum var. robustum	
	N. cf. mutabile	
	N. ramboutan-ake	

TAXOM		NOTES
	Paranephelium nitidum	
	Pometia pinnata	
Sapotaceae	Ganua kingiana	
	G. sarawakensis	
	Madhuca sp.	
	Palaquium beccarianum	
Saurauiaceae	Saurauia acuminata	
Saxifragaceae	Polyosma integrifolia	
Scrophulariaceae	Lindernia sp.	
Smilacaceae	Smilax borneensis	
Sonneratiaceae	Duabanga moluccana	
Sterculiaceae	Heritiera simplicifolia	
	Pterospermum sp.	
	Scaphium affine	
	Sterculia sp.	
Symplocaceae	Symplocos henschelli	
	S. pendula var. hirtistylis	
Tiliaceae	Brownlowia sp.	
	Microcos elmeri	
	Pentace laxiflora	
Theaceae	Adinandra dumosa	
	Pyrenaria cf. kunstleri	
	Schima sp.	
	Ternstroemia sp.	
Thymeleaceae	Wikstroemia androsaemifolia	
	W. tenuiramis	
Ulmaceae	Girroniera nervosa	
Urticaceae	Elatostema sp.	
	Poikilospermum suaveolens	
Verbenaceae	Callicarpa candicans	
	C. longifolia	
	Clerodendron sp.	
	Petraeovitex sp.	
	Teijsmanniodendron holophyllum	
Vitaceae	Ampleocissus sp.	
	Cissus hastata	
	Leea indica	
	Pterisanthes sp.	

TAXOM		NOTES
	Tetrastigma cf. lanceolarium T. papillosum	
Zingiberaceae	Achasma sp. Alpinia sp. Amomum sp. Costus speciosus Globba propinqua Plagiostachys sp.	

SECTION SIX - ANIMAL STUDIES

6.1 : INSECTS

Saikeh Lantoh
Sabah Forestry Department

METHODS

The aim of this 3-day project was to survey the insect fauna (in particular, Lepidoptera and Coleoptera) of the region, and collect specimens for the insect museum of the Sabah Forest Department. Most of the moths and beetles were collected by light-trapping at night.

The various collecting sites are summarized in the table below:-

TABLE 12

INSECT COLLECTION SITES IN MALIAU BASIN

COLLECTION SITE		DISTANCE FROM BASE CAMP	TIME	DATE	WEATHER
1.	Helipad	0.1 km	6.pm-10pm	19/4/88	Dry
	Helipad	0.1 km	6.30pm-10pm	21/4/88	Dry
2.	Trail to Bat Trap	0.2 km	7pm-10.30pm	22/4/88	Prior to rain
3.	River Bank (Sg. Maliau)	0.1 km	7pm-10pm	24/4/88	Dry
4.	To Waterfall	2.0 km	1pm-4pm	18/4/88	Dry
5.	Upper Sg. Maliau	2.5 km	7am-2pm	19/4/88	Dry
6.	Rambutan Ridge	2.0 km	7am-12pm	20/4/88	Dry
7.	Camp II	4.0 km	7am-4pm	21/4/88	Dry
8.	Trail to Rafflesia site	0.8 km	7am-2pm	22/4/88	Dry
9.	Camp II - Jalan Babi	5.0 km	6am-4.30pm	23/4/88	Dry
10.	Trail to Long Ridge	2.0 km	7am-2pm	24/4/88	Dry
11.	Islet (Sg. Maliau)	0.3 km	7am-12pm	25/4/88	Dry

For night collection, the clearing surrounding the helipad (site 1) was the richest in terms of insect species and specimens as many were attracted to the light-trap, which was a simple white sheet (about 2 sq. yds) with 2 common flourescent tubes above, operated by a generator. The least number was recorded at site 2 where the light trap was set in the midst of primary dipterocarp forest. A number of stick insects were collected by En. William Wong and subsequently identified by En. C. L. Chan.

RESULTS

About 60% of the butterflies were captured along the Sg. Maliau river bank and were mostly of three families: Papilionidae, Nymphalidae and Pieridae. The remaining 40% of the butterflies were caught in the forested area along the trail to Camp II. An interesting bug ?Dysdercus spp. (Hemiptera: Pyrrhocoridae) was common in the leaf litter all along the trail to Camp II. A rather rare moth (?Tineidae) deep orange in colour, and an uncommon scarab beetle (?Popillia) were collected from the light-trap at Site 1.

TABLE 13

PROVISIONAL LIST OF THE INSECTS COLLECTED. UNIDENTIFIED SPECIMENS HAVE BEEN SENT TO THE BRITISH MUSEUM (NATURAL HISTORY), IN LONDON, FOR DETERMINATION.

NO.	ORDER	FAMILY	SPECIES	NO.
1	Lepidoptera (butterflies)	Riodinidae	Laxita orphna laocoon Niceville	1
		Lycaenidae	Allotinus leogoron leogoron Frahstorfer	1
			Arhopala cf. metamuta metamuta Hewitson	1
			Arhopala sp.	1
			Cheritra freja frigga Fruhstorfer	1
			Drupadia ravindra moorei Distant	1
			Jamides zebra lakatti Corbet	1
			Miletus valeus Fruhstorfer	1
			Simiskina phalena phalena Hewitson	1
			Laxita teneta Hewitson	3
			Drupadia theda thesmia Hewitson	
		Papilienidae	Graphium agamemnon agamemnon Linnaeus	2
			Graphium delessertii delessertii Guerin-Meneville	1
			Graphium doson evemonides Honrath	2
			Papilio memnon agenor Linnaeus	1
			Papilo nephelus sunatus Corbet	1
		Pieridae	Appias nero figulina Butler	2
			Dercas verhuelli herodorus Fruhstorfer	1
			Eurema simulatrix tecmessa Nioeville	1
			Saletara liberia distanti Butler	4
		Satyridae	Mycalesis croatis ustulata Distant	5
			Mycalezis sp.	1
		Amathusiidae	Thaumantis noureddin noureddin Westwood	1
		Nymphalidae	Athyma pravara helma Fruhstorfer	1
			Charaxes bernardus crepax Fruhstorfer	1
			Cirrochroa sp.	1
			Cyrestis nivea nivalis C & R Felder	1
			Euthalia iapis pusedz Moore	4
			Euthalia pardalis dirteana Corbet	1
			Euthalia sp.	1
			Moduza procris milonia Fruhstorfer	1

		Prothoe franck uniformis Butler	1
		Tanaecia munda waterstraditi Corbet	3
Lepidoptera (moths)	? Teneidae	Unidentified (1 sp.)	1
	Psychidae	? Dappula sp.	1
		Eumeta cf. variegata Snellen	1
	Thyrididae	Unidentified (1 sp.)	1
	Pyralidae	Botyodes asialis Gn	1
		? Susumia sp.	1
		Glyphodes actorionalis Walker	1
		Glyphodes spp.	2
		? Phostria sp.	1
		Toccolosida rubriceps Walker	2
	Zygaenidae	Cyclosia sp.	1
		Pompelon marginata Guerin	1
	Limacodidae	Cania guichardi	2
		Nirwides basalis	1
		Scopeliodes albipalpalis Hering	1
		Setora nitens Walker	4
		Setothosea asigna van Eecke	1
	Bombycidae	Gunda ochracea Walker	1
		Mustilia dierli	1
		Penicillifera apicalis Walker	2
	Lasiocampidae	Kunugia austroplacida	3
		Lajonquierea jermyi	1
		Odoenstis eretilinea Swinhoe	1
		Arguda insulindiana Lajonquiere	1
	Netodentidae	Benbowia kiriakoffi	1
		Blakeia marmorata Kiriakoff	1
		Dudusa vethi Snellen	1
		Gangarides vardena Swinhoe	3
		Parasinga sp.	1
		Unidentified (3 spp.)	4
	Arctiidae	? Asota sp.	1
		Eilema tetragona Walker	1
		Miltochrista roseororatus Butler	1
		Miltochrista rubricostata Herrich-Schaffer	1
		Miltochrista cornicornutata Holloway	2
		Unidentified (1 sp.)	1
	Lymantriidae	Leucoma impressa Snellen	1
		? Redoa spp. (2 spp.)	2
		Euproctis spp. (2 spp.)	2
		Imaus munda collenettei Toxopeus	1
		Rhypotoses humida Swinhoe	1
	Noctuidae	Carea sp.	1
		Chilkasa falcata Swinhoe	1
		Clanterna cydonia Cramer	1

			? Cosmia sp.	1
			Ercheia cyllaria Cramer	1
			Odontodes sp.	1
			? Lephoptera sp.	1
			Paectes sp.	1
			Plusiodonta sp.	1
			Simplicia rufa occidentalis Holloway	2
			Xenotrachea sp.	1
			Anuga sp.	1
			Unidentified (1 sp.)	1
		Drepanidae	Macrauzata sp.	1
			Unidentified (1 sp.)	1
		Geometridae	Boarmia costaria Guenee	2
			Boarmia subdetractaria Prout	1
			Cleora spp. (2 spp.)	3
			? Hemistola sp.	1
			Hypochrosis binexata Walker	1
			Luxiaria emphatica Prout	3
			Ourapteryx sp.	1
			Pingasa ruginaria Guenee	2
			Problepsis delphiaria Guenee	2
			Tanaorhinus rafflesii Moore	2
			Thalassedes hypocrites Prout	2
			Zythes turbata Walker	1
			Inidentified (2 spp.)	2
2.	Coleoptera	Scarabaeidae	Anomala sp. (2 spp.)	4
			Apogpnia sp.	1
			Catharsius cf. molossus	1
			Holotrichia spp.	2
			Lepidieta stigma	2
			Onthophagus sp. (2 spp.)	8
			Oryctes sp.	1
			Plectrone nigrocoerulea	1
			? Popillia sp.	1
			Unidentified (1 sp.)	4
		Bruchidae	Unidentified (1 sp.)	1
		Lucanidae	Prosopocoilus sp.	1
		Tenebrionidae	Setenis sp.	1
		Carabidae	Mormolyce castelnaudi	1
		Elateridae	Alaus sp.	1
			Lacon sp.	1
			Hemiops nigripes	1
		Endomychidae	Endomychus spp.	2
			? Eumorphus spp.	7
		Cicindelidae	Cicindela aurulenta	1
			? Therates spp.	3
		Cerambycidae	? Anoplophora sp.	1
			? Batocera sp.	1

			? Epepeotes sp.	1
			Parepicedia fimbriata	1
			Rhaphipodus hopei	2
			Trirachys orientalis	2
		Bruchidae	Unidentified (1 spp.)	1
		Harpalidae	? Colpodes sp.	1
		Rhynchophoridae	? Hyposipalus sp.	1
3.	Homoptera	Cicadidae	Platypleura spp.	2
			Unidentified (1 sp.)	1
		Nogodinidae	? Mindura sp.	1
		? Issidae	Unidentified (1 sp.)	1
		? Trepiduchidae	Unidentified (1 sp.)	1
4.	Hemiptera	Pentatomidae	? Lelia spp.	1
			? Poecilocoris sp.	1
		Coreidae	? Molipteryx sp.	1
		Pyrrhocoridae	? Dysdercus sp.	2
5.	Dermaptera	? Labiduridae	? Labidura sp.	3
6.	Orthoptera	? Pachymorphidae	? Lonchodes brevipes	1
			? Baculum sp. (2 spp.)	2
		Blattellidae	Unidentified (1 sp.)	2
		Mantidae	Unidentified (1 sp.)	1
7.	Hymenoptera	Apidae	Xylocopa sp.	1
8.	Phasmiela		Acacus sarawacus	1
			Trigonophasma rubsescens	1
			Paraloxopsis sp.	1
			Staelonchodes sp.	1
			Necrosiia sp. 2	2
			Centema sp.	1
Total:	7	45	159	227

6.2 : FISH

Clive Marsh
Yayasan Sabah

METHODS AND RESULTS

Collections were made at four sites, two on the Sg. Maliau and two on small creeks, as follows:

Site 1. Sg. Maliau, near Base Camp

The riverbed is c. 40 m wide with a mostly rocky bottom. Water level in riffles is less than 70 cm at basal flow, but with occasional pools up to 2 m depth. As described by Mykura (Section 4) at base flow the water is stained brown due to colloidal humic substances and has a mean pH of around 5.4. Conductivity is very low (10-30 s) and neither this parameter nor pH varies greatly during storm events, although sediment loads rise greatly. Sg. Maliau may be categorized as an oligotrophic, blackwater stream but with a heavy sediment load during high water.

Collections were made by hook and line by myself and others on more than two dozen occasions and once for three hours with a trammel net. Only two species were ever caught. Field identification was taken from Inger and Chin (1962) and subsequently confirmed by Datuk Chin Phui Kong:

A catfish, Mystus nemurus (Family: BAGRIDAE). Length 15-25 cm

A cyprinoid, Puntius sealei (Family: CYPRINIDAE). Length 10-15 cm

By both methods the two species were caught in approximately the proportion 6 Mystus to 1 Puntius.

Site 2. Below Sg. Maliau Falls

This site is 3 km downstream of Site 1 and below two sets of falls that could not be surmounted by fish. One day's fishing with hook and line and by trammel net was tried in a deep pool of about 1 ha size. The pH was neutral 7.0 but conductivity (20 s) similar to Site 1. The day's catch was 6 Mystus and 1 Puntius and both species were indistinguishable from those at Site 1.

Site 3. Corridor Creek

This is a tiny transient tributary draining lowland forest close to Base Camp. The stream bed 100 m upstream of the kuala is 5 m wide but at the time of sampling flow was reduced to a trickle between small pools (pH 6.5). Two fish species were caught with bread and a hand net; Puntius sealei (< 10 cm length) was the commonest species, while a few fighting fish, Betta unimaculata (5-10 cm) (family: ANABATIDAE) were also caught. As an incidental observation, a small freshwater crab, Parathelphusa valida (superfamily: GECARCINUCOIDEA) was also common. This recently described species was identified by Dr. Peter Ng (National University of Singapore) and is only known elsewhere from northeastern Sabah and the Gomantong area.

Site 4. Creek at Camp II

This small permanent creek at 950 m elevation flows over exposed sandstone with occasional pools upto 1 m depth at base flow. According to Mykura (Chapter 5), the water is notably more acidic (pH 50) than the other 3 sites. Only Betta unimaculata was found, but this was common and easily caught with a hand net.

DISCUSSION

The most notable finding of the study was the paucity of species caught and their relatively small size of even the largest specimens. Although relatively little time was formally devoted to this study, daily fishing for the pot by expedition members failed to produce evidence of either other species or larger specimens. Yet a river of comparable size in, say, the Danum Valley Conservation Area would yield considerably more species and larger specimens.

A likely explanation for the impoverished fish fauna is that the Sg. Maliau and its tributaries are very poor in nutrients, and support only a restricted food web of algae and invertebrates. In this regard, Sg. Maliau is comparable to other tropical "blackwater" rivers draining mangrove, peat swamp and lowland heath forests (eg. Brasil's Rio Negro, see Junk and Furch, 1985).

Within this generally impoverished environment, it is clear that Mystus nemerus is confined to the larger streams, and Betta unimaculata to small ones, while Puntius sealei occurs in water of all sizes, except apparently the acid streams draining directly from heath forest.

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6.3 : BIRDS

Dennis Yong *(WWF-Malaysia)*, **K. W. Scriven** *(WWF-Malaysia)* and **Andrew Johns** *(Aberdeen University)*

INVENTORY

The survey covered all habitats immediately accessible from the Base Camp (ie. the Sg. Maliau and the disturbed vegetation on its swale and immediate fringes, steep-land mixed dipterocarp forest and hill ridge forest) and the sub-camps (ie. the coniferous transition zone, kerangas and lower montane forest). Information on the birds therein was gathered in two ways : (a) field observation of species identified by sight or sound and (b) conducting a short mist-netting programme. This was supplemented by incidental observations received from Clive Marsh, Joseph Gasis, Anthony Lamb, Nick Brown, Hamish Mykura and William Wong either verbally or entered in the daily "log-book".

In total 175 species of 40 families were noted: 173 breeding or presumed breeding residents of Sabah and 2 seasonal visitors. A complete list of the birds recorded, and their distribution by habitats, is given in Appendix I. This list must be seen as reflecting a sample only of the total number of species to be found in the Basin. Further survey work especially at higher elevations will no doubt add more species to this list.

The survey also produced some interesting discoveries, the most important of which is the sighting of a male Bulwer's Pheasant by A. D. Johns in the coniferous transition zone. This is only the third definite record for Sabah of this little-known Bornean endemic. It is regarded as vulnerable by the International Union for the Conservation of Nature (IUCN), so its presence suggests that the Maliau Basin will have an important role to play in the long-term conservation of this rare and cryptic species in the state especially since neither of the Sabah's two previously known populations, at Tenom and Kalabakan respectively, are protected.

MIST-NETTING PROGRAMME

A short mist-netting programme was conducted using nets erected primarily for catching bats. A total of 310 net/hours was amassed, giving a general impression of the bird fauna of the understorey of the lower dipterocarp forest. Birds captured are listed in Table 14 below together with a comparative sample from unlogged forest in the vicinity of the Danum Valley Conservation Area.

TABLE 14

BIRD SPECIES CAPTURED IN 310 NET/HOUR MIST NETTING PROGRAMMES AT MALIAU BASIN AND DANUM VALLEY

FAMILY	SPECIES	MEAN BODY WEIGHT (g)	NO. OF INDIVIDUALS COLLECTED AT Maliau	Danum
Columbidae	Emerald dove	109.0	0	1
Trogonidae	Scarlet-rumped trogon	36.0	0	1
	Diard's trogon	92.0	0	1
Alcedinidae	Black-backed kingfisher	20.0	0	1

Picidae	Checker-throated woodpecker	92.0	1	0
	Rufous piculet	10.0	0	1
Chloropsidae	Greater green leafbird	6.0	1	0
Pycnonotidae	Grey-cheeked bulbul	41.5	2	3
	Yellow-bellied bulbul	29.5	8	0
	Hairy-backed bulbul	15.5	0	3
Turdidae	Chestnut-naped forktail	31.5	1	1
	White-crowned shama	35.5	3	0
Timaliide	Short-tailed babbler	22.5	1	4
	Ferruginous babbler	23.0	2	0
	Brown fulvetta	14.0	2	5
	White-crowned yuhina	13.0	0	1
	Rufous-crowned babbler	32.0	1	0
	Scaly-crowned babbler	16.0	1	0
	Moustached babbler	19.0	0	2
	Fluffy-backed tit-babbler	21.0	1	0
	Grey-headed babbler	23.0	2	0
Silviidae	Yellow-bellied prinia	9.0	2	0
	Ashy tailorbird	11.0	2	0
Muscicapidae	Large-billed blue flycatcher	18.0	1	0
	Borneon blue flycatcher	17.0	0	2
	Rufous-chested flycatcher	10.5	1	0
	Spotted fantail	13.0	0	1
	Paradise flycatcher	22.0	1	2
	White-throated jungle flycatcher	19.0	6	3
	Rufous-winged flycatcher	18.0	4	3
Dicaeidae	Yellow-rumped flowerpecker	8.0	1	0
	Yellow-breasted flowerpecker	8.0	0	3
Nectariniidae	Purple-naped sunbird	11.0	2	4
	Little spiderhunter	14.0	2	28
Total Individuals			48	70
Total Species			23	20

The species of birds captured at both sites include no rarities and are typical of lowland dipterocarp netting samples in the preponderance of species of babblers (Timaliidae) and understorey flycatchers (Muscicapidae) (eg. Wong, 1985). The species-abundance distribution are revealing, however. The high proportion of rare species in the sample from the Maliau Basin gives a high equitability characteristic of pristine ecosystems, whereas the overdominance of a few or a single species (at Danum Valley the little Spiderhunter Arachnothera affinis) is typical of disturbed systems (eg. Beehler et. al. 1987). This suggests that while the forest at the Maliau Basin is undisturbed, forests at Danum Valley show evidence of interference (a possible past history of cultivation along the Segama River and a close proximity of selective timber logging operations). Why the little spiderhunter, which is a species typically associated with early successional banana/ginger seres, should be so dominant in the avifauna at the Danum site is unclear. Mist net samples show great variation within sites, however, and this may not have been typical of the area as a whole.

Overall, these results suggest that the avifauna of the Danum Valley may well have been modified by human influences; the Maliau Basin may be one of the few remaining areas in Sabah where this is not the case.

HORNBILLS

As a proposed conservation unit within a large area of managed forest, the Maliau Basin may have an important role in the conservation of large wide-ranging species, most notably hornbills Bucerotidae. The density of larger species of these birds is generally less than two individuals per sq. km. in lowland rain forest and still less in upland areas (Kemp and Kemp, 1975; Johns 1987). Individual groups of hornbills may have home ranges as large as 10 km2; the two species of genus Rhyticeros are actually nomadic, ranging many kilometres according to the local abundance of fruit sources.

The comparative abundance of hornbills at the two Yayasan Sabah Conservation Areas is shown in Table 15 below. The Maliau Basin supports fewer species than does the Danum Valley. It lacks both the wrinkled and black hornbill (Rhyticeros corrugatus and Anthracocerous malayanus), although this is to be expected since these are very much lowland forest specialists (Wells, 1985). The abundance of hornbills is also less at the Maliau Basin, perhaps a reflection upon the lesser numbers of those fruit trees exploited by hornbills in the upper dipterocarp forests at Maliau. Alternatively, since few trees of any description were fruiting at the time of the surveys, the hornbills may have been less conspicuous. The nomadic wreathed hornbills Rhyticeros undulatus would possess the ability to leave the Basin area at times of fruit shortages, and this may account for the markedly low abundance of what is often the commonest species in Sabahan forests.

TABLE 15

ABUNDANCE OF HORNBILL SPECIES AT THE MALIAU BASIN AND DANUM VALLEY

SPECIES	MEAN GROUP SIZE	NO. OF ENCOUNTERS WITH HORNBILL GROUPS/10 KM WALKED	
		Maliau	Danum
Wreathed Rhyticeros undulatus	3	0.2	0.6
Wrinkled R. corrugatus	2	0	0.1
Helmeted Rhinoplax vigil	2	0.8	1.3
Rhinoceros Buceros rhinoceros	2	0.3	1.2
Black Anthracoceros malayanus	2.5	0	0.5
White-crowned Berenicornis comatus	3	present	0.1
Bushy-crested Anorrhinus galeritus	7	0.2	0.6

Estimates generated by marked survey routes in unlogged forest at each site.
Data are matched to avoid differences due to seasonality.

Continuing studies of hornbill populations in managed forest in Peninsular Malaysia (Johns, 1987; in press) suggest that the combination of Conservation Area and Production Forest over a large land area, as proposed by Yayasan Sabah in southeast Sabah, may well preserve a viable population of hornbills in the long-term. The maintenance of unlogged forest in the Maliau Basin and at Danum Valley, may be central to ensuring their survival.

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APPENDIX

CHECKLIST OF THE BIRDS OF THE MALIAU BASIN AND THEIR DISTRIBUTION BY HABITATS

Key to the habitats :

A: For aerial foragers not obviously limited by slope or vegetation below.

B: River and riparian - the waters of the Sg. Maliau and the disturbed vegetation on its bank and immediate fringes.

C: Steep-land mixed dipterocarp forest around Base Camp.

D: Hill forest on ridge to Camp II and on the approach to the north rim.

E: Coniferous transition zone between Camp II and the heath forest.

F: Kerangas (heath forest)

G: Lower montane forest on the north rim.

	A	B	C	D	E	F	G
FAMILY: Phalacrocoracidae							
Oriental Darter, Anhinga melanogaster		x					
FAMILY: Ardeidae							
Great-billed heron, Ardea sumatrana		x					
Little Heron, Butorides striatus		x					
FAMILY: Accipitridae							
Crested Serpent-Eagle, Spilornis cheela			x	x	x		
FAMILY: Falconidae							
Peregrine Falcon, Falcon peregrinus							x
FAMILY: Phasianidae							
Crimson-headed partridge, Haematortyx sanguiniceps						x	x
Partridge spp.				x			
Bulwer's Pheasant, Lophura bulwerii					x		
Great Argus, Argusianus argus			x				
FAMILY: Phalaropodidae							
Red-necked Pharalope, Phalaropus lobatus		x					
FAMILY: Columbidae							
Mountain Imperial Pigeon, Ducula badia					x		
Green Pigeon spp.				x			

	A	B	C	D	E	F	G
FAMILY: Psittacidae							
Blue-rumped Parrot, Psittinus cyanurus			x				
Blue-crowned Hanging-Parrot, Loriculus galgulus			x				
FAMILY: Cuculidae							
Hodgson's Hawk-Cuckoo, Cuculus fugax			x				
Indian Cuckoo, Cuculus micropterus			x				
Banded Bay Cuckoo, Cacomantis sonneratii			x				
Plaintive Cuckoo, Cacomantis merulinus			x				
Violet Cuckoo, Chrysococcyx Xanthorhynchus			x				
Drongo Cuckoo, Surniculus lugubris			x				
Black-bellied Malkoha, Phaenicophaeus diardi			x				
Raffle's Malkoha, Phaenicophaeus chlorophaeus			x				
FAMILY: Strigidae							
Brown Wood-Owl, Strix leptogrammica			x				
FAMILY: Podargidae							
Frogmouth spp.				x			
FAMILY: Caprimulgidae							
Malaysian Eared Nightjar, Eurostopodus temminckii			x	x			
FAMILY: Apodidae							
White-bellied Swiftlet, Collocalia esculenta	x						
Swiftlet, Aerodramus spp.	x						
Silver-rumped Swift, Rhapidura leucopygialis	x						
FAMILY: Hemiprocnidae							
Grey-rumped Treeswift, Hemiprocne longipennis					x	x	
Whiskered Treeswift, Hemiprocne comata			x				
FAMILY: Trogonidae							
Red-naped Trogon, Harpactes kasumba			x			x	
Diard's Trogon, Harpactes diardii			x				
Scarlet-rumped Trogon, Harpactes duvaucelii			x				
Orange-breasted Trogon, Harpactes oreskios			x	x	x		
FAMILY: Alcedinidae							
Blue-banded Kingfisher, Alcedo euryzonia				x			
Rufous-backed Kingfisher, Ceyx rufidorsus			x				
Banded Kingfisher, Lacedo pulchella			x				
Rufous-collared Kingfisher, Halcyon concreta				x			
FAMILY: Meropidae							
Red-bearded Bee-eater, Nyctyornis amictus			x	x			
FAMILY: Bucerotidae							
White-crowned Hornbill, Berenicornis comatus			x				
Bushy-crested Hornbill, Anorrhinus galeritus			x				
Wreathed Hornbill, Rhyticeros undulates			x	x	x	x	
Rhinoceros Hornbill, Buceros rhinoceros			x	x			
Helmeted Hornbill, Rhinoplax vigil			x	x			

	A	B	C	D	E	F	G
FAMILY: Capitonidae							
Gold-whiskered Barbet, Megalaima chrysopogon			x	x			
Mountain Barbet, Megalaima monticola				x		x	
Yellow-crowned barbet, Megalaima henricii			x	x			
Blue-eared Barbet, Megalaima australis			x				
Black-throated Barbet, Megalaima eximia				x	x		
Brown Barbet, Calorhamphus fuliginosus			x	x			
FAMILY: Picidae							
Speckled Piculet, Picumnus innominatus				x			
Rufous Piculet, Sasia abnormis			x				
Crimson-winged Woodpecker, Picus puniceus			x				
Checker-throated Woodpecker, Picus mentalis			x				
Buff-rumped Woodpecker, Meiglyptes tristis			x				
Buff-necked Woodpecker, Meiglyptes tukki				x			
Great Slaty Woodpecker, Mulleripicus pulverulentus						x	
White-bellied Woodpecker, Dryocopus javensis				x			
Grey-and-Buff Woodpecker, Hemicircus concretus			x				
Maroon Woodpecker, Blythipicus rubiginosus			x				
Orange-backed Woodpecker, Reinwardtipicus validus			x				
FAMILY: Eurylaimidae							
Dusky Broadbill, Corydon sumatranus			x	x			
Banded Broadbill, Eurylaimus javanicus			x	x			
Black-and-Yellow Broadbill, Eurylaimus ochromalus			x				
Green Broadbill, Calyptomena viridis			x				
FAMILY: Pittidae							
Giant Pitta, Pitta caerulea			x				
Blue-banded Pitta, Pitta arquata				x			
Blue-headed Pitta, Pitta baudi			x				
Banded Pitta, Pitta guajana			x				
FAMILY: Hirundinidae							
Pacific Swallow, Hirundo tahitica	x						
FAMILY: Campephagidae							
Bar-winged Flycatcher-Shrike, Hemipus picatus						x	
Black-winged Flycatcher-Shrike, Hemipus hirundinaceus			x				
Large Wood-Shrike, Tephrodornis virgatus			x	x			
Bar-bellied Cuckoo-Shrike, Coracina striata			x				
Lesser Cuckoo-Shrike, Coracina fimbriata			x				
Fiery Minivet, Pericrocotus igneus					x		
Scarlet Minivet, Pericrocotus flammeus			x				
FAMILY: Chloropseidae							
Green Iora, Aegithina viridissima			x				
Lesser Green Leafbird, Chloropsis cyanopogon			x				
Greater Green Leafbird, Chloropsis sonnerati			x				
Blue-winged Leafbird, Chloropsis cochinchinensis			x				

	A	B	C	D	E	F	G
FAMILY: Pycnonotidae							
Black-and-White Bulbul, Pycnonotus melanoleucos			x				
Grey-bellied Bulbul, Pycnonotus cyaniventris				x			
Puff-backed Bulbul, Pycnonotus eutilotus			x				
Cream-vented Bulbul, Pycnonotus simplex			x			x	
Red-eyed Bulbul, Pycnonotus brunneus			x				
Spectacled Bulbul, Pycnonotus erythropthalmos			x				
Ochraceous Bulbul, Criniger ochraceus					x		
Grey-cheeked Bulbul, Criniger bres				x			
Yellow-bellied Bulbul, Criniger phaeocephalus			x				
Hairy-backed Bulbul, Hypsipetes criniger			x				
Buff-vented Bulbul, Hypsipetes charlottae			x				
Streaked Bulbul, Hypsipetes malaccensis					x		
Ashy Bulbul, Hypsipetes flavala					x	x	
FAMILY: Dicruridae							
Bronzed Drongo, Dicrurus aeneus			x				
Spangled Drongo, Dicrurus hottentotus					x		
Greater Racket-tailed Drongo, Dicrurus paradiseus			x				
FAMILY: Oriolidae							
Dark-throated Oriole, Oriolus xanthonotus			x				
Asian Fairy Bluebird, Irena puella							
FAMILY: Corvidae							
Crested Jay, Platylophus galericulatus			x				
Slender-billed Crow, Corvus enca					x		
FAMILY: Sittidae							
Velvet-fronted Nuthatch, Sitta frontalis			x				
FAMILY: Timaliidae							
Black-capped Babbler, Pellorneum capistratum			x				
Temminck's Babbler, Trichastoma malaccense			x				
White-chested Babbler, Trichastoma rostratum		x					
Ferruginous Babbler, Trichastoma bicolor			x				
Horsfield's Babbler, Trichastoma sepiarium			x				
Moustached Babbler, Malacopteron magnirostre			x				
Sooty-capped Babbler, Malacopteron affine			x				
Scaly-crowned Babbler, Malacopteron cinereum			x				
Rufous-crowned Babbler, Malacopteron magnum			x				
Chestnut-backed Scimitar Babbler, Pomatorhinus montanus			x	x			
Striped Wren-Babbler, Kenopia striata			x				
Eye-browed Wren-Babbler, Napothera epilepidota					x		
Rufous-fronted Babbler, Stachyris rufifrons			x				
Grey-throated Babbler, Stachyris nigriceps				x			
Grey-headed Babbler, Stachyris poliocephala			x				
Chestnut-rumped Babbler, Stachyris maculata			x				
Black-throated Babbler, Stachyris nigricollis			x				
Chestnut-winged Babbler, Stachyris erythroptera			x				
Striped Tit-Babbler, Macronous gularis		x	x				
Fluffy-backed Tit-Babbler, Macronous ptilosus			x				
Sunda Laughingthrush, Garrulax palliatus							x

	A	B	C	D	E	F	G
Black Laughingthrush, Garrulax lugubris							x
Chestnut-capped Laughingthrush, Garrulax mitratus							x
White-browed Shrike-Babbler, Pteruthius flaviscapis							x
Brown Fulvetta, Alcippe brunneicauda			x				
Chestnut-crested Yuhina, Yuhina everetti						x	x
White-bellied Yuhina, Yuhina zantholeuca			x	x			
FAMILY: Turdidae							
White-browed Shortwing, Brachypteryx montana							x
White-rumped Shama, Copsychus malabaricus			x	x			
Rufous-tailed Shama, Copsychus pyrropygus			x	x			
Chestnut-naped Forktail, Enicurus ruficapillus			x				
White-crowned Forktail, Enicurus leschenaulti			x				
FAMILY: Sylviidae							
Flyeater, Gerygone sulphurea			x	x	x	x	
Yellow-bellied Warbler, Abroscopus superciliaris							x
Mountain Leaf-Warbler, Phylloscopus trivirgatus							x
Dark-necked Tailorbird, Orthotomus atrogularis			x				
Rufous-tailed Tailorbird, Orthotomus sericeus		x	x				
Yellow-bellied Prinia, Prinia flaviventris		x					
FAMILY: Muscicapidae							
Grey-chested Flycatcher, Rhinomyias umbratilis			x				
Chestnut-tailed Flycatcher, Rhinomyias ruficauda					x		
Dark-sided Flycathet, Muscicapa sibirica			x				
Verditer Flycatcher, Muscicapa thalassina			x	x			
Indigo Flycatcher, Muscicapa indigo					x		
Rufous-chested Flycatcher, Ficedula dumetoria				x			
Little Pied Flycatcher, Ficedula westermanni							x
White-tailed Flycatcher, Cyornis concreta			x				
Bornean Blue Flycatcher, Cyornis superba			x				
Sunda Blue Flycatcher, Cyornis caerulata			x				
Grey-headed Flycatcher, Culicicapa ceylonensis			x	x			
White-throated Fantail, Rhipidura albicollis							x
Spotted Fantail, Rhipidura perlata			x	x			
Black-naped Monarch, Hypothymis azurea			x				
Maroon-breasted Flycather, Philentoma velatum			x	x			
Rufous-winged Flycatcher, Philentoma pyrhopterum			x				
Asian Paradise Flycatcher, Terpsiphone paradisi			x				
FAMILY: Cracticidae							
Bornean Bristlehead, Pityriasis gymnocephala					x		
FAMILY: Sturnidae							
Hill Myna, Gracula religiosa					x		
FAMILY: Nectariniidae							
Purple-naped Sunbird, Hypogramma hypogrammicum			x				
Crimson Sunbird, Aethopyga siparaja						x	
Little Spiderhunter, Arachnothera longirostra			x				
Thick-billed Spiderhunter, Arachnothera crassirostris				x			
Long-billed Spiderhunter, Arachnothera robusta					x		

	A	B	C	D	E	F	G
Spectacled Spiderhunter, Arachnothera flavigaster				x			
Yellow-eared Spiderhunter, Arachnothera chrysogenys				x			
Grey-breasted Spiderhunter, Arachnothera affinis				x			
FAMILY: Dicaeidae							
Scarlet-breasted Flowerpecker, Prionochilus thoracicus							x
Yellow-breasted Flowerpecker, Prionochilus maculatus			x				
Yellow-rumped Flowerpecker, Prionochilus xanthopygius			x				
Yellow-vented Flowerpecker, Dacaeum chrysorrheum						x	
Orange-bellied Flowerpecker, Dicaeum trigonostigma						x	
Black-sided Flowerpecker, Dicaeum monticolum						x	
Scarlet-backed Flowerpecker, Dicaeum cruentatum						x	
FAMILY: Zosteropidae							
Black-capped White-eye, Zosterops atricapilla							x
Pygmy White-eye, Oculocincta squamifrons						x	
FAMILY: Ploceidae							
Dusky Munia, Lonchura fuscans		x					

6.4 : MAMMALS

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INTRODUCTION

There is limited scope for any detailed studies on mammals during a short period, especially on rugged terrain in the interior of Borneo, a region where population density of mammals is generally low in comparison to tropical moist forests elsewhere. The survey reported here concentrated primarily on bats (AJ), primates (AJ and JG), rodents (JP) and large herbivorous mammals (JP and JG).

METHODS

(1) Forty cage traps suitable for catching treeshrews and small rodents were brought to the Maliau Basin. Bait used was dried salt fish and dried, roast coconut pieces; fresh whole bananas, a preferred bait, were not brought because of weight limitations and their perishable nature. The traps were set out at sites typically used by small mammals, notably loops in liana stems, fallen trees and pathways on the forest floor (Table 16). In total, there were 224 trap-nights in upland dipterocarp forest (520-610 m a.s.l.); 27 trap-nights in hill dipterocarp forest (850-990 m a.s.l.); 15 trap-nights in conifer forest (990-1050 m a.s.l.) and 18 trap-nights in heath forest. Animals caught in the traps were identified by visual inspection and released either immediately or the following day.

TABLE 16

SMALL MAMMAL TRAPPING SCHEDULE AT MALIAU BASIN

TRAPPING PERIOD	TRAP ARRANGEMENT	TOTAL NO. OF TRAPS SET
Apr 26-27	16 east/14 south-west of Base Camp	30
Apr 27-28	16 east/22 south-west of Base Camp	38
Apr 28-29	as Apr 27-28	38
Apr 29-30	as Apr 27-28; morning, collect 20, close 18	38
Apr 30-May 1	3 near Camp II; 6 above Camp II in upper dipterocarp forest; 5 in conifer forest; 6 in heath forest	20
May 1-2	as Apr 30-May 1	20
May 2-3	as Apr 30-May 1; morning, collect all 20 traps	20
May 3-4	35 south-west of Base Camp	35
May 4-5	35 south-west of Base Camp	35
May 5-6	10 south-west of Base Camp	10

(2) Line transect surveys were carried out along a trail 8 km in length which included Rambutan Ridge and the parallel ridge on the southeast side of Corridor Creek, joined by the southern end of Long Ridge. The trail was marked at 100 m intervals. Most surveys were done between 0800 and 1500 hours. This period is later and longer than most similar surveys in tropical forests because early morning mist made visibility poor, because many mammals were active late in the morning in the Maliau Basin (as the sun became visible over the elevated horizon), and because the trail length was unusually long. Walking speed was 1 km/hour.

(3) A nocturnal mist-netting programme was conducted to sample the bat fauna, nets being established in several locations near Camp I and along the trail to Camp II.

(4) Casual observations were made daily during the daylight hours, and with the aid of a headlamp after dark, by JG (April 14 - May 5), AJ (April 18-25) and JP (April 26 - May 5). Binoculars were carried at all times. Areas visited included the ridge to the west and north-west of Base Camp, Rambutan Ridge, Corridor Creek, the southern end of Long Ridge, the Maliau Falls, the trail to Camp II, the trail from Camp II to Jalan Babi, and the forest beyond the heath forest plateau, nearly to the southern rim of the Maliau Basin. Additional information was obtained from specialists in other disciplines who traversed areas further from the Base Camp.

RESULTS AND DISCUSSION

Moonrat (family Erinaceidae). The odour of moon rats (Echinosorex gymnurus) was detected in the gulleys west of Base Camp.

Treeshrews (family Tupaiidae). AJ saw a common treeshrew (Tupaia glis) twice (one had eaten most of a ferruginous babbler from a mistnet-line near to Base Camp) and one large treeshrew (T. tana) at 550 m on the Main Trail. JG saw one large treeshrew. JP glimpsed treeshrews (probably common treeshrews) twice in the dipterocarp forest on moderate topography. None were caught in the cage traps. Only rarely are treeshrews not caught at all in a total of more than 200 trap-nights. The use of non-preferred bait does not permit direct comparison with results from elsewhere, but treeshrew population density appears to be relatively low in the study area, in comparison with similar habitat elsewhere.

Bats. Nine species of bats were captured, all insectivores (Table 17). None of the fruit bats which are generally common in forest habitat elsewhere (eg. the short-nosed bat, Cynopterus brachyotis and the spotted-winged fruit bats, Balionycteris maculata) were captured, but undoubtedly they do occur in the region. Almost all bats were captured either at dusk or dawn, implying that they were moving from or to their roosts in the understorey. The sheath-tailed bats were actually netted in front of a roost under an overhanging cliff. Very few bats were observed in flight in the forest understorey, although some were seen feeding over the Maliau River. One of the bat records (the least horseshoe bat) is the first for Sabah and only the second for Borneo.

TABLE 17

BATS MIST-NETTED IN THE MALIAU BASIN

SPECIES	MEAN BODY WEIGHT (g)	NO. OF INDIVIDUALS
lesser sheath-tailed bat * Emballonura monticola	7.0	2
greater sheath-tailed bat * E. alecto	7.0	3
Bornean horseshoe bat Rhinolophus borneensis	11.5	5
least horseshoe bat R. pusillus	10.0	1
lesser woolly horseshoe bat R. sedulus	10.0	2
trefoil horseshoe bat R. trifoliatus	16.5	5
diadem roundleaf bat Hipposideros diadema	45.0	1
fawn roundleaf bat H. cervinus	9.5	1
small woolly bat Kerivoula intermedia	3.5	1

* captured at daytime roost

The small numbers of bats caught, with no fruit bats, may have been due to the dryness of the understorey and lack of fruiting plants during the netting period. Despite the paucity of fruiting trees in the Maliau Basin, trees on an island in the Maliau River near to Base Camp were used as a roost by large numbers (estimated at between 200 and 400) of flying foxes, Pteropus vampyrus, throughout the survey period. These possibly fed outside the Basin, returning to roost each morning, often not until at least 1000 hours.

Primates. No nocturnal primates were recorded, despite nocturnal surveys and the setting of mist nets, but this does not prove their absence. The red leaf monkey (Presbytis rubicunda), grey leaf monkey (P. hosei) and Bornean gibbon (Hylobates muelleri) were the commonest primates in the Maliau Basin, and this is usual for dipterocarp forests in Borneo. However, the abundance of all three species was unusually high in the line transect area. This is demonstrated by a comparison with Danum Valley, one of Sabah's richest known primate sites (Table 18). AJ's line transect surveys, analysed by Fourier series analysis of group sightings, revealed a total primate group density of 9.8 groups per sq. km. in the Maliau Basin survey area at least twice that of most other areas surveyed in Sabah. JG's data, analysed by Webb's method (Burham et al, 1980), and counting individual primates rather than groups, suggest an even higher density of primates (Table 19). The abundance of leaf monkeys is especially surprising, as there is no obvious indication of abundant food (typically, seeds and young leaves, especially of legumes) for these animals. Possibly the high population densities are actually localised to the transect area, and not indicative of primate abundance throughout the Basin. None of the primates were observed or heard above the dipterocarp zone, either in conifer or heath forest.

TABLE 18

ESTIMATED PRIMATE GROUP DENSITIES IN THE MALIAU BASIN & DANUM VALLEY

SPECIES	MEAN GROUP SIZE	POPULATION DENSITY (Groups/sq.km.) Maliau Basin	Danum Valley
orang-utan	2	0	0.3
Bornean gibbon	3	3.9	1.6
red leaf monkey	7	3.7	1.8
grey leaf monkey	7	1.5	0.3
silvered leaf monkey*	6	0	0.1
proboscis monkey*	?	+	+
long-tailed macaque*	25	+	0.1
pig-tailed macaque	40	0.7	0.8

Population densities calculated from AJ's data by Fourier Series analysis (Burnham et al, 1980).

Species
marked with * are characteristically associated with riverine forest (although not invariably so). ? = highly variable. + = present. Danum Valley data, obtained and analysed in the same way as the Maliau Basin data, are extracted from unpublished records of AJ.

TABLE 19

ESTIMATED POPULATION DENSITIES OF SOME MAMMAL SPECIES IN THE MALIAU BASIN

SPECIES	*POPULATION DENSITY INDIVIDUALS/SQ. KM.	TOTAL NO. SEEN ON TRANSECT	OA	TA
large treeshrew	1.0	1	7	1
Bornean gibbon	32.6	25	18	8
red leaf monkey	37.9	50	24	14
grey leaf monkey	7.4	15	25	21
pig-tailed macaque	2.7	8	30	28
giant squirrel	2.2	3	20	14
Prevost's squirrel	11.1	2	2	1
horse-tailed squirrel	0.7	1	39	14
shrew-faced ground squirrel	2.6	1	12	4
teludu	2.6	2	10	8
mongoose	7.1	2	12	3
mousedeer	3.0	3	12	11

barking deer	15.4	13	19	9
sambar deer	2.2	2	14	10
bearded pig	8.2	6	22	8

* Population density calculated from JG's data by Webb's method (Burnham et al, 1980).

OA mean distance in metres between observer and animal.

TA mean distance in metres between animal and nearest distance from the trail.

Population structure within both leaf monkey species seemed to be typical of that observed elsewhere in Sabah. A solitary male red leaf monkey was seen near the Maliau Falls; one group observed clearly contained one adult male, three adult females, a juvenile and reddish infant; three groups contained at least five or six animals, and at least two contained a whitish infant. A group of six grey leaf monkeys, including infant, was seen by JG. Groups of red and grey leaf monkeys were twice seen in close proximity, once feeding together on newly-ripe Lithocarpus fruits. Gibbons were heard throughout dipterocarp forest in the study area and at least seven groups were seen. Most groups appeared to contain three individuals, and only two clearly contained a small individual dependent on an adult. Elsewhere, gibbon groups typically contain 3 or 4 individuals, including one dependent infant.

The pig-tailed macaque (Macaca nemestrina) is a wide-ranging species, generally occupying home ranges of at least 3 sq. km., and is rarely common anywhere. A group of at least twenty individuals was seen by JP at the southern end of Long Ridge. The riverine forest along the Maliau River (not surveyed by line transect) contained a large population of long-tailed macaques (M. fascicularis) but no silvered leaf monkeys (P. cristata).

A small group of proboscis monkeys (Nasalis larvatus) was seen once on April 20, 1988, at 650 m on the Main Trail by Mr. Anthony Lamb and others. One immature male was found on the ground, dead with one arm missing and severe bite marks around the thighs. Two other individuals were heard calling in the tree canopy nearby; they were not seen clearly, but appeared not to be mature males. A short distance away, a proboscis monkey was seen to chase a grey leaf monkey to the ground. The proboscis monkeys were not seen again during the expedition. This species is typically an animal of lowland and coastal riverine and swamp forests. The Maliau Basin is approximately 600 km upstream from the coast. It would seem likely that this was a wandering group, far from the normal species range, and not evidence of the presence of this species throughout the upper Kuamut region. There are reports of such small groups or individuals seen occasionally far into the interior hill ranges of Sarawak (E. Bennett, personal communication).

The presence of orang-utans (Pongo pygmaeus) can be detected readily by looking for signs of their nests. There was no evidence of the presence of orang-utans in the Maliau Basin. No expedition member saw any signs of this species, and Mr. Steven Kolis, who has worked extensively in the forest in this region of Sabah noted that the nearest signs of orang-utans that he had ever seen were on the lower half of the Kuamut River. Two members of the four-man expedition which traversed the Maliau Basin in May 1986 (Jon Rees and Paul White) informed JP that they had seen a single large orang-utan on Long Ridge. Their description does not allow for any confusion with red leaf monkeys and must be accepted as correct. As occurs with proboscis monkeys, there are records of large, solitary orang-utans from parts of Sabah and Sarawak outside the normal range of this species, and it is likely that the animal seen in 1986 was one such individual.

The unusual, single records of both proboscis monkeys (1988) and orang-utan (1986) in the Maliau Basin are of importance in demonstrating that the presence of an animal in a particular region cannot necessarily be interpreted as evidence of the presence of a breeding population of that species in that region. The point should be noted especially by those involved in the establishment of conservation areas in the forests of South East Asia. It has been hypothesised that a lack of one or more essential minerals in the environment may limit the distribution of orang-utans and other large mammals in the hill ranges of interior Borneo (Payne, 1988).

Squirrels (family Sciuridae). Giant squirrels (Ratufa affinis) were common (seen four times and heard calling three times by JP; and seen three times on the transect by JG), and all records were in dipterocarp forest, up to just below the conifer zone. One individual was seen resting near to its nest at 0715 hours, as if it has recently emerged. Giant squirrels in the Kerau Wildlife Reserve, Peninsular Malaysia typically become active well after dawn, and later than most diurnal mammal species (Payne, 1979); possibly this is a characteristic of the genus.

Prevost's squirrels (Callosciurus prevostii) were seen twice, with one record just below the conifer zone. As elsewhere, this species appears to occur at relatively low population density in hill dipterocarp forests, in comparison to lowland forests, while the giant squirrel appears to occur at rather similar abundance from sea level up to the highest parts of the dipterocarp zone. Just above Camp II, two individuals of an unidentified tree squirrel species were seen in the branches of a tall tree. Belly colour appeared to be buffy-grey and no lateral stripes were visible, but they were not members of the genus Sundasciurus; probably they were the Bornean black-banded squirrel (C. orestes; Payne et al, 1985). In the upper dipterocarp forest, not far below the conifer zone, many individuals of the red-bellied sculptor squirrel (Glyphotes simus) were seen daily feeding in the crown of a strangling fig tree on a steep hill slope below the ridge-top trail. At least ten individuals were present, probably many more, and at least several individuals were active at any one time throughout the daylight hours. This strange squirrel (indeed, the genus) is unique to the hill and mountain ranges of northern Borneo, and nothing has previously been recorded of its ecology. It is characterised by upper incisor teeth which are, a) concave (not convex) on the front surface, b) relatively large for an animal of such small body size (total length, including tail, when flat, less than 20 cm) and c) splayed outwards, away from each other, in an inverted V shape. The function of such oddly-shaped teeth has remained a mystery, although it has been assumed that they are adapted to an unusual dietary specialisation. Observations made on the individuals seen in the Maliau Basin suggest an answer to the mystery. The most commonly-observed activity of these squirrels in the crown of the strangling fig was the following. Individuals hung by their hind feet from the petiole of a fig leaf or from the stem near to a leaf. The leaves were rather large - perhaps 15-18 cm long. The front feet grasped each side of the leaf, about two-thirds the way along from the petiole, such that the squirrel was suspended below the undersurface of the leaf. The squirrel then ran its slightly-open mouth along the mid-rib of the underside of the leaf, from leaf base towards the tip of the leaf, apparently with the leaf mid-rib between the splayed upper incisor teeth. Thus the teeth skimmed along the mid-rib and adjacent leaf blade. No insects were visible, but there were leaf-eating insect holes in the fig leaves, and it would seem likely that these squirrels were feeding on small insects on the underside of the fig leaves.

A third unusual sighting at this locality above Camp II was recorded by Mr. A. Lamb of the black-eared pigmy squirrel Nannosciurus melanotis. This was not confirmed by another expedition member, but if true, it represents a new species record for Sabah. This squirrel is widespread in southern parts of Borneo and has been recorded as far north as Gn. Dulit in Sarawak.

JG saw one horse-tailed squirrel (Sundasciurus hippurus). Many Low's squirrels (S. lowii) were seen by AJ and JP, especially around Camp II. Plain pigmy squirrels (Exilisciurus exilis) were seen several times, mainly on flat land near to Base Camp. One striped ground squirrel (Lariscus species) was seen by AJ near a riverbank. JG saw a shrew-faced ground squirrel (Rhinosciurus laticaudatus) on two consecutive days taking nesting material into a hole near the base of a large tree, on the east side of the Maliau river, near to Base Camp. A tufted ground squirrel (Rheithrosciurus macrotis) was seen by JP, leaping along on the ground on a broad ridge in the conifer forest at 1110 hours on May 3. This spectacular Borneo endemic, with no close relatives anywhere else in the world, is naturally rare where it occurs; it was the only mammal other than a barking deer observed in the conifer forest. Another individual of the same species was seen by several other observers during the first half of the expedition at about 600 m a.s.l. feeding on fruits in the canopy of a Canarium spp. tree. No flying squirrels were reported during the expedition.

Rats (family Muridae). The following forest rats were caught in cage traps, all in dipterocarp forest, and the highest just above Camp II, below 950 m a.s.l.; one immature brown spiny rat (Maxomys rajah), identified by its brown dorsal streak; three immature spiny rats of uncertain species (either brown, or possibly red spiny rats, M. surifer); one whitehead's rat (M. whiteheadi); and one long-tailed mountain rat (Niviventer rapit). The immature spiny rats were all caught in widely-spaced localities. The Whitehead's rat had an entirely buffy-coloured venter, but was distinguished from the small spiny rat (M. baeodon) by its soft, sparse spines. We have followed specialists in Malesian rat taxonomy (eg. Guy Musser, personal communication; Medway, 1977) in recognising six Bornean members of the genus Maxomys. The variation in external morphology of this group, with some seemingly intermediate forms, has led both JP and R. Stuebing (vertebrate biologist at UKM Sabah) to question whether there are six or more species. In the absence of definite evidence to refute the conclusions of previous authors, however, it is assumed that there are six species exhibiting wide variation, and possibly some hybridisation.

The numbers of rats caught during this study (6 in 251 trap-nights in dipterocarp forest) is much lower than is usual for this habitat. A number of factors may be involved, notably the use of bait other than bananas. Possibly, rat population density is actually low in the Maliau Basin. JP has consistently noted relatively high catch rates during dry periods and low catch rates during rainy periods, both in Sabah and in Peninsular Malaysia. During this study, traps were set during rather rainy weather after a long dry spell. Stuebing (personal communication) has not experienced this effect, however, and notes that the reverse has sometimes been true during his trapping sessions. Chance plays a part; in all studies of small Malaysian forest mammals, observers note that many more individuals are seen or caught on some days than on other days, even though weather conditions are identical.

Carnivores. Claw marks of a sun bear (Helarctos malayanus) were seen in dipterocarp forest on a tree on the east side of Long Ridge (Lim P S), but there were no other records of this species. Other carnivores recorded were: yellow-throated marten (Martes flavigula; three individuals on the ground 1 km from Base Camp, C. Marsh; and one 400 m above Camp II); teludu (Mydaus javanensis; two individuals together on the line transect, JG); Malay civet (Viverra tangalunga; one male made repeated visits to Camp II to scavenge food remnants, and another was seen near Base Camp); banded palm civet (Hemigalus derbyanus; one 200 m along the Main Trail, AJ); collared mongoose (Herpestes semitorquatus; one crossing the river near Base Camp, C. Marsh); two mongooses (species uncertain; JG); clouded leopard (Neofelis nebulosa; one 400 m along the Main Trail, AJ).

Rhinoceros. Footprints and dung of the Sumatran rhinoceros (Dicerorhinus sumatrensis) were found at two sites within the Corridor Creek drainage, once near the ridge trail towards Camp II, and at three sites in the heath forest. The four separate signs seen by JP were many weeks old, possibly several months, too old for reliable measurements, but recent footprints in Corridor Creek were measured by JG at 21 cm wide and 26 cm long, typical for this species. A small sample of dung found and collected by the 4-man May 1986 expedition about half way up Long Ridge was shown to JP and identified as definitely belonging to a Sumatran rhino or Malayan tapir (fossil evidence proves that the latter species once occurred in Borneo, but there have been no reliable reports in recent historical times). Presence of tapir was suspected because footprints near the dung were reported by P. White as "small". The footprints seen in 1988 were of rhino, not tapir, and so there is no evidence to suggest that tapirs may be extant in Borneo. Dung found during the 1988 expedition in the heath forest included leaf and twig fragments of heath forest plants, indicating that the rhino(s) had fed in this habitat and not merely passed through. Apart from (possibly) barking deer, this appears to be the only mammal species which feeds in heath forest in the Maliau Basin.

Despite the great human activity in the Maliau Basin during the 1988 expedition, the only signs of rhino found were within two general areas, and no fresh signs were seen. No wallows were found. In other areas where rhinos are present and known to be relatively abundant (eg. Danum Valley and Tabin Wildlife Reserve core area) equivalent survey effort would have revealed many more signs of rhinos, including fresh signs in several localities. Clearly, rhinos occur in the Maliau Basin, but only in relatively small numbers, at least in the areas covered. This finding is of considerable interest. Prior to the 1988 expedition, it would have been predicted either that rhinos are absent from the Basin (if ecological factors preclude their existence) or that the species would exist at relatively high population density (because of the low incidence of hunting in this remote region, as compared to more accessible regions in eastern Sabah). Instead, the species is present, seemingly at lower population density than in, say, Tabin Wildlife Reserve, where illegal hunting has continued for many years. This finding suggests either that ecological factors restrict population density of rhinos in a graded fashion, or that illegal hunting has had a much greater impact in the Maliau Basin than previously realised. The limited available knowledge is equivocal. The discovery during this expedition of two fragments of glazed pottery (probably a celadon dish) below the topsoil within the Basin, not on any route between human settlements, proves an old human presence. It is unlikely that any settlement existed within the Basin, because of its extreme remoteness and rugged topography. For the same reasons, it is also unlikely that the people who brought the dish into the Basin were collecting damar or rotan. The only items of great value within the Basin for collectors of forest produce are gaharu wood and rhino horn, both of which are believed to have been exported from Brunei from the 7th century AD. A large semi-permanent camp of Iban rhino hunters was reported to exist in the upper reaches of the Kuamut River in the mid 1960s (W. Meijer, unpublished report in Forest Department file), not far from or conceivably within the Maliau Basin. During the present expedition, unexpected evidence of human activity was discovered on both sides of Long Ridge by D. Yong, Tungah Surat, H. Mykura, Lim P. S. and Saw L. G. They found small (one or two man) camps, repeated identical carvings on trees (like a Z or M shape) and a wire noose trap. It was reckoned that the signs were more than one but no more than several years old. These are not the signs of geological explorations or casual expeditions, but of rhino hunters. Most plausibly, the hunters entered the Basin from the western side, when logging operations in 1986-87 brought road access almost to the Basin's rim. In total, the observations could indicate a long history of periodic rhino hunting within the Basin over many centuries. With the almost complete isolation of the Basin by its steep peripheral escarpments, and little chance of immigration by rhinos from elsewhere, long periods of intensive localised hunting could conceivably have almost exterminated a previously large rhino population. In the absence of any objective data, however it is equally plausible that hunting pressure in the Basin has been similar to that elsewhere, and that rhino numbers are limited by productivity of food plants and/or by availability of essential minerals.

Other large herbivores. No signs of the presence of either elephants (Elephas maximus) or banteng (wild cattle or tembadau, Bos javanicus) were found within the Maliau Basin, and it may be assumed that neither species occurs there. Both species of mousedeer are present; the lesser (Tragulus javanicus) and the greater (T. napu). Individuals of the lesser were seen on flat land near to Base Camp, feeding at night on fallen Lithocarpus acorns, and one individual was caught by hand by Alen C. H. Greater mousedeer were seen on Rambutan Ridge, one feeding on fallen acorns. The coloration of both mousedeer species was very similar, heavily suffused with black, and darker than typical for other regions of Sabah. The sambar deer (Cervus unicolor) was present but rare, with only two clear sightings recorded, both females (JG). Barking deers were heard and seen commonly throughout the area by many observers, from near to Base Camp, up to and including the heath forest. JP had never previously seen such great numbers, except in old logged forest in the Bakapit area, on the south side of the Dent Peninsula. This deer exhibited the greatest altitudinal range of any mammal recorded in the Basin. JG saw an average of about two barking deer during each line transect walk, and estimated a population density of 15.4 individuals/sq. km. Of particular interest was to determine which species is/are present. Payne et al (1985) accept the conclusion of Groves and Grubb (1982) that there are two species of barking deer extant in Borneo, the common red (Muntiacus muntjak) and the Bornean yellow (M. atherodes). The male of the former has larger, rough, branched antlers, while that of the latter has slender, smooth, unbranched antlers. Some zoologists reject the supposition that these are two species, and believe that there are two forms of the same species, the phenotype depending on habitat or other factors. JP saw four barking deer, all clearly conforming with typical M. muntiacus in size and colour, but in no case were antlers seen. Other observers noted that the barking deer seen by them were rather large and dark reddish in colour. JG reported seeing a large, reddish barking deer with unbranched antlers, intermediate between the two known forms. Apart from this puzzling observation, it seems most likely that the common red barking deer is present in the Maliau Basin.

Evidence and sightings of bearded pigs (Sus barbatus), adult and immature, were reported from many areas, including the heath forest. JP saw a group of two adults and six juveniles, about one-third grown, feeding on falling acorns under the Lithocarpus trees in which groups of red and grey leaf monkeys were feeding together. On another occasion, a group of three pigs of different sizes were seen travelling in single file along a hillside. JG twice saw groups of three individuals. AJ saw pigs, possibly in much larger numbers, moving across Corridor Creek at night. The clear path through the heath forest was named Jalan Babi, because it was undoubtedly formed and maintained by large numbers of pigs migrating into and out of the Basin in search of fallen fruits as food. There was no evidence of a recent migration of pigs in the Basin, but the species is evidently widespread, common and resident. Bearded pig nests, probably 2-3 months old, were recorded. The abundance of Fagaceae trees within the Basin probably contributes both to the sustenance of a resident population and to the attraction of the Basin to pigs from elsewhere when surrounding forest regions at lower altitude offer inadequate food.

CONCLUSIONS

(1) Forty-seven species of mammals were recorded during the three-week survey period in the Maliau Basin. The Basin supports a mammal fauna typical of the interior hill ranges of Sabah. Preservation of the Basin under natural forest cover will serve to maintain this fauna in a natural state unrivalled elsewhere within the State.

(2) No mammal studies were done at high altitude in the northern half of the Basin. Two mammal species characteristic of middle altitudes on the mountain ranges of northern Borneo (the Bornean black-banded squirrel and red-bellied sculptor squirrel) occur between about 760 m and 915 m a.s.l. in the southern half of the Basin. All other mammals recorded are wide-ranging species typical of dipterocarp forests from sea level to about 915 m a.s.l.

(3) Only three mammal species were recorded in the heath forest: bearded pig (probably passing through), barking deer and Sumatran rhinoceros (which feeds there). Only barking deer and tufted ground squirrel were recorded in the conifer forest. All other mammals were recorded only within dipterocarp forest. Probably no mammals are resident exclusively within heath forest or conifer forest.

(4) Small mammals (treeshrews, bats and rats) appear to exist at low population densities in comparison to similar forest elsewhere in Sabah. However, the low catch rate of these taxa during this expedition may be due entirely to chance factors.

(5) Population densities of leaf monkeys and gibbons were very high in the area surveyed, in comparison to sites elsewhere in Sabah. Proboscis monkeys were seen, but there is no evidence of a resident breeding population of this species within the Basin. No evidence was found of the presence of orang-utans and it is concluded that there is no breeding population within the Basin.

(6) Both sun bear and clouded leopard, Sabah's largest carnivores, occur within the Maliau Basin.

(7) No evidence was found of the presence of either the Asian elephant or banteng.

(8) The Sumatran rhinoceros occurs within the Basin but, in the area surveyed at least, population density is lower than in some parts of eastern Sabah. There is evidence of periodic hunting of rhinos in the Basin from centuries past up to the present time.

(9) The Maliau Basin is probably a seasonally important source of food (Fagaceae and Dipterocarpaceae fruits) to bearded pigs, both those resident within the Basin and those migrating from outside. In this respect, conserving the forest in the Basin will assume increasing importance in the future, as forest is logged elsewhere in the region.

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APPENDIX

CHECKLIST OF MAMMAL SPECIES RECORDED IN THE MALIAU BASIN

moonrat
Sunda shrew
common treeshrew
large treeshrew
flying fox
lesser sheath-tailed bat
greater sheath-tailed bat
Bornean horseshoe bat
least horseshoe bat
lesser woolly horseshoe bat
trefoil horseshoe bat
diadem roundleaf bat
fawn roundleaf bat
small woolly bat
red leaf monkey
grey leaf monkey
proboscis monkey
long-tailed macaque
pig-tailed macaque
Bornean gibbon
giant squirrel
Prevost's squirrel
Bornean black-banded squirrel
red-bellied sculptor squirrel
horse-tailed squirrel
Low's squirrel
plain pigmy squirrel
? black-eared pygmy squirrel
striped ground squirrel
shrew-faced ground squirrel
tufted ground squirrel
brown spiny rat
Whitehead's rat
long-tailed mountain rat
sun bear
yellow-throated marten
teludu
Malay civet
banded palm civet
collared mongoose
clouded leopard
Sumatran rhinoceros
lesser mousedeer
greater mousedeer
common red barking deer
sambar deer
bearded pig

? indicates uncertain identification

SECTION SEVEN - MANAGEMENT

Clive Marsh
Yayasan Sabah

PAST AND PRESENT LAND USE

The Maliau Basin is presently one of the least disturbed ecosystems in Malaysia, or indeed anywhere in South-east Asia. The 7-day reconnaissance visit organised by Yayasan Sabah in 1982 found no signs of old trails, camps or other evidence of visitation. This impression of a "Lost World" was, in fact, an illusion since the pottery fragment found in 1988 can only have come from much earlier wanderers and Payne et al (Section 6.4) believed that rhinos have probably been hunted irregularly in the Basin for a long time past. Nevertheless, apart from rhino poaching, the area remains almost uniquely free of human disturbance. Today the only visible patches of human disturbance in an area of 390 sq. km. are five helipads – three on the western rim, and two in the centre built by the BHP Company survey team and the present expedition, all of which will quickly become overgrown again.

POSSIBLE FUTURE RESOURCE EXPLOITATION

Timber Extraction

The most obvious form of potential disturbance is logging, as harvesting in adjacent areas west of the Basin (outside the Yayasan Sabah Concession) began in 1986 and the rest of the surrounding area which lies within the Yayasan Sabah Concession will probably be harvested sometime in the next decade. The Basin itself, however, is presently only a limited commercial attraction. Lowland (hill) dipterocarp forest comprises only about 45 sq. km. or 11.7% of the Basin area, none of which is easily accessible. The few workable areas, such as Rambutan Ridge are all in the centre and would require circuitous road access from the southern rim, around the perimeter to the north-west and then inward on Long Ridge. The higher elevation forests and, particularly those just below the montane heath forest zone are of lower stature but are quite rich in conifers, including some Agathis dammara, which is a valuable timber species. Nevertheless, in relation to its size the Basin contains only a modest stocking of commercial timber, which would have a high cost of production because of the long, difficult road access. A critical environmental consideration, highlighted in Sections 3 and 4, is that the predominance of soft mudstones outcropping onto steep slopes make the water catchment exceptionally prone to erosion. Natural landslides already occur at high frequency. Any attempt to send tractors to the centre of the Basin would have a disastrous impact on water sediment loads. Thus, a combination of low volume benefits and high production and environmental costs renders the area completely unsuitable for logging. Anticipation of this conclusion was the main reason that the Basin was designated a Conservation Area in 1981, even before its biological conservation value had been assessed in the field.

Mineral Extraction

As described in Section 2, the Maliau Basin forms part of the sedimentary Tanjong Formation which is up to 12 km thick. It is reckoned a very promising area for hydrocarbon deposits of at least two kinds. At the time of writing this report, Broken Hill

Proprietry Company (BHP) has a licence to prospect for coal, and has found a high quality seam up to 2.8 m thick which surfaces near the base of the north rim escarpment, 10 km from Kg. Inarad. The Company's preliminary appraisal indicates that if this seam was deemed commercial – many non-geological factors effect this assessment – and if mining was permitted, extraction would be by means of lateral tunnels following the seam under the Basin. The only disturbance necessary within the Basin would be for ventilation shafts although these would presumably be sunk using heavy equipment requiring road access. Outside the Basin, near Kg. Inarad, there would inevitably be much more disturbance in the form of a township, pitheads, spoil tips, road or railway connections and so on. One nearby natural feature that would likely be despoiled is Lake Linumunsut.

Other mineral prospects in the area are oil and gas, for which another prospecting licence has recently been issued, to a consortium of Carigali Petronas (the Malaysian national oil exploration company), Sun Malaysia Company and Gulf Canada. This was announced in the press on November 19, 1988. The area covered by the licence is 30,000 sq. km. and includes the western half of the Yayasan Sabah Forest Concession. The press statement specifically mentions the Maliau Basin as one of the areas of interest. The geologists of the present expedition have suggested that if oil does occur it is likely to have accumulated not in the Basin but along the Pinangah and Kuamut faults, which run outside to west and east. Thus the Basin itself might be spared from drilling activities.

Both coal and oil prospects clearly pose a major threat to the integrity of the Maliau Basin as well as the surrounding Ulu Kinabatangan region. From a conservation standpoint, any mineral development of the area is highly undesirable because a wilderness of this quality is bound to be compromised when large numbers of people encamp nearby, even if the project does not directly disturb the Basin itself. If, however, the Government reckons that the economic benefits outweigh all other considerations then no expense should be spared to avoid disturbance to the Basin itself. Social and economic impacts on the communities of Ulu Kinabatangan should also be a major consideration. By law, any kind of mining or drilling activity would now require a full Environmental Impact Assessment before Federal or State Government approval can be given. This should be commissioned independently at the early planning stage, given broad terms of reference (coal mine wastes could potentially pollute the entire river system) and sufficient time for full consultation with local residents, and the establishment of baseline monitoring studies.

Hydroelectric Potential

The Maliau Basin has prima facie potential as a hydroelectric dam site. The river is substantial in size, and from the Maliau Falls to the Gorge exit falls about 250 m over 5 km. The inclination of the rock strata within the gorge is such that they would tend to form an impervious seal with any dam constructed there. The main technical drawback to exploitation of this potential is the remoteness of the site from any urban area - 110 km in a straight line from Tawau. There are several other potential hydroelectric sites much closer and more accessible. Dam construction in the Maliau Gorge would obviously have great impact on the lowland portion of the Basin ecosystem, depending on the size of the impoundment. The Maliau Falls themselves are a major spectacle which should never be submerged. Below the Falls, the riverside forest is not rated a principal biological feature of the Basin, but a significant point to be noted is the importance of pig migration routes, which cross the river from the south to reach the oak-rick forests on Long Ridge. Although one main arterial route probably crosses the Sg. Maliau in the vicinity and upstream of Base Camp, it is possible that other routes cross the river lower downstream, perhaps around the big kuala below the Falls. With the demise of primary forest in surrounding areas, the Basin is likely to become an even more critical reserve for maintaining migratory pig populations for which both lowland and montane forests are needed.

ASSESSMENT OF CONSERVATION VALUE

In attempting to assess the conservation value of the Maliau Basin in a state and national context, the following features should be noted :

A. Physical Features

(1) Sub-circular shape of the Basin and large size (25 km maximum diameter). A geologically similar formation, the Malibo Basin, occurs 10 km to the east but is nowhere near so grand in scale.

(2) Cliffs up to 1,000 m in height and around 35 km in length on the north and east rim have no parallel in Malaysia, although much higher but narrower precipices occur, for example, on Mt. Kinabalu. Total altitudinal range of the Basin from 220 m to 1,900 m is impressive but the summit is not exceptionally high among Bornean mountains.

(3) Broad saucer-shaped dip slopes on the inward face of the rim become steeply dissected by gorges and ridges towards the centre of the Basin. The 16 km Long Ridge is outstanding, as is the Maliau Gorge where it exits the Basin.

(4) Numerous waterfalls occur, but most notably the twin Maliau Falls of 28 m and 15 m, respectively. Both higher falls (eg. on Mt. Kinabalu) and wider ones (eg. Wasai Mayo, on Sg. Kuamut) occur in Malaysia but few, if any, match these for combined height and volume. They are an outstanding spectacle.

(5) 20 ha Lake Linumunsut just below Gn. Lotung on the north rim escarpment. This is Sabah's only lake, apart from ox-bows in the flood plains of the larger rivers. Although not visited on the present expedition, it is of considerable geomorphological and biological interest and should be added to the Conservation Area.

B. Biological Features

(1) A naturally defined and protected tropical forest ecosystem currently free of disturbance to a degree probably unequaled elsewhere in Malaysia, and noteworthy even in a global context.

(2) At least five distinguishable forest types, viz. lowland (hill) dipterocarp, lower montane oak and coniferous forests, and both lower and upper montane heath forests. The lower montane coniferous forest, which is an ecotone between hill dipterocarp and lower montane heath forest has no close parallel elsewhere in Sabah. The occurrence of heath forest on flat terrain at a range of altitudes is also exceptional.

(3) In the hill forest habitat both fruit trees and rotans are exceptionally abundant. In view of their rapid depletion elsewhere, a large unharvested concentration of rotans may one day be of great value as a source of breeding material.

(4) Known plant rarities include:-

- Rafflessia tengku-adlini : one of only two known localities.

- 6 species of Nepenthes, including N. hirsuta (first record for Sabah) and a new hybrid between N. veitchii and N. stenophylla.

- 37+ orchids, including 1 possibly new species related to Coelogyne odoardi, the newly discovered Corybas piliferus and Nephelaphyllum trapoides, a new record for Sabah. Other rare species were recorded on the 1982 expedition, eg. Dendrobium sculptum.

- a species of mango, Mangitera bullata, is a new record for Borneo.

(5) Reflecting the range of habitats, the fauna is diverse and can be segregated into an abundant lowland section and a low density section in heath forests and in the rivers that drain them. Rarities include Bulwer's Pheasant, peregrine falcon, proboscis monkey, Sumatran rhinoceros, clouded leopard and the squirrels Glyphotes simus and Rheithrosciurus macrotis. An unconfirmed sighting of another squirrel, Nannosciurus melanotis, may be a new record for Sabah.

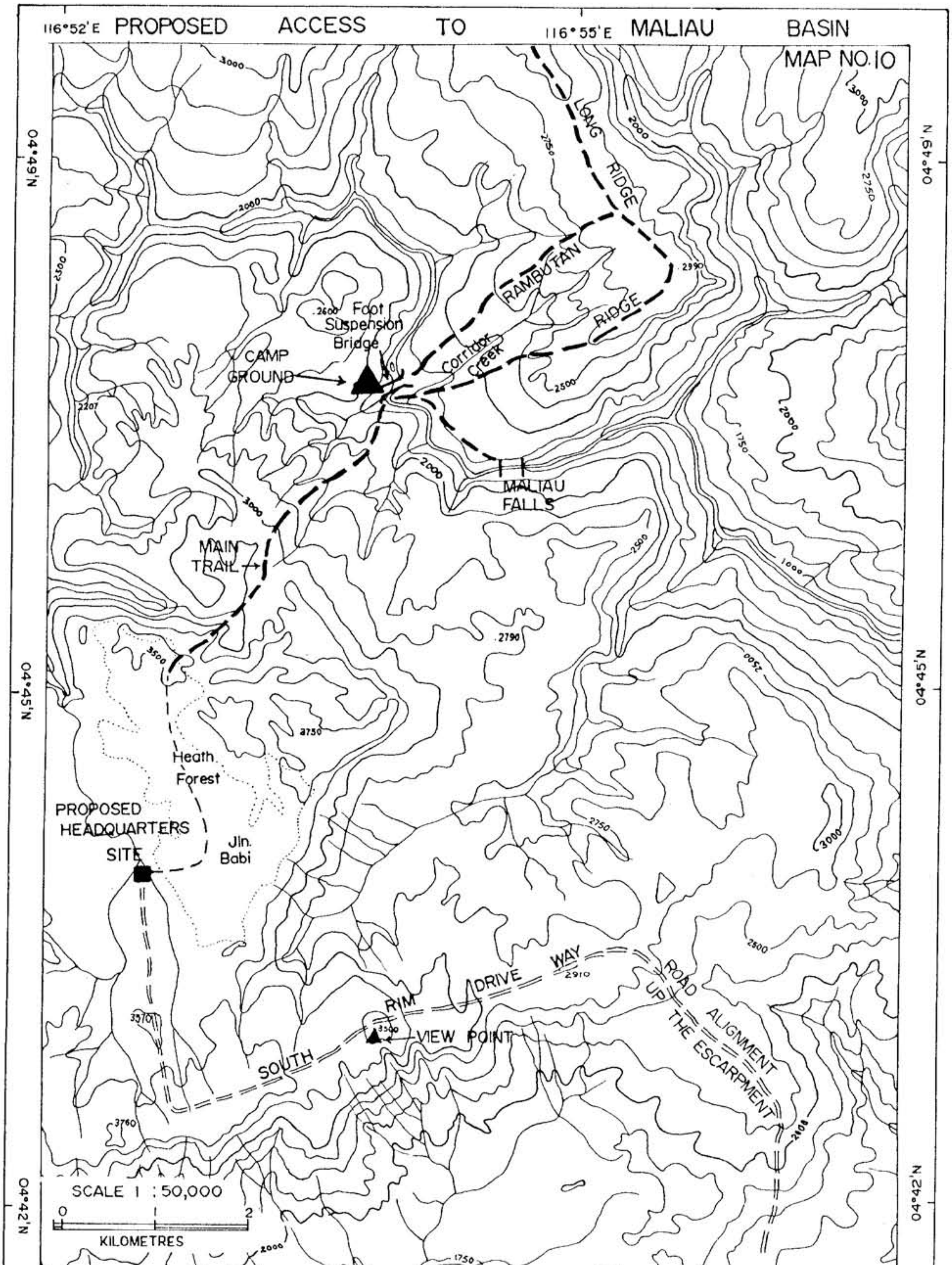
(6) The bearded pig trail on the south rim is dramatic and probably crucial for one of the few big migratory populations remaining in Sabah. The trail highlights the inaccessible and largely self-contained nature of the Maliau Basin ecosystem.

CONSERVATION DEVELOPMENT PLANS

Were it not for the imminent threat of mineral exploitation, the Maliau Basin could probably safely be left passively conserved for many years to come; for it is under very little threat from conventional pressures for land or even timber. This strategy would allow its development perhaps early in the next century when Sabah will have a post-timber economy and probably a much stronger tourism sector dependent on wildlife attractions. By then the route from Tawau to Keningau may even be a sealed road!

Such a strategy will not be suffice if mineral deposits are exploited nearby, because roads and incoming labour will open the whole area up to poaching, illegal logging, rotan collection, etc. What will be required is an accelerated development plan brought forward possibly to the early 1990s when Yayasan Sabah's logging operation will bring roads to the southern edge of the Basin. This is the obvious point of access because it is the lowest in altitude and permits the easiest road alignment.

Development plans should strictly limit road access so as to maintain the wilderness quality of the Basin but should make accessible by foot such outstanding spectacles as the Maliau Falls. Map 10 shows the location of proposed developments. The road would reach the rim via the southernmost approaching ridge and then follow the rim westwards for about 5 km. This should prove a beautiful scenic drive with views both north across the Basin and south over the edge of the escarpment. As the terrain in this area is almost flat sandstone plateau, there would be very little erosion damage. The proposed site for a headquarters complex is at the closest point to the access ridge that has an adequate water supply and is not in a gorge. This happens to be near the western side of the south rim heath forest.


116°52'E PROPOSED ACCESS TO 116°55'E MALIAU BASIN
MAP NO.10
04°49'N
04°45'N
04°42'N
116°52'E
116°55'E
LONG RIDGE
RAMBUTAN RIDGE
Foot Suspension Bridge
CAMP GROUND
Corridor Creek
MALIAU FALLS
MAIN TRAIL
Heath Forest
PROPOSED HEADQUARTERS SITE
Jln. Babi
SOUTH RIM DRIVE WAY
ROAD ALIGNMENT UP THE ESCARPMENT
VIEW POINT
SCALE 1 : 50,000
0 1 2
KILOMETRES

Appropriate visitor facilities at the headquarters would probably be a few self-catering chalets. Nearby attractions include the streams, the heath forest and Jalan Babi. Access to the centre of the Basin would be on foot only and follow the main route of this expedition via Jalan Babi, past Camp II and down the ridge to Base Camp. This is an easy day's walk going down and a rather harder one going back! Expedition Base Camp should be developed with permanent camping facilities and a suspension bridge across the river at the helipad. The falls would be a return day trip from here and anyone wishing to hike all the way to the north rim would follow Long Ridge. The vast majority of the Basin would remain as it is today - totally unvisited and unspoilt. But patrolling of accessible points on the rim would be needed to minimize encroachment by hunters or other unauthorized visitors.

Finally, the beautiful Lake Linumunsut should be protected by adding it to the existing Conservation Area. Following the catchment boundary of tributaries feeding the Lake, the size of this salient running north from Gn. Lotung would need to be only about 6 sq. km. in size, one third of which is above the 2,500 ft (672 m) contour line (Map 2). This is a trivial loss of timber land to protect a unique lake set against the stunning backdrop of the north rim escarpment. The site has obvious potential one day to be made accessible to visitors via Kg. Inarad. Murut legend maintains that the Lake is inhabited by a dragon whose tail holds back flood waters. Periodically, it moves its tail causing floods downstream, presumably because it has been offended. A creature of this kind should be left well alone!