SOIL

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8. SOILS

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INTRODUCTION

Before the 1977-78 expedition, soil observations in the Gunung Mulu National Park had been very scanty. Wall (1965) climbed the mountain, and described and named the montane peat soils of Mulu family. The only other pedological observations at the higher altitudes were those made by Baillie during a brief visit to the mountain in 1972. The soils of the lowland parts of the Park were slightly better known. Brunig had examined some of the soils on the higher Medalam terraces during his ecological studies of the Sarawak kerangas forests (Brunig, 1974). The soils of the lower parts of the Melinau valley were surveyed by the Canadian International Development Agency team, as one of their sample areas, for the soils reconnaissance of North Sarawak (Eilers and Loi, 1982).

These patchy data were insufficient to give a clear idea of the pedological variation in the Park. In particular there was insufficient information on the soil variation with altitude on the clastic sedimentary rocks of Gunung Mulu itself.

Soil data from other north Sarawak mountains are also scanty. Moreover, they are mostly from intermediate and basic volcanic rock outcrops, and are therefore not directly relevant to Mulu (Beckett and Hopkinson, 1961; Eilers and Loi, 1982).

The aim of the pedological work during the 1977-78 expedition was to characterise the main soils of the Park, and to indicate their variation and distribution, particularly in relation to other aspects of the Park environment.

DATA COLLECTION

The soils of the lowland areas in the western part of the Park were surveyed at semi-detailed level, according to normal Sarawak procedures. Compass traverses were planned by pre-interpretation of the aerial photographs and geological maps. The traverses were aligned to cut across the main geological, topographic and vegetational trends of the area. They were cut and pegged under the supervision of Agricultural Assistants. The soil surveyors examined the soils along the lines by free survey. Edelman augerings were taken to the lithic contact or one metre depth, at points indicated by the main discontinuities in the topography or vegetation. The augering interval usually averaged out at about 75-100 m. Profile pits were described and sampled in order to give more details of the main soils encountered.

In the mountainous eastern part of the Park, constraints of time and access precluded such detailed and systematic soil survey. Instead, the main effort was concentrated on an examination of the altitudinal sequence of soils found on the clastic sediments of the Mulu Formation. Particular attention was paid to the soils of the biological plots along the main West Ridge path to the summit. These plots were originally established during the botanical zonation study of the West Ridge (Martin, 1977). Some of them were reopened for soil zoological studies by Dr N.M. Collins during the expedition. The soil zoological zonation plots consisted of five parallel 30 m lines running more or less at right angles to the path. For the characterisation of the soils a profile pit was described and sampled on each of lines 1, 3 and 5 of the plot. The soils of lines 2 and 4 were examined by Edelman augering.

In addition, less detailed examinations were made of the off-ridge soils on the upper slopes of the Tapin watershed, the sandstone soils of the Northeast Ridge, and the limestone soils up the Api Pinnacles path.

The soil samples were analysed at the laboratory of the Agricultural Research Centre, Semongok, using the methods described by Sim (1965), except that atomic adsorption is now used for cation determination, rather than flame emission photometery or titration.

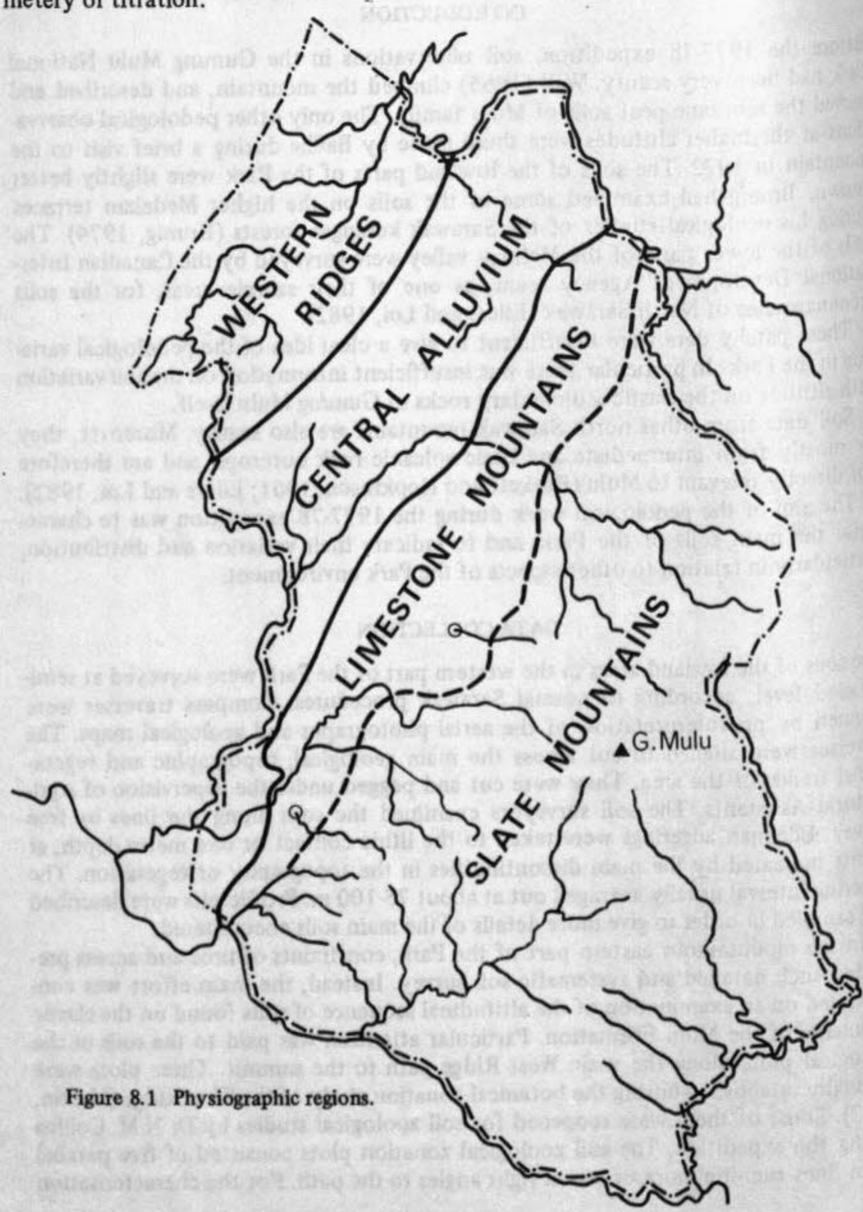

Figure 8.1 Physiographic regions.

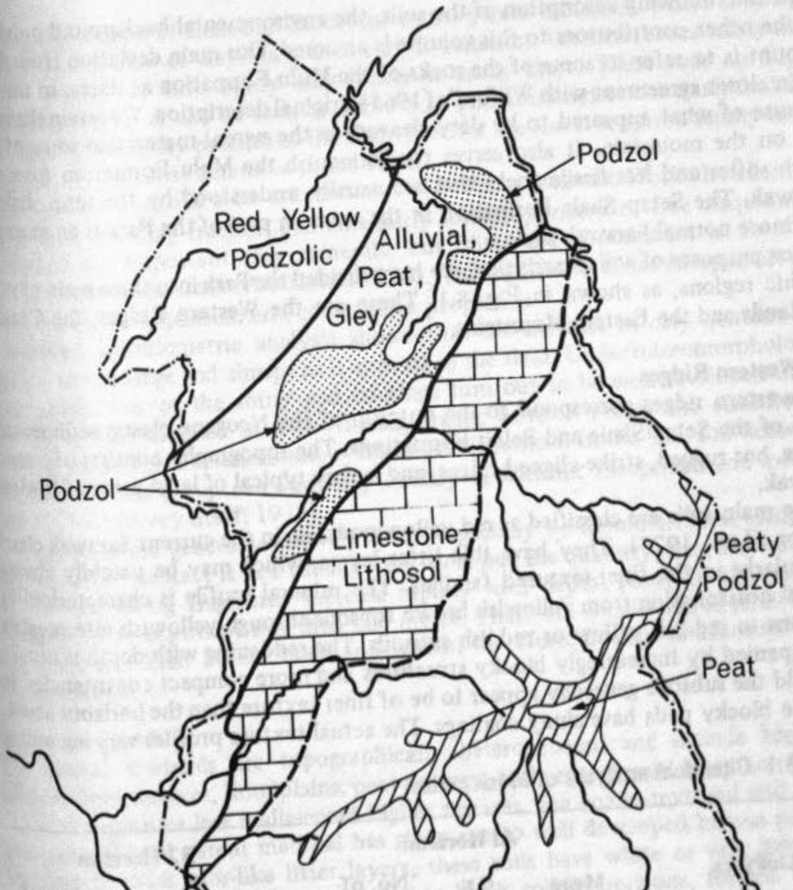

Figure 8.2 Soil regions.

THE SOILS

A full account, including large scale maps, of the soils work during the 1977-78 expedition has been issued by the Sarawak Department of Agriculture (Tie *et al*., 1979). Those requiring further data than is given in this account are referred to that publication; a map at 1: 50,000 scale is to be found in the end pocket of this volume.

In the following description of the soils, the environmental background provided by the other contributors to this volume is assumed. Our main deviation from their account is to refer to some of the rocks of the Mulu Formation as slates. In this we are in closer agreement with Wilford's (1961) original description. We retain the term because of what appeared to be slaty cleavage in the parent material in some of the pits on the mountain. It also serves to distinguish the Mulu Formation from the much softer and less fissile rocks that are usually understood by the term shale in Sarawak. The Setap Shale Formation in the western part of the Park is an example of a more normal Sarawak shale.

For purposes of soil description, we have divided the Park into three main physiographic regions, as shown in Fig. 8.1. These are the Western Ridges, the Central Lowlands and the Eastern Mountains.

The Western Ridges

The western ridges correspond to the outcrop of the Neogene clastic sedimentary rocks of the Setap Shale and Belait Formations. The topography consists of a series of low, but rugged, strike-aligned ridges, and is very typical of large areas of lowland Sarawak.

The main soils are classified as red yellow podzolic in the current Sarawak classification (Lim, 1975). They have thin litter layers, which may be patchily absent, particularly in the finer-textured families. The mineral profile is characterised by gradual horizonation from yellowish brown topsoils through yellowish intermediate horizons to reddish yellow or reddish subsoils. The reddening with depth is usually accompanied by increasingly blocky structures and more compact consistencies. In the field the subsoils generally appear to be of finer texture than the horizons above, and the blocky peds have shiny coatings. The actual texture profiles vary according

Table 8.1 Chemical analyses of Merit series.

	Al Horizon			B2 Horizon		
Analyses	**Mean**	**S.E.**	**No. of samples**	**Mean**	**S.E.**	**No. of samples**
Clay (%)	30.6	4.8	4	36.7	2.1	8
pH (H_2O)	4.5	0.3	4	4.5	0.3	8
C (%)	2.87	0.90	3	0.28	0.11	7
N (%)	0.22	0.04	3	0.04	0.01	8
C:N	13	2	3	7	1	9
Ext. Ca (me/100g)	0.50	0.03	3	0.52	0.02	7
Ext. Mg (me/100g)	0.08	0.01	2	0.04	0.03	7
Ext. K (me/100g)	0.06	0.04	3	0.06	0.02	7
CEC (me/100g)	14.93	2.16	3	7.93	1.50	6
Base Sat. (%)	4.5	0.8	3	9.1	2.5	5
Av. P (ppm)	4	5	3	1	0	7
'Reserve' Mg (ppm)	1159	282	4	1863	323	8
'Reserve' K (ppm)	3004	781	4	4652	1042	7
'Reserve' P (ppm)	114	6	4	66	21	8
P Retention (%)	63.1	9.1	4	44.6	6.3	7
Group III oxides (%)	–	–	–	11.54	2.46	8
Free Fe_2O_3 (%)	–	–	–	3.08	0.65	8

to the proportions of shale and sandstone in the parent materials. Where shales predominate, a profile of clay loam over clay is common. On sandstones sandy loam topsoil may grade into sandy clay loams or sandy clays. These soils are highly leached and acid, as can be seen in Table 8.1. This summarises the analytical data from the Merit family profiles in the Park. Merit is the finest-textured family in this group, and is the most extensive in the Park.

Red yellow podzolic soils are common in lowland Sarawak. Work elsewhere has shown that the clay fraction contains fairly low proportions of free sesquioxides. Kaolinites are important clay minerals, but illites are codominant in the finer-textured soils from shale (Andriesse, 1975). The significant illitic component gives rise to moderate expansion and contraction properties.

Detailed granulometric analysis shows that the increase in clay content with depth is not as large and abrupt as it appears in the field. Under micromorphological examination few of the shiny ped coatings turn out to be well-developed illuvial clay skins. This absence of a convincing argillic horizon makes the classification of these soils in global taxonomic systems problematical. In the U.S. soil taxonomy members of this group can variously qualify as Ultisols, Inceptisols and a few as Oxisols (Soil Survey Staff, 1975).

These soils are generally not very deep, especially by humid tropical standards. The paralithic contact is not usually very clear but the quantity, size, and hardness of the weathering fragments increase rapidly with depth. Many of the soils are unaugerable at depths of less than one metre. There are small areas of related soils which are less than 50 cm deep and which, therefore, qualify as lithosols of the Meluan family.

Central Lowlands

The central lowlands are topographically heterogeneous and include high and medium level terraces, floodplains, peat swamps, and protruberant limestone hills.

On the more or less undissected higher terraces, the coarse-textured and highly quartzose alluvial parent material has given rise to well developed humus podzols. Underneath thick mor-like litter layers, these soils have white or very light grey eluvial horizons overlying dark brown or black spodic horizons, formed by the deposition of illuvial organic matter. Some of these spodic horizons are extremely indurated and impermeable. The resultant lack of surface drainage has led to the formation of very wet secondary woody peats. Because of the extremely quartzose parent material, these soils are of very low chemical fertility. They carry the highly distinctive and adapted kerangas forest.

There are also extensive floodplains and recent, low-level terraces in the central lowlands. These sediments are predominantly fine grained, in contrast to the older terrace deposits. The soils of the floodplains are very heterogeneous, varying considerably over short distances according to local conditions of drainage and parent material. The most extensive soils are the alluvial soils. These are imperfectly drained with gley horizons, if present, found only below 50 cm. They are predominantly fine-textured, although there may be considerable textural variation down the profile. This stratification is almost entirely inherited from the depositional history of the parent material, and is not due to argilluviation. These soils are leached and acid, but are slightly more fertile than the red yellow podzolic soils of the hills. Subsoil pH may rise as high as 6, and base saturation, as measured at pH7, may exceed 20%.

There are also extensive areas of poorly drained gley soils in the lower parts of the floodplain. In some of the more or less stagnant low-lying back-swamp sites, there are also some very wet woody peat deposits. These may be up to 3 m deep in places.

There are some steep-sided limestone hills protruding up through the alluvial deposits. They vary considerably in size, some of them only a few metres in each direction, and some over a kilometre in length and with local relief of almost 200 m. All slopes are extremely steep and rugged, and there is little soil cover except for pockets of organic material in between boulders and pinnacles. On the whole these limestone outcrops appear to have surprisingly little chemical effect on the surrounding alluvial soils.

The central lowlands of the Park are similar in many ways to other alluvial landscapes in the interior of Sarawak. One local peculiarity is the apparently erratic fluctuations in base level, possibly indicating recent tectonic adjustments. As well as the general relative depression of base level and the formation of terraces, there are also places where base level appears to have risen. For example, on the Forest Ecology Group's alluvial forest plot there is an apparently drowned humus podzol. This profile morphology was presumably initially developed during a free draining and intense leaching moisture regime. Now, however, it is influenced by the generally high water table conditions of the local area. Its spodic horizon is below the water table and wet, woody peat is developing at the surface.

The Eastern Mountains

This physiographic region can be subdivided into the limestone massifs and the shale and slate mountains and ridges, as shown in Fig. 8.1.

Soil fieldwork on the limestone was limited to a brief examination of the soils of the limestone forest ecological plot and up to the Api Pinnacles path.

Because of the purity of the Melinau limestone there is little residuum for soils formation after solution weathering. Much of the land surface is bare rock, weathered into a variety of surface forms. The soils are mostly shallow pockets of mixed organic matter and limestone rubble in crevices between pinnacles and boulders. Unlike the woody peats of the lowlands or the mossy peats of the higher altitudes on Gunung Mulu, the organic matter is eutrophic.

There are some small areas where ferruginous impurities or cements in the limestone have given rise to the shallow and stony reddish brown blocky clays. These are very different from any other mineral soils in the Park. They are of neutral reaction and appear to be almost wholly base saturated, with calcium, of course, as the dominant exchangeable cation. The fine earth contains very high proportions of HCℓ – extractable Group III sesquioxides, and the free Fe_2O_3 content is 10 – 15% (compared with 5% in the red yellow podzolics on clastic sediments). As well as a good base status, these soils have high reserve phosphorus contents and appear to be chemically the most fertile soils in the Park.

As soil development is everywhere so rudimentary, little altitudinal zonation is apparent in the limestone soils. The organic litter appears to be thicker and more moder-like above about 1000 m, but even here bare rock predominates.

This contrasts strongly with the marked altitudinal zonation of the soils on Paleogene clastic sediments of the Mulu Formation. Much of this area is below 1000 m and is covered with various types of mixed dipterocarp forest. The soils on these lower slopes are morphologically and chemically similar to the red yellow podzolic soils of the western ridges. The main morphological differences are the tendency to less distinct horizonation, the more erratic variation in stone content with depth, and the deeper sola. The weaker profile development qualifies these soils for the Tutoh family of regosols in the Sarawak classification (Lim, 1975). This generally rudimentary horizonation is thought to be due to the high frequency of disturbance of the regolith by mass movements (Day, 1979) and to reflect the considerable mobility and depth of the colluvium on the long and steep slopes. Chemically these soils appear to be more or less indistinguishable from the red yellow podzolic soils.

The main morphological changes with increasing altitude are the accumulation of surface peat and increasingly severe gleying of the upper mineral horizon. At 1000-1200 m the peat is usually about 10-12 cm deep and overlies a strongly mottled mineral horizon of about equal thickness. This grades into a well-drained subsoil horizon that is very similar to those of the Tutoh family of regosols downslope.

By 1500 m the peat is often as thick as 50 cm, and the upper mineral horizon is a truly gleyed, wet and sticky clay. This horizon may be as much as 30 cm thick. The transition to the underlying well drained and brightly coloured clay subsoil is usually abrupt and rather wavy. It is frequently marked by a distinct thin iron pan, which is usually black or dark brown on the upper surface but grades to reddish or strong brown on the lower side. The pan is often coherent and continuous and marks a line of seepage in profile faces and it clearly impedes downwards percolation. There may be multiple pans, but the upper one is usually the best developed and the most continuous. The pans may be extremely convoluted.

These soils have not been described before in Sarawak, and have been named as Tumau family (after Bukit Tumau on Mulu's West Ridge), and provisionally assigned to the group of gley soils. They are similar in morphology, and probably in genesis, to the peaty gley podzols or stagnopodzols of upland Britain. As with the British soils, the peat is thought to be initially climatogenic. Its sponge-like nature keeps the upper mineral horizons more or less perpetually moist, causing mobilisation of some iron. This iron is redeposited as a pan at the top of the better drained subsoil. Once well formed, the pan acts as a barrier to percolation, and thus intensifies the poor surface drainage conditions initially responsible for its formation (Crompton, 1956).

On the upper slopes and summit of Mulu, the decrease in rainfall (Walsh, Chapter 3, this volume) is more than offset by the reduced temperatures and evapotranspiration. Surface conditions are very wet, and the depth of mossy peat increases. These climatogenic peats blanket the entire surface above about 1800 m and peats of more than 50 cm depth were found even on the slopes steeper than 25 degrees. The peat often lies directly over more or less unweathered shale or slate, but there may be a thin intervening horizon of wet, grey, structureless clay. This horizon may be rust mottled, but there are no continuous iron pans. These deep peats are those that were described and named as Mulu family by Wall in 1965.

The surface peats of Tumau and Mulu families are oligotrophic with pH values below 4 and low contents of plant nutrients, as can be seen in Table 8.2. The underlying mineral horizons are leached and acid, but are thought to be less weathered than the subsoils of the low altitude soils.

There appears to be a marked association between the main soils and the main types of vegetation. The red yellow podzolic soils and regosols of the lower slopes are associated with mixed dipterocarp forest. The peaty gley podzols of Tumau family more or less coincide with the lower montane forest. The transition to the peats of Mulu family is parallelled by a vegetation change to the more stunted upper montane forest.

As with the forest types, the altitudinal boundaries of the main soils vary with the local topography. The boundaries tend to be depressed on exposed ridge and

Table 8.2 Chemical analyses of surface peats of Mulu family.

Analyses	Mean	Standard error	Range	No. of samples
$pH(H_2O)$	3.5	0.4	3.0 – 4.3	12
N (%)	1.30	0.50	0.77 – 2.24	10
Ext. Ca (me/100g)	0.11	0.15	0.05 – 0.60	12
Ext Mg (me/100g)	0.38	0.27	0.08 – 0.90	12
Ext. K (me/100g)	0.30	0.19	0.03 – 0.56	12
CEC (me/100g)	61.9	11.5	44.0 – 81.4	11
Base Sat. (%)	2.3	2.6	0.5 – 9.2	11
Av. P (ppm)	61	17	38 – 80	6
Av. Fe (ppm)	62	19	34 – 86	7
Av. Cu (ppm)	1.10	0.72	0.48 – 2.66	7

spur crests and elevated in sheltered valley head sites. Thus the Tutoh/Tumau family boundary may be as low as 1200 m on the main ridges, but as high as 1450 m on the mid slopes of the Sungai Tapin valley.

The main soils of the Park are summarised in Table 8.3; and the approximate distribution of the main soil regions is shown in Fig. 8.2.

DISCUSSION

The lowland soils of the western part of the Park are similar to many other areas of Sarawak. Detailed surveys, descriptions and discussions of similar soil assemblages can be found in the publications of the Sarawak Soil Survey Division and in, for example, Andriesse (1975).

The eastern mountains represent a much less common type of Sarawak landscape. There are other areas of limestone mountains, but those of Mulu are the highest and most extensive in the state. It is thought that the only large area comparable with the slate and shale mountains of Gunung Mulu itself is probably the Gunung Murud range. This is very inaccessible and little visited, and there is no soils data from the area yet available.

The altitudinal sequence of soils on Mulu therefore cannot be compared with other localities in Sarawak. However, there is sufficient data from other mountains of siliceous rock in South-east Asia to suggest the Mulu sequence of lowland soils – peaty gley podzols – peats is quite common. The most comprehensive studies of montane soils in Malaysia have been by Burnham (1974, 1978). His detailed work on granite soils shows a very similar sequence, with particularly well-developed peaty gley podzols marked by prominent and continuous iron pans. His data from sedimentary rocks are less extensive, but they suggest that there is considerable variation with grain size and soil permeability. In the finer-textured soils the intermediate altitude soils tend towards peaty gleys, with less prominently well-drained subsoils and iron pans. On the more coarse grained sandstones, there are often well-developed humus or humus/iron podzols. The organic surface material in these soils is somewhat drier than those on finer grained rocks and may be classed as 'Hydromor' rather than peat (Burnham, 1978).

The occurrence of mid-altitude podzols on sandstones is confirmed by observations on the North-east Ridge of Mulu. This differs from the more closely examined

Table 8.3 Main soils of Gunung Mulu National Park.

Group	Characteristics	Distribution in Park	Main families in Park	Extent in Park* Km²	Extent in Park* % of Park
Red yellow podzolic soil	Leached, acid, well drained, moderately deep, moderately horizonated mineral soil	Western ridges and lower slopes of Mulu	Merit (clay) Bekenu (silt) Nyalau (loam)	100	18
Podzol	Mor humus over bleached sand over black illuvial organic horizon	High and medium terraces	Miri (indurated) Buso (non-indurated)	45	8
Alluvial soil	Well or imperfectly drained, poorly horizonated mineral soil	Low terraces and floodplain	Seduau (clay) Bemang (loam)	40	7
Gley soil	Poorly drained mineral soil	Floodplain	Bijat (clay)	25	5
Lithosol	Shallow, humose or clay soil over limestone	Limestone hills and mountains	Meluan	70	13
Regosol	Poorly horizonated, well drained, leached, acid, sometimes stony	Lower slopes of Mulu	Tutoh	245	45
Gley (peaty gley podzol)	Peat over wet clay over thin iron pan over reddish well drained clay	Midslopes of Mulu	Tumau	14	3
Organic (peat) soils	(a) Woody peat	Floodplain backswamps	Anderson (deep) Mukah (shallow	5	1
	(b) Moss peat	Upper slopes of Mulu	Mulu	1	Tr
			Total	545	100

*includes estimates from compound mapping units.

West Ridge in that quartzitic fine and medium grained sandstones outcrop from about 500 to 1700 m. A feature of the North-east Ridge is the occurrence of a belt of weakly developed and shallow humus podzols at about 1100 to 1400 m. Downslope these soils grade into coarse-textured red yellow podzolic soils, and upslope into peaty gley podzols. This insertion of non-gleyed podzols between the lowland soils and the peaty grey podzols is also confirmed by Askew's (1965) observations on the sandstones of the east ridge of Kinabalu in nearby Sabah.

Work from further afield also confirms the general sequence found on Mulu. For example, a similar set of soils has been described at intermediate altitudes on siliceous rocks in the wetter parts of New Guinea (Reynders, 1964; Haantjens *et al.*, 1967).

It is clear that there is much pedological work to be done in the Park which is likely to prove a particularly valuable study area for three groups of soils. These are the montane soils on the clastic sediments of Gunung Mulu itself, the lithosols of the limestone mountains and the alluvial and gley soils of the floodplain. These floodplain soils are not unique to the Park but, as was repeatedly brought out at the symposium following the 1977-78 expedition, other areas of these soils in Sarawak have almost entirely been cleared for agricultural production, especially wet-land rice. The floodplain areas of the Park represent one of the largest remaining tracts of such soils still under forest. For this and all the biological conservation reasons, it is to be hoped that the floodplain and its forest will not be unduly disturbed by development of the Park facilities.

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