A SCIENTIFIC JOURNEY THROUGH BORNEO

BARIO

THE KELABIT HIGHLANDS OF SARAWAK

Edited by
GHAZALLY ISMAIL
LAILY BIN DIN

INSTITUTE OF BIODIVERSITY
& ENVIRONMENTAL CONSERVATION

THE FACULTY OF RESOURCE
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Pelanduk
Publications

Published by
Pelanduk Publications (M) Sdn Bhd
(113307-W)
24 Jalan 20/16A 46300 Petaling Jaya
Selangor Darul Ehsan, Malaysia.

Address all correspondence to
Pelanduk Publications (M) Sdn Bhd
P.O. Box 8265, 46785 Kelana Jaya
Selangor Darul Ehsan, Malaysia.

Perpustakaan Negara Malaysia Cataloguing-in-Publication Data

A scientific journey through Borneo: Bario: The Kelabit highlands of Sarawak / edited by Ghazally Ismail, Laily bin Din.
ISBN 967-978-622-6
1. Bario (Sarawak) – Discovery and exploration. 2. Kelabit (Bornean people) – Sarawak – Bario – Social life and customs. 3. Biology – Research – Sarawak – Bario. 4. Botany – Research – Sarawak – Bario. 5. Zoology – Research – Sarawak – Bario.
I. Ghazally Ismail. II. Laily Din.
915.9522

Printed by Academe Art & Printing Services Sdn Bhd.

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INTRODUCTION

Bario: The Highland of the Kelabit People

Bario lies 1,200 metres above sea level, on a plateau in the Kelabit Highland, southeast of Miri in the Fourth Division of Sarawak. It is bordered by the Tamabu range in the west and Apo Duat mountain to the east. It has a mild and cool climate, temperature of 18-22°C and an annual rainfall of about 2,213mm. Today this Kelabit country is effectively shielded from outside cultural and socio-economic influences because it is encircled by a continuous rugged and mountainous range including Batu Iran, Batu Buli, Batu Lawi and Gunung Murud; a stretch of rich tropical forests of 164,500 hectares now designated as the Pulong Tau National Park. Mount Murud is the highest mountain in Sarawak. Inaccesibilty by road and river transport and the remoteness of the highland areas have helped to preserve the culture and traditional longhouses as well as the diverse fauna and flora. All of these presents a wide field of research opportunities.

The Impact of Development

The Kelabits have been traditional rice growers for centuries. In fact, the entire economic system of the Kelabits revolves around agricultural production; especially notable is their cultivation of wet paddy of which their aromatic "Bario rice" is regarded as a form of rare delicacy in Malaysia. Today, the 5000 or so Kelabits living in the highlands of Bario are at the crossroads of change. Outward migration of its own people and the migration of workers from across the Indonesian border, have significantly altered the population distribution pattern of this once self-sustaining and peaceful community. Because of this outward migration, Bario suffers from severe labour shortage. The impact of these changes on gender relations in the context of agricultural production and the role played by outward migration and immigration of foreign labour in agricultural production are issues that need to be addressed. The gender perspective is crucial to devel-

opment planning and will have significant implications for development policies and projects in the Bario highland. Also of interest is the decision making process concerning agriculture within the Kelabit households, given that agricultural production is the mainstay of the economy.

The Aesthetic Perspective

The Kelabit community has a unique system of aesthetic values and identity. This is illustrated in their richly refined culture and values, etiquette, rituals, and particularly in their artforms, which reflect the intimate interaction of the people with the natural environment. Beadwork, tatoo, and packaging designs are rich in 'content' and 'form'. They are indicative of a positive response to the community's complex social structures. The ethnomusicology of the Kelabits is a heritage that needs to be appreciated from both historical and socio-cultural perspectives; including the factors that have contributed to the musical forms, instruments and music performances of the Kelabit people. Singing has always played an important role in the life of the Kelabit, but the songs sung before and after they became Christian are different. Some of the original Kelabit songs about ritual celebrations such as Kuab, Lakuh, Adih, Sikih and Lipun-Aluh, that were popularly sung prior to their conversion, are today heard only during special ceremonial functions.

The Expedition

From the 8-20 April 1995, about 100 researchers from both local and foreign universities converged into Bario to participate in the sixth expedition in a series called 'Scientific Journey through Borneo' organised by Universiti Malaysia Sarawak (UNIMAS). The participants were drawn from a multitude of expertise and interest including water quality, climate, geology, flora and fauna, public health, anthropology, social science, ethnobotany, ethnomusicology and socio-economy. The general objective of the expedition is to enrich our understanding of the cultural and natural heritage of the Kelabit highland and its people. Indeed, the publication of this Bario: The Kelabit Highland of Sarawak as a continuing series of the Scientific Journey through Borneo, at this time is opportune. It is at a time when Sarawak is experiencing an unprecedented growth in economic development at all levels of its constituencies and society. The impact of this enviable progress has been translated into widespread socio-cultural and economic changes which in turn have begun to filter down to remote areas of Sarawak including the Bario highland. Now a distinct possibility exists that Bario, as the last custodian to a rich enclave of lush tropical forested area, will, in the not too distant future, be subject to rapid clearance for unsustainable exploitations of forest resources and infrastructural developments like roads and new townships; all in the name of economic progress. The result will be the disappearance of many natural ecosystems accompanied by a mass extinction of millions of tropical plant and animal species that are yet to be discovered by science. Such enormous and irrevocable loss of species foredooms a large majority of people in the third world to misery and poverty because people here still, to a large extent, depend on the diversity of genetic resources as a source of food, medicine and their daily economic activities. Many opportunities to increase scientific knoweledge will be lost irretrievably if immediate action is not mounted to inventorise and document these genetic resources. This expedition is the result of such resolve. Within the limited period we were in Bario, the scopes of study in certain interest areas were undeniably inadequate and barely scratched the surface. It is our sincere hope that this unpretentious documentation of our expedition can help trigger interest in other researchers to start a more comprehensive and meaningful investigation of some of the many pertinent aspects of Bario and the Kelabit people that we have considered them a matter of urgent priority.

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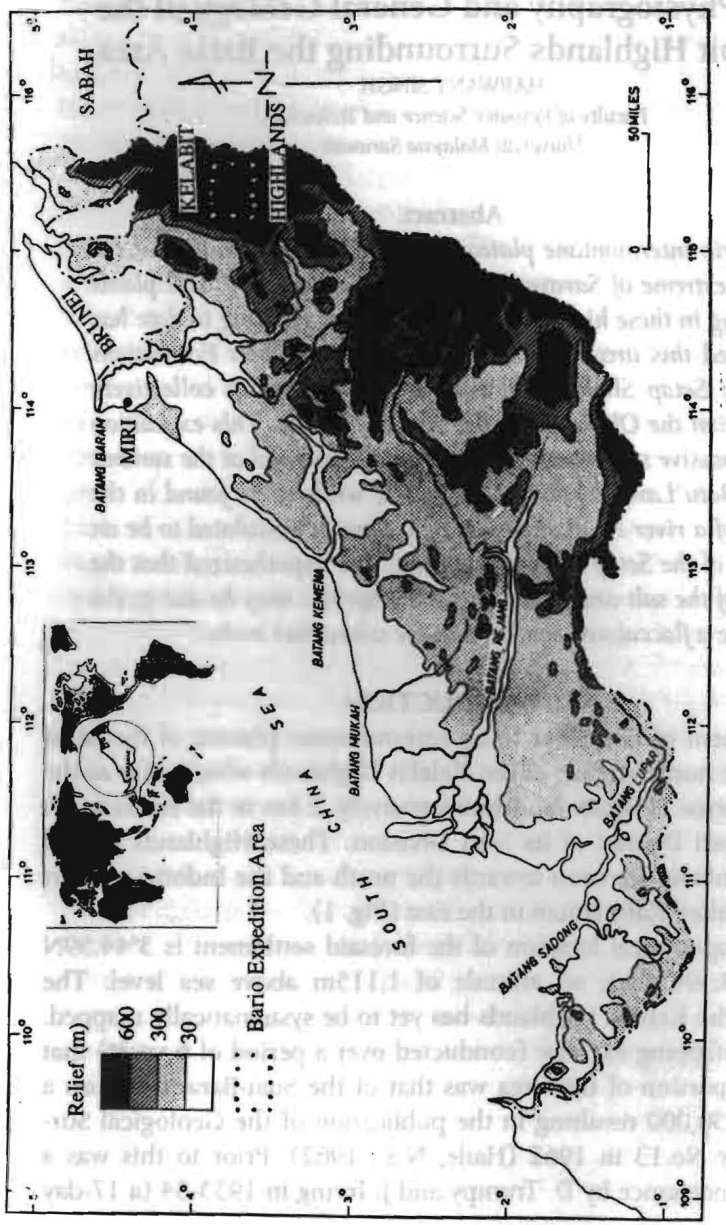


Figure 1: Relief of Sarawak (from Jackson, 1968). Inset: Geographic location of Sarawak.

walk from the Upper Limbang to Lio Matu, Ulu Baram), a reconnaissance by W.F. Schneeberger and R. Bachlin in 1940 (report in Dutch) that covered the boundary area between the Kelabit Highlands and Indonesia and a reconaissance of the Upper Baram area in 1953 by H. Widmer.

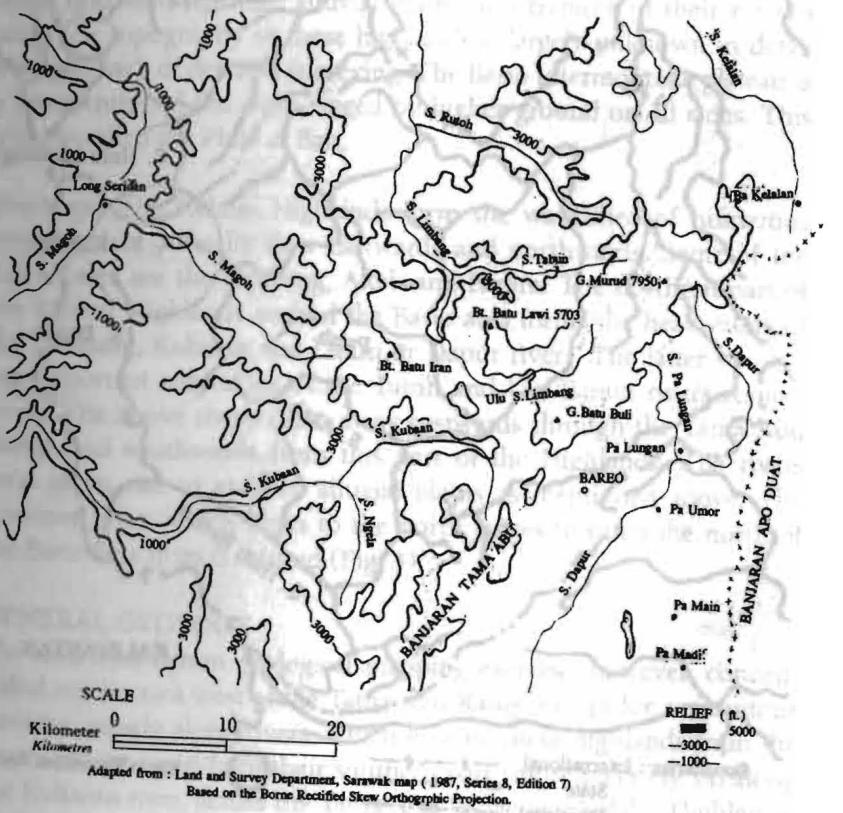
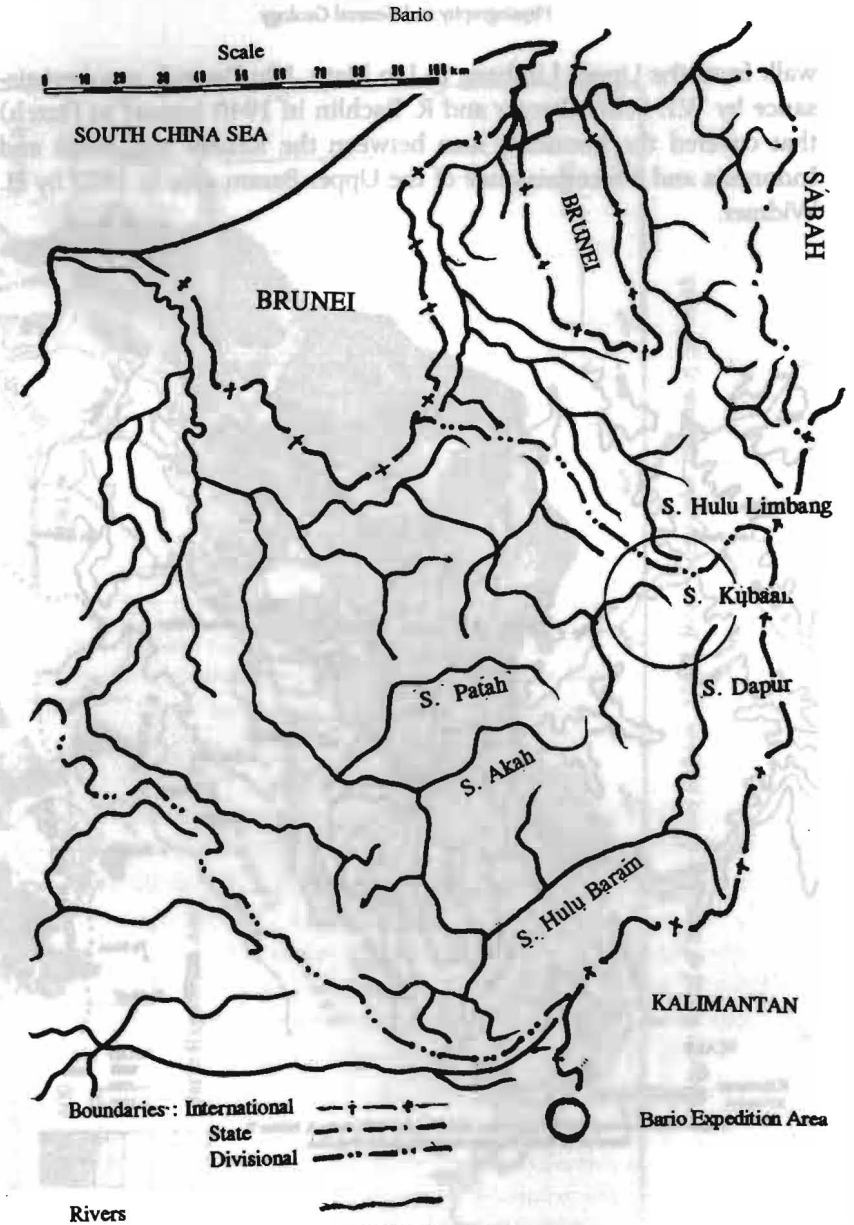


Figure 2: Topography of the North Kelabit Highlands surrounding Bario.



Source: Dept. of Irrigation and Drainage, Sarawak

Figure 3: Rivers in the Kelabit Highlands region.

Geomorphology. The highly elevated topography of the Kelabit Highlands surrounds this settlement (Fig. 2). The Kelabit Highlands have a distinctive and regular topography. They are bounded on the west and north-west by the Tama Abu Range which are a series of ridges. These ridges lie in a north-south direction averaging 4,000 to 5,000 ft in height and have an irregular extention in a north-eastern direction giving rise to prominent peaks like Mt. Murud (7,950 ft) and the striking twin peaked Mt. Batu Lawi (6,650 ft). The Kelabit Highlands also have encased alluvial plains and terraces in their eastern part. The topography of these highlands is largely unknown in detail owing to lack of detailed surveying. The Bario intermontane plateau is a forementioned flat plain ringed by higher ground on all sides. This plain is called the Plain of Bah.

Drainage. The Kelabit Highlands form the watershed of numerous rivers which generally flow eastwards and northwards. Some of the major ones are the Limbang, Akah and Baram. The northern part of the Kelabit Highlands around the Bario area forms the headwaters of the Limbang, Kuba-an and Libun or Dapur rivers. The latter two being important tributaries of the Tutoh and Ulu Baram rivers respectively. The above rivers drain away eastwards through the Tama Abu Range and southwards from this part of the Highlands. The rivers have given rise to encased alluvial plains as mentioned above. The Limbang river, which flows to the north, arises towards the north of the Bario area from G. Murad (Fig. 3).

GENERAL GEOLOGY

The said Suai-Baram geological mapping exercise, however, concentrated on the area west of the Tama Abu Range except for a circuitous traverse, mostly along rivers, which entered these highlands from the north and emerged from their southern part (more precisely, up along the Kuba-an river, across the Tama Abu Range and Kelabit Highlands, to the point on the Kelapong river then following it for a distance after which it went cross country to the Puak river, following it downstream into the Ulu Baram until the latter left the Kelabit Highlands in

the southern part). From the geology observed along this traverse, a geological map was produced with the geology of the intermittent areas (between the traverses) extrapolated from the geology seen along these traverses and aerial photographs (Fig. 4).

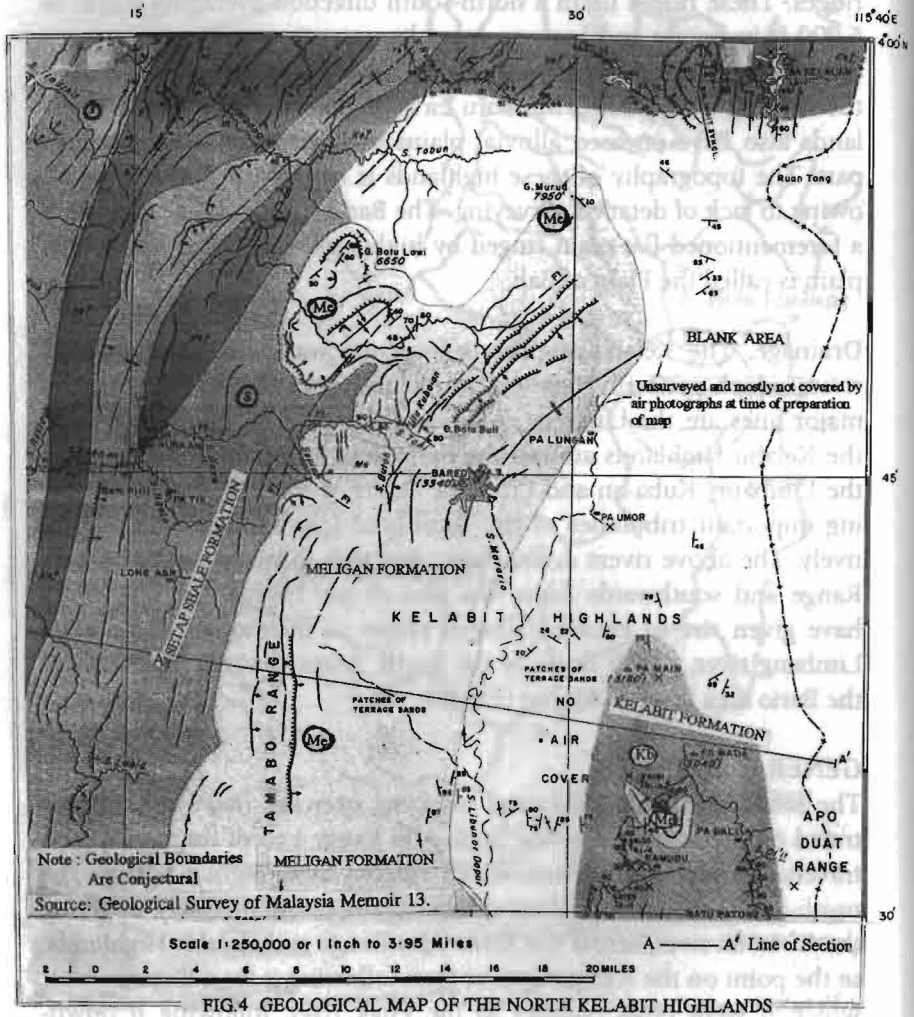


FIG.4 GEOLOGICAL MAP OF THE NORTH KELABIT HIGHLANDS

Figure 4: Geological Map of the North Kelabit Highlands.

Stratigraphy. The geological map above shows that this region and the area adjacent to it towards its west is classified into three formations on the basis of their lithological characters and fossil contents. Their geological boundaries are, however, conjectural.

The two formations constituting the northern Kelabit Highlands are as follows:

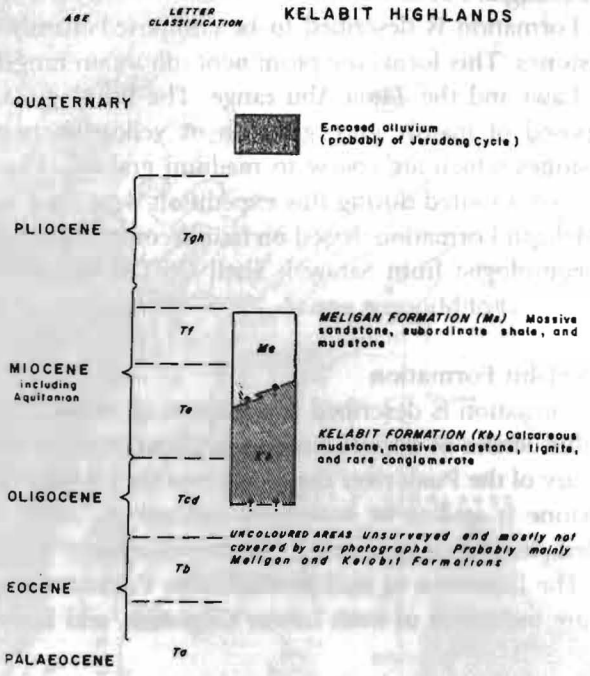
1. **The Melingan Formation**
   This Formation is described to be composed mainly of massive sandstones. This forms the prominent mountain ranges including Batu Lawi and the Tama Abu range. The lithology is said to be composed of mainly grey, greenish or yellowish-grey quartzose sandstones which are coarse to medium grained. The lithologies of two sites visited during this expedition were seen to consist of the Meligan Formation. Based on faunal composition identified by a paleontologist from Sarawak Shell Co Ltd this Formation belongs to that of Miocene age.

2. **The Kelabit Formation**
   This Formation is described to comprise of mudstone, sandstone and thin lenses of impure limestone. It outcrops in the Kelapang tributary of the Puak river that flows into the Ulu Baram river. The mudstone is said to be commonly calcareous, sandy and poorly bedded. Its colour is stated to be brownish-grey to light bluish-grey. The limestone is well bedded. This Formation yields fossils that are indicative of both Lower Oligocene and Lower Miocene ages.

Adjacent to the Meligan Formation in the west is the Setap Shale Formation which is described as a thick monotonous succession of shale with subordinate sandstone and a few mainly thin lenses of limestone. The lithology is uniformly monotonous consisting of grey shale, grey mudstone and a few limestones. No outcrop of this Formation is described from the Kelabit Highlands or Tama Abu Range. This Formation is believed to be exclusively of Miocene age.

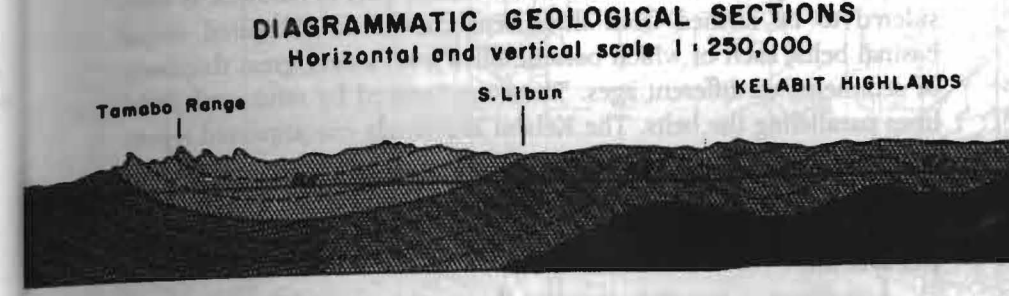
Apart from the above, encased alluvial plains and terraces also occur in the Kelabit Highlands belonging to the Quarternary age. The Bario plateau is one such plain underlain by alluvium encased by the surrounding higher grounds.

Based on the above the following stratigraphy emerges:



Structure. The Meligan Formation is stated to rest conformably on the Setap Shale Formation towards the west and probably on the Kelabit Formation in the east. This postulated structure may be diagrammatically represented in a cross section and the following cross section

from the Central Kelabit Highlands (Haile, N.S.,1962) most likely represents the structure of the area (Fig. 4 for location & orientation).



Geological History. The rocktypes reported so far are almost exclusively sedimentary and are envisaged to have been deposited in large sedimentary basins of regional extent. The rocks range from the Oligocene to the Quarternary but with the absence of the Pliocene. This almost complete succession is of sandstone along with calcareous mudstone, lignite and rare conglomerate. The Quarternary is represented by encased alluvium. Adjoining to the west are Miocene shales.

This area formed part of the subsidizing northwest Borneo which was covered with sea in which this enormous thickness of sediment forming the above rocktype strata was deposited. The subsidence is believed to have begun in Cretaceous times. The source of this huge quantity of detritus is not known but is thought partly to be from the central granitic part of Borneo. Since the earliest rocks here are Oligocene they could have been derived from the earlier deposited strata.

The deposition of the Kelabit Formation in the Kelabit Highlands is thought to have started as early as the Oligocene and probably continued into the Miocene. The Meligan Formation was deposited later during the Miocene; after which the deposition is thought to have stopped. A period of uplift and deformation in the Pliocene times is envisaged which raised the area above sea level.

Erosion began after this with widespread regional peneplaination cycles occurring. During these periods the encased alluvium in the Kelabit Highlands may have formed along with the rejuvenation of the

rivers. The configuration of the present land surface, referred to as the landform, has evolved since this period.

In the regional context, the northwestern part of Sarawak is considered to be formed from three semi-concentric elongated major basinal belts; each of which became filled with a very great thickness of sediments of different ages. These are marked by structural trend lines paralleling the belts. The Kelabit Highlands encompassed a portion of both the Neogene and Paleogene basins which are in the inner part of the semi-concentric ring. According to the older geosynclinal theory, these constitute what is referred to as the 'Northwest Borneo Geosyncline'.

According to the plate tectonic theory, this part of Borneo was a subduction trench where the sea floor was forced under the then continental crust which was moving northwestward. At this collision zone the continental crust was forced upwards which caused it to warp and form basins. This caused the sedimentary deposition in this part of Sarawak. The various environments of deposition formed which lead to the deposition of different rocktypes with sandstones along the shoreline and shales offshore. Due to continued subduction there have been subsequent uplift and folding with the size of the folds increasing inland. Currently the most reliable estimate of the rate of uplift for this region is almost 20mm per century for at least the last two million years. There has, of course, also been continued erosion and denudation.

It may be inferred that the Kelabit Highlands are a result of the deposition of the sedimentary strata caused by the creation of basins, giving rise to different depositional environments, which have been subsequently uplifted and denudated.

EXPEDITION ACTIVITY

Two sites were investigated around the said plateau and a traverse was made on foot (taking 5 days) to Mt. Batu Lawi. The route of the mentioned traverse and location of the sites are illustrated below (Fig. 5)

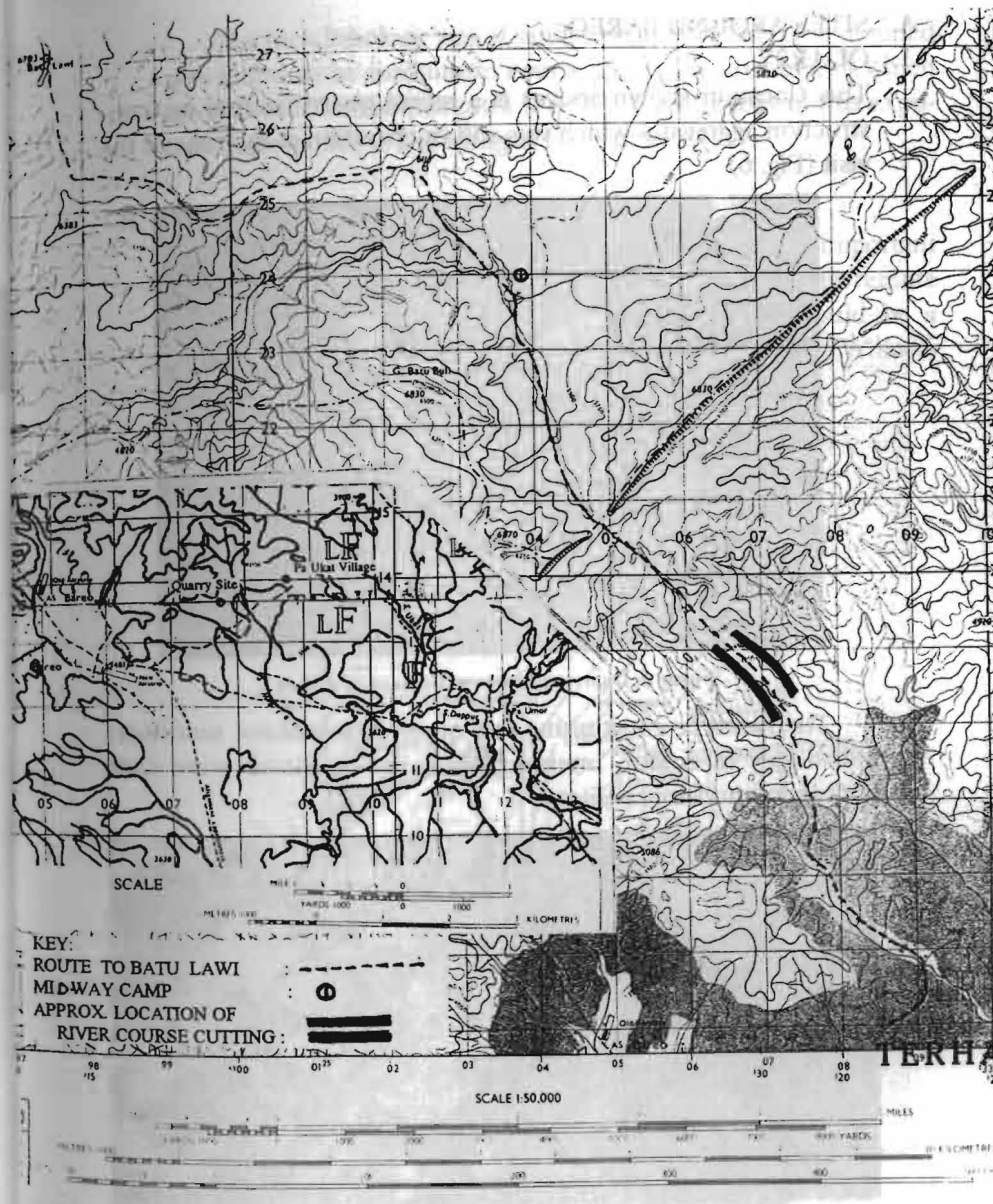


Figure 5: Route of foot traverse to G. Batu Lawi from Bario with inset of Bareo and vicinity showing quarry site.

A. SITES AROUND BAREO:

I. QUARRY

This (location shown above) is a recent quarry started for construction aggregates which was still in operation at the time of the visit (Fig. 6).

Figure 6: Quarry site between Bario and Pa'Ukat.

The rocktype constituting this quarry was massive sandstone bluish-grey in colour. Interspersed in the sandstone were dark nodules of mudstones (Fig. 7)

Figure 7:Sandstone with Nodules.

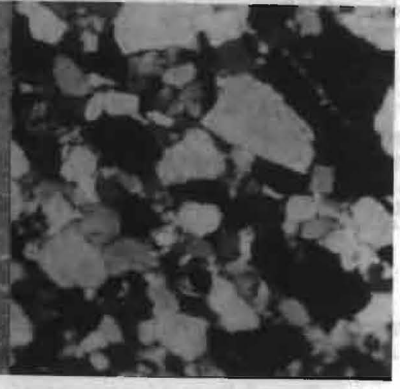


Figure 8: Sandstone from Quarry

The rock lithology was of sandstone and the sample examined was found to be medium to course grained quartz arenite which are also called orthoquartzites (Fig. 8). The lithology of this exposure corresponds to the Meligan Formation.

II. SALT SPRINGS.

Salt springs occur in the Kelabit Highlands and are an important source of salt for the people and wildlife who inhabit this remote area far removed from the coast which otherwise could be a source for salt. These were investigated by G.E. Wilford (Wilford, G.E., 1957).

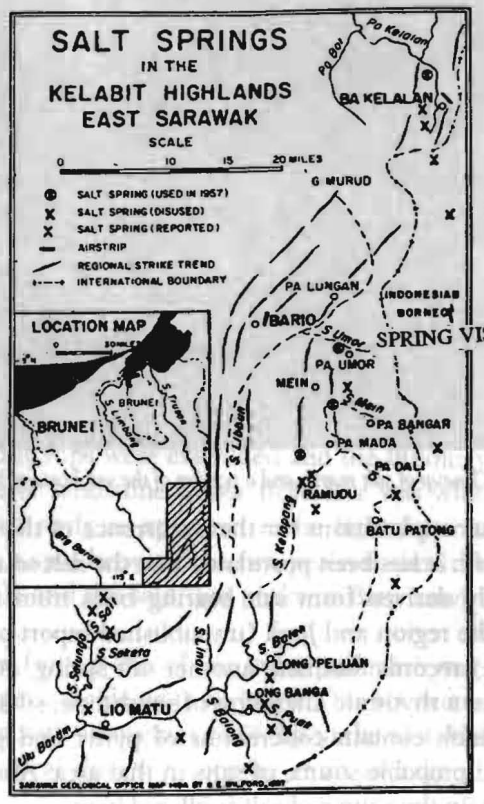


Figure 9: Salt Springs in the Kalabit Highlands showing spring visited at Pa' Umor.

The origin of the salt is not known but the springs occur in a belt parallel to the regional strike of the rocks in this region. A salt marsh east of Bario at Pa' Umor, which lies in the above belt, was examined to determine the mode of occurrence of the salty water. The saltish water was observed to occur in swampy ground (Fig. 10). No source was observed and the water thus seems to seep to the surface from below. No rock outcrop was seen at the surface in the vicinity of the swamp which occurs in the soil cover of the area.

Figure 10: Closeup of salt marsh and a portion of the soil horizon in which it occurs.

Various explanations for the occurrence of the salt have been put forward. It has been postulated that the salt sources and water is probably derived from salt bearing beds from the subsurface rocks in the region and *Jordi* (unpublished report of Sarawak Oilfields Ltd.) records that near another salt spring, at a place called Ba Kelalan, a rhythmic alteration of sandstone, siltstone and shale occurs which contain concretions of pyrite and gypsum which can be the probable source of salts in that area. Another hypothesis to explain the source of salt is offered here.

Clay-sized particles when laid down in a marine and brackish environment have very high porosity due to their being laid down in a flocculated condition, i.e., the particles are arranged in clumps - a 'card house' structure with edges of particles attracted to faces (Fig. 11). When the clay is above sea level and is exposed to freshwater moving through it the salt in the pore fluid is removed (Moore & Reynolds, 1989).

Figure 11: Clay particles displaying flocculated fabrics.

The Formations in this region consist of clay which constitutes the shale and mudstone and thus is the probable source of the salt from which it seeps upwards.

B. Traverse to Batu Lawi

(I) Batu Lawi

Batu Lawi is a striking feature with two peaks aligned in a north-south direction (Fig. 12).

Various outcrops were examined and the lithology was found to be of massive sandstone whose fresh face was white in colour. The weathered surfaces appeared to be light brownish-grey. An outcrop from a spot between the two peaks is shown below (Figs. 13(a) and (b)) and the said two peaks of Batu Lawi (Figs. 14(a) and (b)).

The inner face of one of the taller peaks are marked by two sets of cleavages considered to be joints. One set occurs in an east-west direction with an average of 5° dip to the east while the other set is in a vertical direction dipping at an average of 80° to the west.

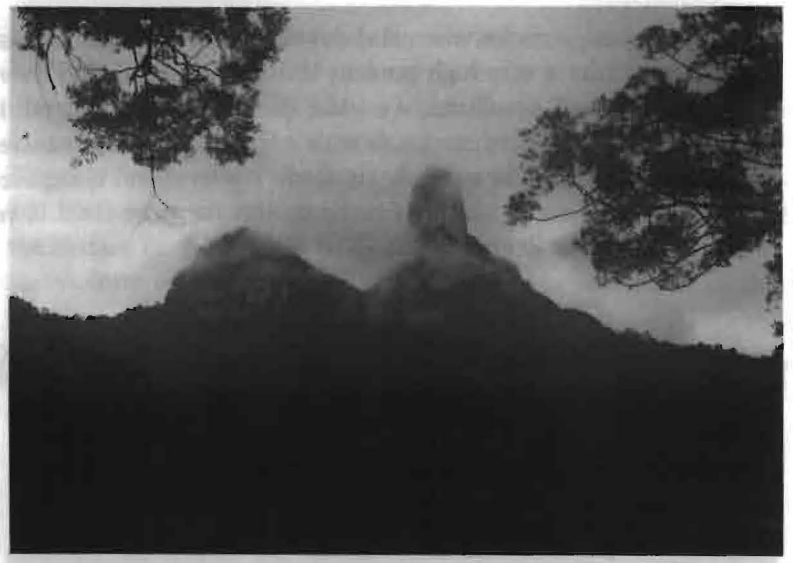


Figure 12: The twin peaks of Batu Lawi.

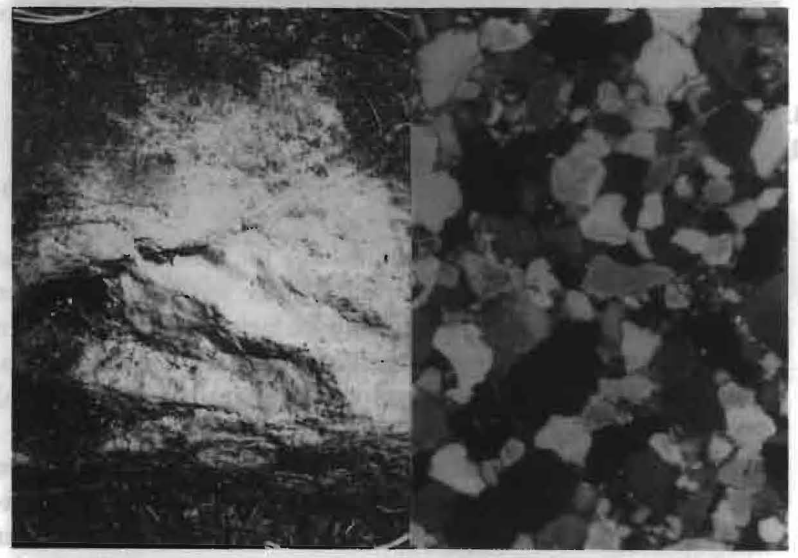


Figure 13a: Rock outcrop on Batu Lawi between its twin peaks.

Figure 13b: Sandstone from atop Batu Lawi

Figure 14a: Southern peak of Batu Lawi. *Figure 14b: Northern peak of Batu Lawi*

The inner face of the other shorter peak is covered with vegetations which has split the rock surface and cause it to be uneven. The rocktype of the Batu Lawi peak is massive sandstone and the sample investigated was found to be medium- to coarse-grained quartz arenite called orthoquartzite (Fig. 13(b)). The lithology indicates that this belongs to the Melingan Formation.

II. Stream Course Cuttings

Several streams were crossed along the way. The course of two of these (one of them is believed to be the Sungai Ukat), were followed for a distance along the route to Batu Lawi and it was noticed they had cut into a different rock type for a certain distance than the hitherto exposed sandstone. In both these instances the rock type encounterd was the same grey shale. It is postulated that this outcrop is significant enough and is considered to be an exposure of the Setap Shale over which the massive sandstone Mel-

ingan Formation lies. No contacts were observed and it was seen that these rocktypes, which were not exposed to a great height above the river channel, were directly overlain only by a soil cover. The rocktype from one of the stream beds which outcropped for about 15m is shown below. The attitude of the strata had a dip of 85° (in the direction of 155°). The appearance of this shale is given below. (Fig. 15(a) and (b)).

Figure 15a: Shale

Figure 15b: Shale exposure on river course.

DISCUSSIONS

The detailed geology of the Kelabit Highlands surrounding the Bario settlement is not yet known due to the absence of systematic mapping. The geology of the intervening areas between the traverses taken is extrapolated mostly from aerial photographs.

The expedition's traverses have yielded additional information by way of the description of the lithology of the rocks, particularly, from the new quarry site and the stream course. The lithology of Batu Lawi had been described but no record of a petrographic description has been found in literature to date. The observation of sandstone from Bareo to Batu Lawi along the traverse, except along the stream, reinforces the deciphering of this stretch north of Bario as the Meligan Formation constituted of sandstone.

It is also seen from the geological map that the Setap Shale is present north to a fault paralleling S. Butoh where it dents the continuity of the Meligan Formation. It is also reported that the sandstone interbedded with light brownish-grey mudstone and soft grey mudstones outcrop in the Kuba-an river, which lies north of the mentioned S. Butoh. The outcrop of greyish mudstone encountered along a stretch of the river (believed to be the Sungai Ukat) which was followed along the route to Batu Lawi lies further south east to the above two shale occurrences. This encountered outcrop is considered as an exposure and it is postulated that it is a continuation of the Setap Shale Formation which lies under the Meligan Formation or otherwise it is a mixed zone above which the Meligan Formation proper was deposited.

If the above is to be true this would indicate that a significant amount of the Meligan Formation must have been eroded away. In the absence of any faulting, the presence of a northeast-southwest trending high scarp separating Bario and Batu Lawi with a fall in its elevation on both sides supports this fact. The topographical surface decreases in elevation more rapidly towards the direction of the Bario Plateau and the rivers also flow in this direction. The possibility of the occurrences of such shale exposures are more likely to be on this side of the scarp. If the trend of this scarp is followed southwestward on the topographical map, it is observed that it merges with a topographical surface of an equal height which lies northwest-southeast with intermittent breaks giving rise to Batu Lawi.

ACKNOWLEDGEMENTS

I would like to thank Mr. Richard Mani Banda, Mr. Justin Jok Jau and Mr. Chen Shick Bei of the Geological Survey of Malaysia, Sarawak for their kind assistance. I also thank my Dean, Prof. Laily Din for his constant guidance. I am also grateful to Prof. Ghazally Ismail for his encouragement and all my co-expeditionist. Finally, my thanks to my field guide on the traverse to Bt. Batu Lawi, Mr. Paul Martin.

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The River System and Water Quality in The Bario Highlands, Sarawak

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Abstract

The river system draining the Bario Highlands was verified and the water quality of the streams in the vicinity of Bario Asal was determined. The pH of the water in this subregion was found to be unexpectedly low, at about 4.8 to 5.2. Streams draining the settlement areas around Bario Asal proper were found to have excellent water quality, with high level of dissolved oxygen and relatively low concentrations of suspended solids, dissolved solids and nutrients. However, the water of streams draining the eastern side of Bario, such as the Pa' Ukat, Pa' Umor and Sg. Dappur were inferior in quality due to relatively higher load of suspended solids. The stream siltation was attributed to deforestation for agricultural activities, which included rice cultivation. Pollution from agrochemicals and fertilizers was insignificant as the usage of these chemicals in the Bario Highlands was still minimal.

INTRODUCTION

The Kelabit Highlands, where Bario Asal settlement is located, forms the uppermost catchment of the Baram River watershed. The highlands plateau is about 1,200m above mean sea level, with annual rainfall of 2,300mm and daily mean temperature of between 19° and 22°C. The plateau, which resembles a huge volcanic crater, is bordered in the west, north and south by the Tamabo (or Tama Abu) mountain range. The eastern side of the plateau is bordered by the Apo Duat mountain range which is slightly lower in elevation than the Tamabo Range (Janowski, 1991).

The soils of Kelabit Highlands are derived from accreting and non-accreting alluvium, composed mainly of poorly drained clays,

podzolic sands and 'climatogenic' organic soils. The natural drainage system of the plateau is not well developed, and there are waterlogged areas covering most of the valley bottom soils. The soil, however, are suitable for rice cultivation, while the better-drained residual and non-accreting alluvial soils are suitable for vegetables, citrus fruits and others. As the surrounding mountain ranges are very steep and the surface runoff is very rapid the valley of Bario is always subjected to flash floodings (Eilers, 1982).

Bario Asal settlement area is drained by four small streams of between 1 to 4m in cross-sections. These streams, namely Pa' Marario, Arul Dalan, Pa' Lap and Pa' Ramapoh converge into Sg. Dappur which is one of the main tributaries in the upper Baram River. There has not been any earlier study of the water quality of streams in the Bario subcatchment. This paper presents the findings of a study carried out during the *Scientific Journey through Borneo – the Bario Expedition* (10-20 April, 1995) organized by the Universiti Malaysia Sarawak. The purpose of this study was to document the status of water quality of the streams and establish a baseline reference for Bario watershed.

MATERIAL AND METHODS

Water and sediment samples were collected from the streams that run through the catchment. The location of the sampling sites are shown in Figure 1. The streams location and identity were verified with the assistance of a guide who was the Arul Dalan village head. Information from the local guide was found to differ slightly from the printed maps issued by the Department of Land and Survey, Sarawak in terms of the names and routes of the streams.

Water quality parameters studied were the temperature, pH, dissolved oxygen (DO), biochemical oxygen demand (BOD), electrical conductivity, turbidity, suspended solids, heavy metals (As, Cd, Cr, Cu, Fe, Hg, Mn, Ni, Pb and Zn), inorganic nutrients (phosphate, nitrate, ammoniacal nitrogen and sulphate), colour and acidity. The pH, temperature, DO, turbidity and electrical conductivity were measured *in situ* using the multiprobe Horiba Water

Checker. Due to unavailability of the necessary equipment and chemicals in the field, BOD analysis was carried out by determining the difference in the DO level (measured using Horiba Water Checker) in samples before and after 5 days of sample incubation, in aluminium foil-wrapped BOD bottles, at room temperature (*ca.* 25°C).

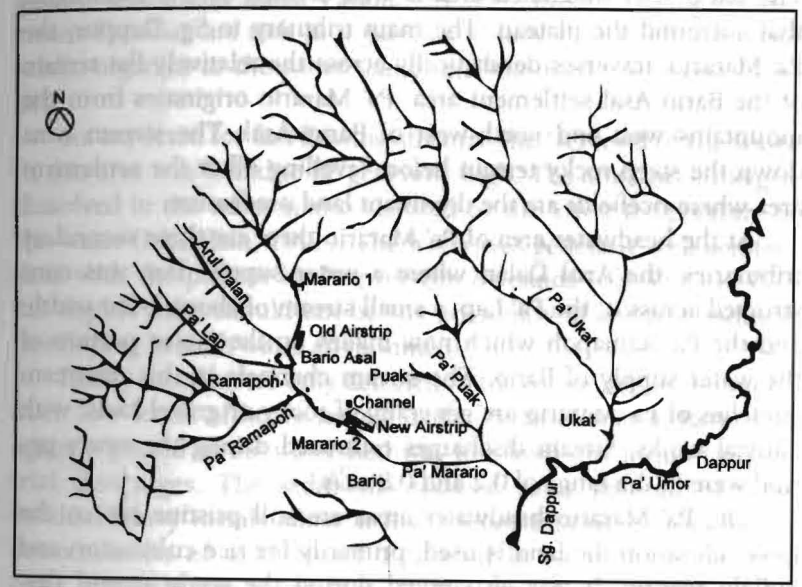

Figure 1: Map of Bario and the Sampling Stations

Suspended solids value was determined by filtrating water samples through a pre-weighted 0.45 µm membrane filter and calculating the weight difference after drying the filtered solids at 60°C to a constant weight (Standard Methods, 1992). The filtrate from the suspended solids separation was analysed for inorganic nutrients and heavy metals. Colour and nutrients (phosphate, nitrate, sulphate and ammoniacal nitrogen) were analysed using the Hach DR700 kit. Soluble heavy metals were analysed using the Perkin Elmer P2000 ICP-AES spectrophotometer. For sedimetary

heavy metals, sediment samples were oven dried at 60°C for 24h. A five-gramme portion of the sample was then digested with HNO_3/HCl according to the Standard Methods (1992). The digested samples were analysed with ICP-AES.

RESULTS AND DISCUSSION

The Bario Asal watershed area is well defined by the mountains that surround the plateau. The main tributary to Sg. Dappur, the Pa' Marario, traverses dendritically across the relatively flat terrain of the Bario Asal settlement area. Pa' Marario originates from the mountains west and north-west of Bario Asal. The stream runs down the steep rocky terrain before levelling off at the settlement area where ricefields are the dominant land use feature.

At the headwater area of Pa' Marario there are three secondary tributaries: the Arul Dalan where a water supply dam was constructed across it; the Pa' Lap, a small stream of about 1-2m width; and the Pa' Ramapoh which now makes up the major portion of the water supply of Bario. The stream channels in this upstream stretches of Pa' Marario are generally of rocky or gravel beds, with alluvial banks. Stream discharges estimated during the study period were in the range of 0.2 and 0.8 m^3/s.

The Pa' Marario headwater areas are still pristine but at the lower elevation the land is used, primarily for rice cultivation and buffalo rearing. It was also noted during the study period that humicified runoff from a wetland area was being drained off by the construction of a man-made channel running parallel to the Bario Airstrip, into the lower reaches of Pa' Marario.

During the present study, thirteen water quality parameters were studied for eight locations in the watershed. The results of the water quality examination are given in Table 1. The temperature of the water within the Bario watershed was found to be in the range of 20-23°C. However water temperature at night might fall to below 20°C as the air temperature dropped to as low as 10°C in the extreme. The mean minimum air temperature recorded was 18°C.

The pH of the stream waters was found to be around 5.5, an unexpectedly low level for a rural environment like Bario. The low pH readings might be the result of a combination of factors. These include the inputs of humicified surface runoff and organic leachates from the soil, and the low buffering capacity of the soils in the catchment. The soils in this region are those of the Bijat, Dalan, Umor and Bareo Families (Eilers, 1982). The Bareo and Umor Families are rich in organics and may thus leach out some acidic organics to the water that contribute to the lowering of its pH.

As expected for fast flowing streams, the DO level of the water in this area was found to be generally high. The amount of oxygen dissolved in the water is also elevated by the lower temperature of the water (Manahan, 1991). The water was generally well aerated; thus with the present loading oxygen demands (e.g. BOD of 0.7-1.3 mg/L), there should not be any possibility of anoxic condition developing in such water environment.

Heavy metals were only detected in trace amounts in the water. Such low levels of heavy metals in the surface water at Bario was again expected as the watershed was free from any form of industrial discharges. The sediments showed some amount of non-residual heavy metals albeit at low concentrations. Generally, the concentration of sedimentary Fe found in Sarawak stream and river channels was more than 10,000ppm (Lau, 1995) but the Bario watershed gave much lesser values.

Table 1: In-situ measurement of water quality parameter at Bario Watershed.

Station	time/date	pH	Conductivity µS/cm	Turbidity (NTU)	DO mg/L	Temp. (°C)
Marario 1	11:18/ 11 April	5.57	90	35	7.35	20.3
Marario 2	10:10/ 12 April	5.90	83	65	7.45	20.2
Ramapoh	14:20/ 11 April	5.71	82	27	8.10	20.2
Arul Dalan	12:20/ 11 April	5.75	90	25	7.95	20.2
Channel	12:00/ 12 April	5.10	84	40	6.8	23.2
Ukat	14:00/ 12 April	5.12	91	69	6.80	20.3
Dappur	15:30/ 12 April	5.15	133	240	6.60	20.2
Puak	16:30/ 12 April	6.05	106	10	6.70	21.0

Table 2: Laboratory analyses of water samples from Bario Watershed.

Station	NH_{3-N} mg/L	NO_{3-N} mg/L	SO_4^{2-} mg/L	PO_4^{3-} mg/L	TSS mg/L	BOD mg/L	colour Pt/Co	acidity mg/L
Marario 1	0.04	0.11	30	12	31	0.9	29	0.08
Marario 2	0.03	0.11	23	16	96	2.0	9	0.08
Ramapoh	0.06	0.06	12	9	33	0.7	5	0.08
Arul Dalan	0.04	0.10	12	12	37	0.9	6	0.08
Channel	0.27	0.07	43	34	65	1.3	66	0.04
Ukat	0.22	0.09	39	12	40	1.2	55	0.08
Dappur	0.17	0.11	43	12	161	1.3	67	0.08
Puak	0.06	0.10	24	11	26	0.9	12	0.08

Table 3: Heavy metal contents in sediments from Bario Watershed.

	Marario 1	Marario 2	Ramapoh	Arul Dalan	Channel	Ukat	Dappur	Puak
As (ppm) dl=0.1000	<2	<2	<2	<2	<2	<2	<2	<2
Cd (ppm) dl=0.0200	<0.4	2.8	1.2	1.2	2.8	<0.4	1.0	<0.4
Cu (ppm) dl=0.0500	4.0	8.0	7.6	4.2	8.2	5.2	6.2	5.6
Cr (ppm) dl=0.0500	2.0	8.0		2.0	7.6	2.8	3.2	3.2
Fe (ppm) dl=0.0250	5,360	16,780	8,920	5,240	16,250	5,580	6,680	6,800
Hg (ppm) dl=0.0020	<0.04	<0.04	<0.04	<0.04	<0.04	<0.04	<0.04	<0.04
Pb (ppm) dl=0.1000	10.6	24.2	24.0	12.0	22.4	15.4	18.6	17.8
Ni (ppm) dl=0.0500	7.8	9.0	6.6	7.2	8.6	5.4	6.8	5.0
Se (ppm) dl=0.1000	8.0	17.8	<2	6.0	10.2	<2	<2	10.0
Zn (ppm) dl=0.0250	14.6	37.2	24.0	14.2	42.0	16.8	26.6	19.4

Despite the fact that the four rivers (Pa' Marario, Arul Dalan, Pa' Lap and Pa' Ramapoh) irrigated the rice fields of Bario Asal, their inorganic nutrient and dissolved solids were found to be low. This was reflected by the low electrical conductivity of the water, which was less than 10 µS/cm. One would expect that rice fields would be the main source of nitrate, sulphate and phosphate input to these water bodies as the farms would be regularly fertilized with chemical fertilizers. The analyses conducted showed that this was not the case in Bario. Fertilizer application to the farms was

seldom carried out by the farmers as cost of fertilizers was high and most of the farmers were not operating on commercial scale (Joseph, 1995).

Water samples from two of the sampling sites gave a slightly higher ammoniacal nitrogen content. The sites were Ukat and the man-made channel near the air strip. The sampling point at Ukat was located in the vicinity of a buffalo ranch and part of the ranch was found flooded during sampling. The source of ammoniacal nitrogen was most likely from the animal dungs. The man-made channel by the airstrip at Bario on the other hand has two toilets built across it and the domestic wastewater drained directly into the channel. The ammoniacal nitrogen detected was thus probably from domestic and sanitary wastes.

The main pollutant of water in this subregion was the suspended solids. Suspended solids were introduced into the rivers through surface run-off from farm lands, unsurfaced roads and hill slopes. The area had a high annual rainfall and the soil in this area constituted the podzolic sand and organic soil which could be easily washed away by rain water. The major sources of suspended solids were from the hill farming of pineapple and pepper. This was evident from our observation that areas with minimal hill farming (Bario Asal) recorded only low levels of suspended solids (31-37 mg/L) while areas with high activity of hill farming and large area clearing (Pa' Umor and Pa' Ukat) the suspended solids were in the range of 40-160 mg/L. The colour of the water was found to be in the range of 5-9 for the Bario Asal area while the bigger streams (Pa' Ukat and Pa' Umor) gave colour readings of between 55 and 67 Pt/Co unit. The colour of these stream waters could be attributed to the loadings of ferroceous (soil-based) hydrocolloids and humic substances such as humic acid and fluvic acid.

CONCLUSION

The water quality of Bario watershed is considered good and may belong to the Class II category. Presently there is no sign of indus-

trial pollution or extensive agricultural runoff and discharges that may threaten to pollute the river system in the Bario Highlands. However, human activities, particularly the rice farming, forest clearing and road constructions occurring in the area today have significantly contributed to most of the suspended solids loading in these waterbodies. With improved transportation system in the future, the small-scale rice and pineapple farming at the moment may be replaced by larger farms that would require more chemical applications. Since the watershed is small, the surface water can thus become easily overburdened with inorganic nutrients, biocides and suspended solids. Future development strategies for Bario must therefore take into consideration the potential danger of contaminating the watershed.

ACKNOWLEDGEMENTS

The authors would like to thank UNIMAS and the Sarawak Forestry Department for organising the scientific expedition in April 1995. The authors too are indebted to UNIMAS for providing the research grants for this project.

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An Account and Checklist of the Flowering Plants at Kelabit Highlands, Bario, Sarawak

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Abstract

The Kelabit Highlands at Bario is about 1,100m above sea level and the vegetation consists of submontane forests on the hills and mainly kerangas forests on the plateau. A total of 166 specimens of flowering plants was collected and many more were observed during the expedition. They were identified and classified into 197 species, 143 genera and 68 families. Three new records for Sarawak; viz. Garcinia bancana, Aporosa nervosa *and* Actinodaphne pruinosa *were herein reported, four rare species, namely,* Deplanchea bancana, Illicium stapfii, Persea sterculiodes *and* Ficus laevis *were also collected together with some Bornean endemic species such as* Rhododendron lanceolatum, R. polyanthemum, R. suaveolens, Vaccinium clementis, Litsea opppositifolia, Cyclea robusta, Artocarpus melinoxylus, Ardisia livida *and* Scyphostegia borneensis. *Many more specimens were not identified to the species level.*

INTRODUCTION

A scientific expedition to the Kelabit Highlands at Bario was organized by the Universiti Malaysia Sarawak and the Department of Forestry, Sarawak with the objectives, among others, to document the rich and diverse flora of the Kelabit Highlands at Bario. The expedition began on 8 April and ended on 20 April 1995. Several collecting trips were undertaken along the following trails: Pa' Umor with some diversions to Sg. Dappur; Pa' Umor to Pa' Ukat; the quarry at Pa' Puak; behind the old and new airstrips; Alur Jalan to the water reservoir and in the vicinity of the base camp.

The Bario area which form the uppermost catchment of the Sg. Baram is quite close to the Kalimantan border. It sits on a plateau at about 1,100m above sea level surrounded by hills.

VEGETATION

The Kelabit Highlands constitute a flat plateau surrounded by hills, of which the highest peak is Gunung Murud. The local Kelabits are known for their successful and sustainable cultivation of a special wet rice "Beras Bario" and pineapple "Nenas Bario". As subsistence farmers they also grow vegetables and fruit trees.

The vegetation on the hills surrounding the Bario settlement was observed to be primarily composed of mixed dipterocarp forests. Human interference and economic activities could readily cause irreversible change and degradation of the natural forests transforming them into both wet and dry kerangas forests (Whitmore, 1975). Along the undisturbed rivers and streams of the Kelabit Highlands, reasonably long stretches of pristine riparian vegetations still occur. On higher elevations, especially on the trail leading to the peak of G. Murud, montane vegetation dominates. The soils were derived from both the accreting and non-accreting alluvium which are mainly constituted of poor sandy clays and shales alternating with sandstones (Liechti et al., 1960); typical of the Kelabit Formation. This type of soil is known to be able to support luxuriant growth of mixed dipterocarp forests. Limestone outcrops occur at several locations including the dominant landmark structure known as Gunung Batu Putih at Lawi-lawi.

CHECKLIST OF FLOWERING PLANTS

The specimens collected during the expedition were deposited at the Universiti Malaysia Sarawak, Universiti Kebangsaan Malaysia (UKMB), the Forest Department of Sarawak (SAR), and the Forest Research Institute at Kepong (KEP). Some collections, however, remained unidentified to the species level and one to the genus

level at the time when this account was written. Those that were identified were summarized by families in Table 1.

The following checklist is arranged alphabetically, the families are followed by species and notes on them.

Table 1. Summary of the taxa collected and observed.

No.	Family	No. genus	No. species
1.	Actinidiaceae	1	2
2.	Anacardiaceae	2	2
3.	Annonaceae	4	5
4.	Apocynaceae	1	1
5.	Aquifoliaceae	1	1
6.	Araceae	3	3
7.	Araliaceae	2	2
8.	Arecaceae	6	6
9.	Asclepiadaceae	1	1
10.	Asteraceae	3	3
11.	Begoniaceae	1	1
12.	Bignoniaceae	1	1
13.	Bombacaceae	2	3
14.	Burmanniaceae	1	2
15.	Caprifoliaceae	1	1
16.	Casuarinaceae	1	1
17.	Celastraceae	1	1
18.	Chloranthaceae	1	1
19.	Clethraceae	1	1
20.	Clusiaceae	3	4
21.	Cyperaceae	2	2
22.	Dilleniaceae	1	1
23.	Elaeocarpaceae	1	1
24.	Ericaceae	3	9
25.	Euphorbiaceae	7	11
26.	Fabaceae	5	5
27.	Fagaceae	3	3
28.	Flacourtiaceae	1	1
29.	Gesneriaceae	1	1
30.	Hanguanaceae	1	1
31.	Hypoxidaceae	1	2
32.	Illiciaceae	1	1
33.	Junglandaceae	1	1

34.	Lauraceae	7	9
35.	Liliaceae	1	1
36.	Linaceae	2	2
37.	Loganiaceae	2	2
38.	Loranthaceae	3	3
39.	Marantaceae	3	3
40.	Melastomataceae	7	10
41.	Menispermaceae	2	2
42.	Moraceae	3	12
43.	Myrsinaceae	2	4
44.	Myrtaceae	3	7
45.	Nepenthaceae	1	2
46.	Ochnaceae	1	2
47.	Oleaceae	1	1
48.	Pandanaceae	1	3
49.	Piperaceae	1	1
50.	Polygalaceae	1	1
51.	Rhamnaceae	2	2
52.	Rosaceae	2	3
53.	Rubiaceae	10	15
54.	Rutaceae	1	1
55.	Santalaceae	1	1
56.	Sabiaceae	1	1
57.	Sapindaceae	1	2
58.	Scyphostegiaceae	1	1
59.	Simaroubaceae	1	1
60.	Smilacaceae	1	1
61.	Solanaceae	1	1
62.	Staphyleaceae	1	1
63.	Symplocaceae	1	1
64.	Theaceae	4	5
65.	Urticaceae	1	1
66.	Vitaceae	3	8
67.	Winteraceae	1	1
68.	Zingiberaceae	4	5
	Total	143	197

1. **ACTINIDIACEAE**

Two species of *Sauraia* were collected and remained unidentified.

1.1 *Saurauia* sp. 1 (ALM 4290). Along the trail to Alur Jalan. Shrub of 3m., fruits capsule, hairy, 3-valved.

1.2 *Saurauia* sp. 2 (ALM 4182). Track to Pa' Umur. Tree of 5m., fruits on branches about 3cm. diameter, peduncle long, glabrous, white.

2. **ANACARDIACEAE**

On Kelabit highlands members of Anacardiaceae apparently were scarce, only the fruits of *M. odorata* were observed in the local store on sale, presumably originated from the village orchards in Bario.

2.1 *Mangifera odorata.* Fruits large, grey, globose, about 15cm. diameter, flesh yellow, fibrous and sweet.

2.2 *Campnosperma auriculata.* Observed.

3. **ANNONACEAE**

3.1 *Annona muricata.* Cultivated in the villages.

3.2 *Alphonsea* sp. (KMS 4587) Track to Pa' Umor.

3.3 *Friesodielsia* sp. (KMS 4576) Track to Pa' Umor. Climber, common.

3.4 *Goniothalamus fasciculatus* Boerl. Observed along Alur Jalan.

3.5 *Goniothalamus longistipites* Mat-Salleh ined. (KMS 4617, 4624) In the hills near Kg. Baru. Endemic to Sarawak.

4. **APOCYNACEAE**

4.1 *Alstonia angustifolia* Wall. ex A.DC. (ALM 4265). Near the new airstrip. Common.

5. **AQUIFOLIACEAE**

5.1 *Ilex sclerophylloides* Loesener (ALM 4208). Track to Pa' Umor. Common at high altitude.

6. **ARACEAE**

6.1 *Amorphophallus* sp. Observed along the trail to Alur Jalan.

6.2 *Homalomena propinqua* Schott. (ALM 4258). Trail to Pa' Puak quarry. Common.

6.3 *Scindapsus* sp. (ALM 4242). Trail to Pa' Ukat. Herb of 30cm with spadix, *ca.* 8 by 1cm.

7. ARALIACEAE

7.1 *Arthrophyllum* sp. (ALM 4180). Track to Pa' Umor. Shrub of 1m., with fruits; leaves almost orbicular, apex rostrate.

7.2 *Schefflera* sp. (ALM 4305). Trail beyond the new airstrip. Treelet of 3m., leaves trifoliolate, alternate and infructescence terminal.

8. ARECACEAE

Only two palms were collected and the others were observed.

8.1 *Pinanga* sp. (ALM 4312). Beyond the airstrip. Palm of 1m., fruits ellipsoidal at the trunk base, reddish. Very elegant and promised a great pontential for potting plants.

8.2 *Plectocomia muelleri* Bl. (ALM 4225). Track to Pa' Umor. An elegant palm with long pleated inflorescence.

8.3 *Eugeissona tristis*. Observed. This is an element normally present whe n the forest is cleared.

8.4 *Licuala* sp. Observed near the paddy fields. Seems quite allied to the more common *L. spinosa.*

8.5 *Calamus* sp. Observed.

8.6 *Korthalsia* sp. Observed.

9. ASCLEPIADACEAE

9.1 *Dischidia* sp. (ALM 4191). Track to Pa' Umor, at elevation 1,115m, in kerangas forest; scrambler with white latex, flowers pinkish purple; leaves very tiny *ca.* 1.0 by 0.8cm, ovate.

10. ASTERACEAE

10.1 *Blumea balsamifera* (L.) DC. (ALM 4260). Trail to Pa' Puak quarry. A common weed.

10.2 *Erechthites valerianifolia* (Wolf) DC. (ALM 4236). Trail to Pa' Ukat. A common weed in open highland habitats.

10.3 *Vernonia arborea* Buch.-Ham. (ALM 4173, KMS 4582). Track to Pa' Umor. The only tree species in the family and very common throughout western Malesia.

11. BEGONIACEAE

11.1 *Begonia* sp. (ALM 4282). Along the track to Alur Jalan.

12. BIGNONIACEAE

12.1 *Deplanchea bancana* (Scheff.) Steen. (ALM 4233). Just a little away from the base-camp along the trail to Pa' Umor. An elegant tree with large showy yellow flowers. Apparently rare.

13. BOMBACACEAE

13.1 *Durio oxyleyanus* Griff. Observed along the track to Pa' Umor.

13.2 *Durio zibethinus* Murray. Observed planted in orchard.

13.3 *Ceiba pentandra.* Observed.

14. BURMANNIACEAE

14.1 *Burmannia disticha* L. (ALM 4199). Track to Pa' Umor. Rare, herb confined to highlands.

14.2 *Burmannia gracilis* Ridley (KMS 4592). Track from Pa' Umor to Pa' Ukat.

15. CAPRIFOLIACEAE

15.1 *Viburnum sambucinum* Bl. (ALM 4241). Trail to Pa' Ukat. Common in hill and montane forests.

16. CASUARINACEAE

16.1 *Gymnostoma sumatrana* (Jungh. ex de Vriese) L.A.S. Johnson (ALM 4246). In the dry kerangas along the trail to quarry at Pa' Puak. Common and very elegant.