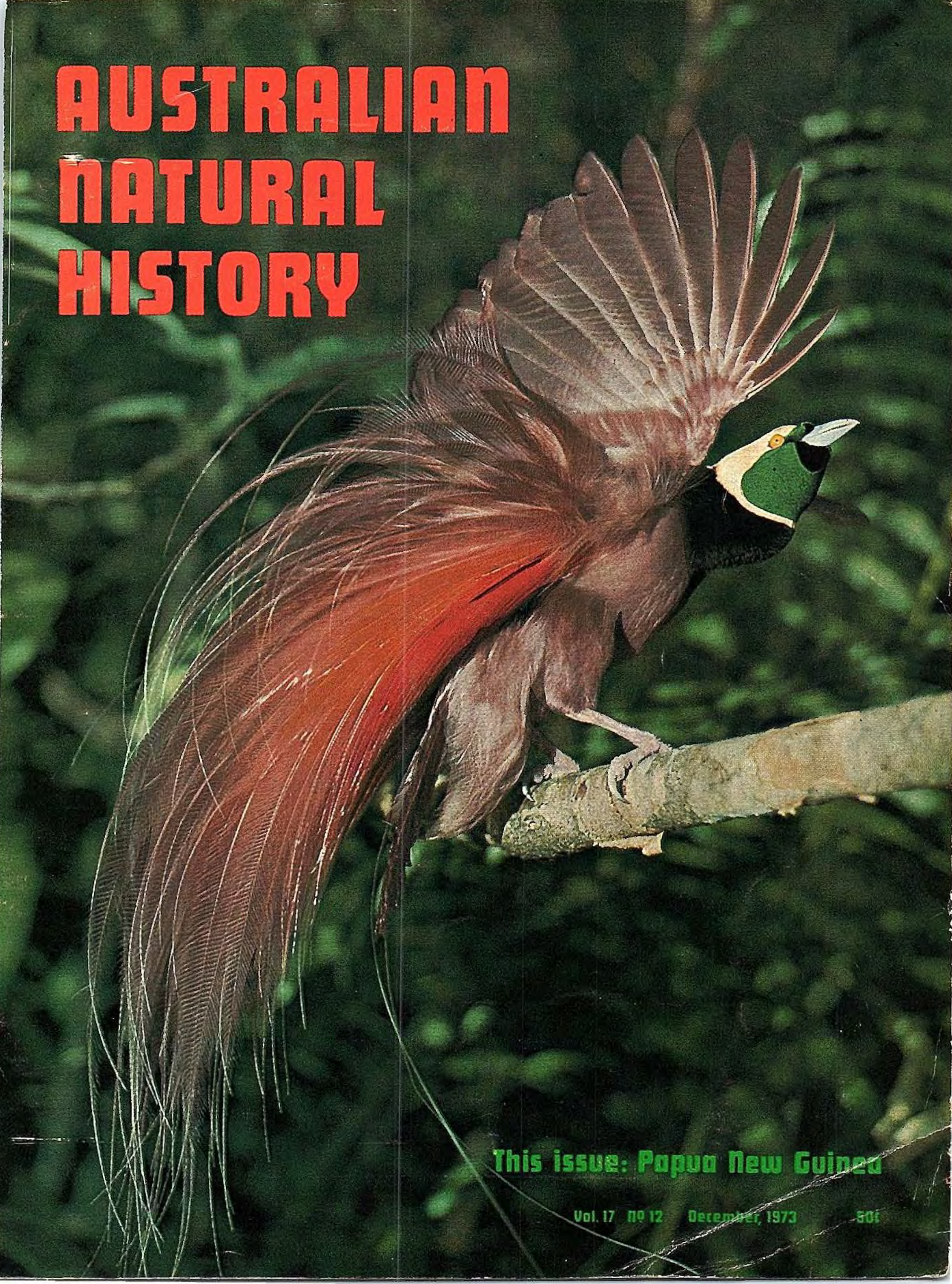
AUSTRALIAN NATURAL HISTORY



This issue: Papua New Guinea

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AUSTRALIAN NATURAL HISTORY

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VOL. 17, NO. 12 — DECEMBER 15, 1973

This issue is devoted to the natural history of Papua New Guinea. It contains 40 extra pages.

CONTENTS

● **FRONT COVER: The Raggiana Bird-of-Paradise (*Paradisaea raggiana*) is to be found in south-central and eastern Papua New Guinea and is a common rainforest bird of the lowlands. It is probably the most likely long-plumed bird-of-paradise to be seen by visitors, as it is still found in odd remaining patches of rainforest around Port Moresby. It is usually the females and immature males which are seen; adult males are not very common and are usually found close to their selected trees in which they display. The birds feed on fruit. [Photo: W. Peckover]. BACK COVER: The Kaironk Valley, which lies between the Bismarck and Schrader Ranges in Papua New Guinea, was a major collecting site for an Australian Museum expedition to study reptiles and frogs in 1963–64. These two children from the valley displayed an outstanding knowledge of local animals and plants. There is a great need to document such knowledge before it is lost because of increasing acculturation. [Photo: H. G. Cogger.]**

FOREWORD

By Michael Somare, Chief Minister of Papua New Guinea

Papua New Guinea has the task of rebuilding many of the values which have been destroyed through the process of colonization. Papua New Guinea also has the task of studying the flora and fauna which are threatened with extinction by the process of modernization. In these tasks the Public Museums of Papua New Guinea play a vital role in preserving the country's inheritance and saving a nation from irretrievably losing its past, since it is on this past that the future must be built.

The Government does not support museums in order to amaze and amuse overseas visitors with displays of "primitive culture" or the natural resources of a "tropical paradise." The prime focus of the museums is to preserve for present and future generations our very rich heritage—one of which all Papua New Guinea should be proud.

In order to fully meet this requirement the Trustees of the Papua New Guinea Public Museum and Art Gallery are developing as rapidly as possible a comprehensive plan which will ensure that major art works and significant natural history collections remain within the country. At the same time, training programmes are being implemented which will produce well-equipped educational officers, conservators and preparators.

The development of regional museums is scheduled for the near future. These institutions are being designed to fulfil the immediate needs of regional populations and to make a meaningful contribution to the educational system. These museums will have the further responsibility of involving and inspiring our people by presenting the people's heritage in its true dignity.

I believe that museums in my country have an important part to play, not only in protecting our national treasures and investigating our plants and animals, but also in creating a national identity by making our people appreciate the importance of Papua New Guinea. I believe that museums will also bring home to Papua New Guineans the realization that we are basically one nation, unified by our culture and our geography, rather than divided by them.

THE PHYSICAL GEOGRAPHY OF PAPUA NEW GUINEA

By DAVID LEA
Professor of Geography, University of Papua New Guinea

NEW GUINEA, the second largest island in the world, lies between the equator and 11° S. latitude. It forms part of a great arc of unstable fold mountains, the Circum-pacific Fire Belt, which extends through Asia and Indonesia into the Pacific Ocean (see figure 1). Situated near the Wallace Line between Asia and Australia, New Guinea offers many interesting comparisons with both these continents and acts as a biogeographical transition zone between the two landmasses.

Although it lies completely within the tropics, the island has a wide variety of physical conditions, varying from hot, wet, swampy lowlands to high alpine grasslands; outlying islands vary from tiny coral atolls to large continental-type islands, such as New Britain. The dominant physical feature is the Central Cordillera, which laterally divides the island. The coastline is frequently bordered by impenetrable mangrove swamps, or it may rise from a coral reef directly to steep mountains; good harbours and the wide, white-sand beaches of the tourist brochures are rare. Inland, mighty ranges with steep slopes and jagged ridges contain lovely intermontane valleys, often densely populated.

Papua New Guinea can conveniently be divided into five physiographic regions: the south coast, the Central Cordillera (which is the backbone of the island), the northern intermontane trough, the northern mountains, and the islands (see figure 2).

The south coast

In southwestern Papua, the Oriomo Plateau is west of Daru and south of the Fly River. It is only about 80 metres (about 260 feet) high and largely covered with alluvium. Unlike most of the rest of New Guinea, which is geologically young and liable to frequent and severe earthquakes, this area is very stable and is in fact an extension of the ancient Australian continental rocks which underlie the shallow waters of Torres Strait. The plateau itself is mainly grassland, with some eucalypt and pandanus scrub.

North of the Oriomo Plateau the great delta plains of the Fly, Bamu, Turama, Kikori, and Purari Rivers form part of one of the most extensive swamps in the world. For 32 km (20 miles) inland from the coast very little land rises above high-tide level. Mangrove forest extends along the coast and, where the water is brackish, nipa swamps are characteristic. Further inland these communities are replaced by sago swamps, swampy grasslands, reed marshes, and lakes, the largest of which is Lake Murray.

East of the Kukukuku Lobe the coastal plain narrows and there are only narrow marshy stretches between the coast and the foothills of the Central Cordillera. Subsidence has resulted in some good harbours, such as Port Moresby, and a few fringing and barrier coral reefs are found along this section of the coast.

The Central Cordillera

Inland from the south coast is a zone of foothills which often rise in tiers to the Central Cordillera, although near Kerema the Kukukuku Lobe comes very close to the coast, as do the mountains east of Port Moresby. There has been much faulting in the southern foothills and old volcanic mountains, such as Mt Bosavi (with its radial drainage pattern), Mt Favenc, Mt Giluwe, and Mt Murray, are prominent. Karst landforms occur between the Strickland and Purari Rivers, and the sheer limestone walls, sink-holes and subterranean rivers make transportation and agriculture extremely difficult.

The Central Cordillera consists of a series of ranges, roughly parallel to each other. All the ranges are extremely steep and rugged, and the highest peak in Papua New Guinea is Mt Wilhelm (4 450 metres or about

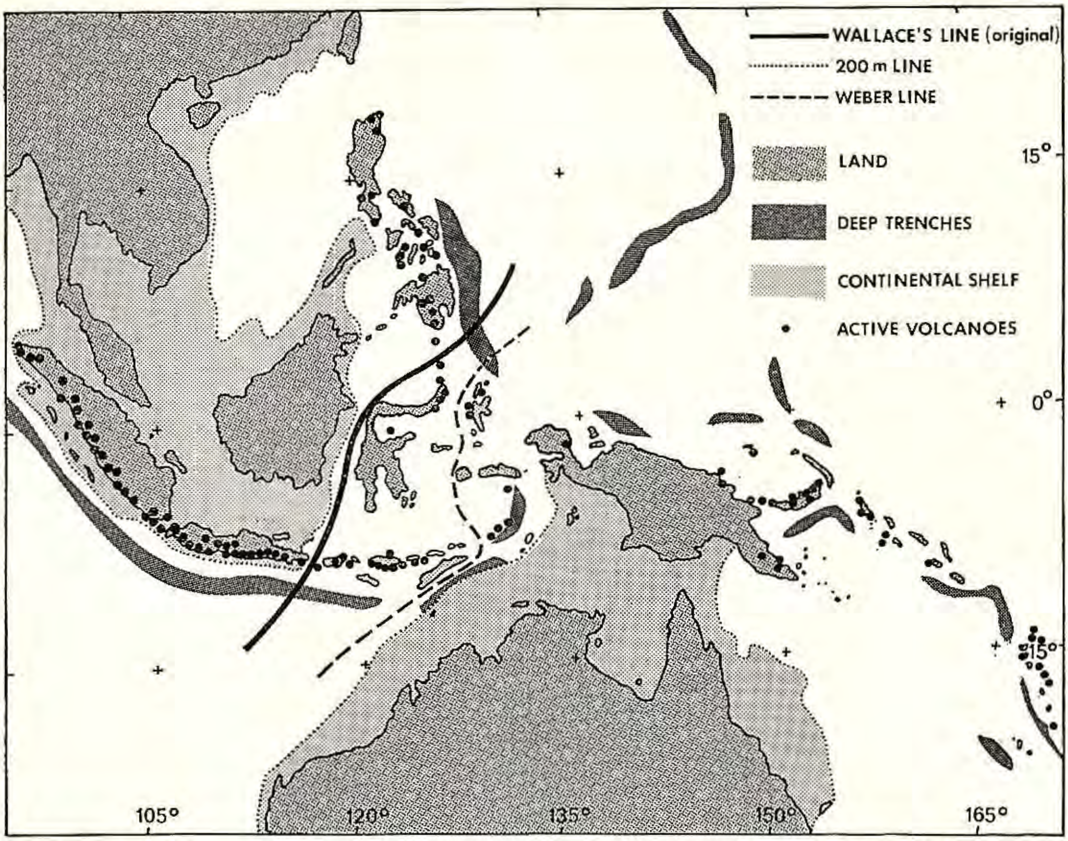

Figure 1.—A generalized map showing the location of New Guinea between Asia and Australia and its position in relation to the belts of tectonic instability (incidated here by volcanoes and deep oceanic trenches).

14,600 feet) in the Bismarck Ranges; the Kubor, Schrader, Central Star, Hagen, Kratke and Owen Stanley Ranges all have peaks over 3 000 metres (about 9,840 feet) high. Many of the ranges between Kainantu and Wabag are separated from each other by broad, grass-covered, highland valleys which have mild, equable climates. These valleys are some of the most densely populated areas in New Guinea.

The main range passes southeasterly through Papua, where it is generally lower than the cordillera to the west and is known as the Owen Stanley Range. Here there are no broad upland valleys. Further to the east the cordillera continues to dip and the islands of the Louisiade Archipelago and the D'Entrecasteaux Islands are the peaks of submerged mountains.

The intermontane trough

Running parallel to the Central Cordillera area is a great trough, probably still sinking, which includes the wide valleys of the Sepik, Ramu, and Markham Rivers. These are plains of deposition formed on both sides of the trough by the rivers carrying quantities of sediment down from the mountains. The rivers are braided or they meander through wide flood-plains containing many scrolls, levees, cut-off meanders, swamps, and lakes.

Away from the swampy areas near the rivers, there are grassy plains which rise gradually to the northern mountains. The southern sides of the intermontane trough rise steeply through deeply dissected and densely forested hills to the Central Cordillera.

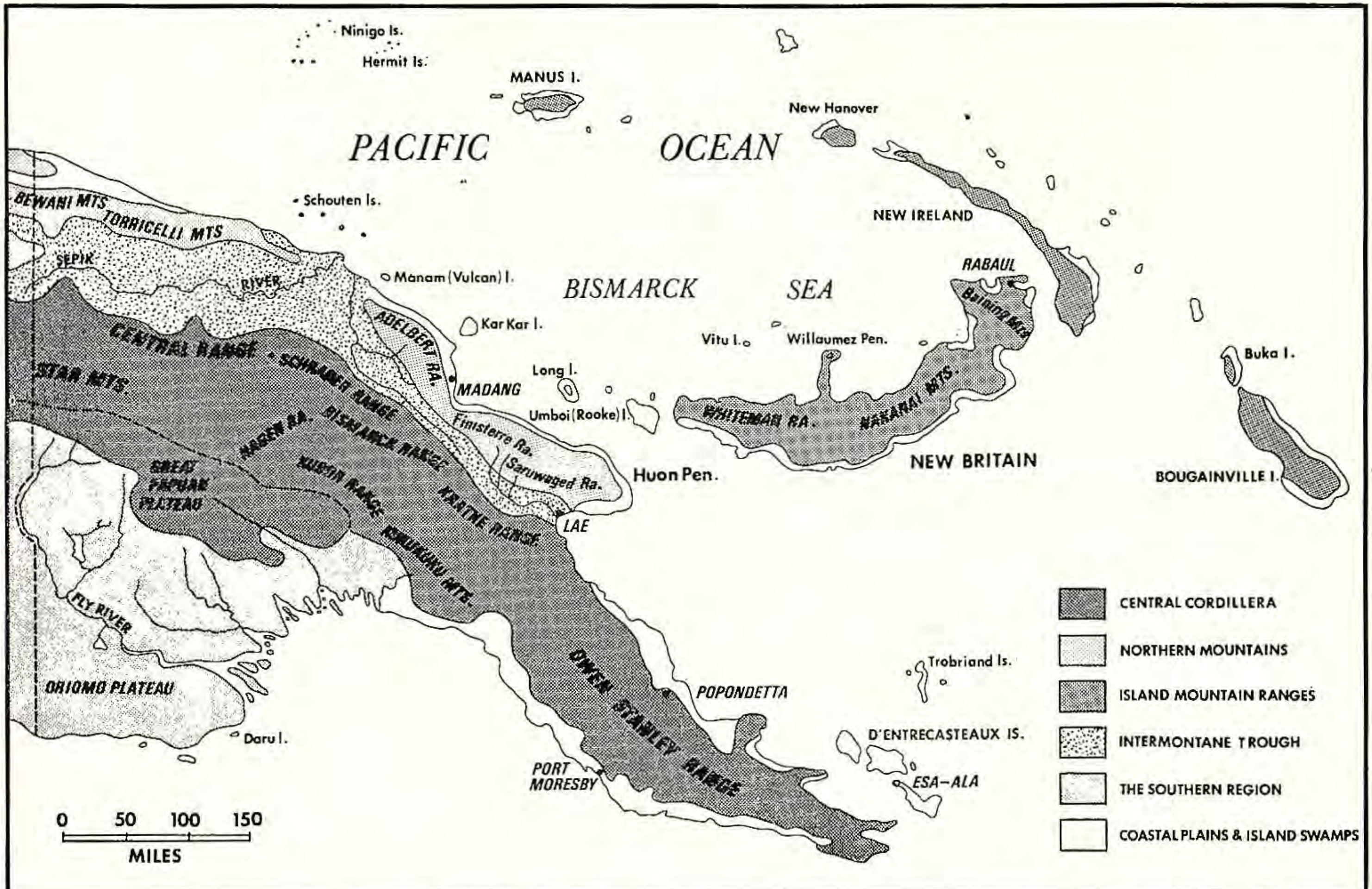

Figure 2.—A generalization of the main physiographic regions of Papua New Guinea (adapted from Lea and Irwin 1971, page 11).

The northern mountains

The northern chain of mountains is neither as wide, lofty or continuous as the Central Cordillera. There is a big break where the Sepik and Ramu Rivers enter the sea. The altitude of the Bwani, Torricelli, and Prince Alexander Ranges north of the Sepik River only exceeds 1 800 metres (about 6,000 feet) near the West Irian border, but some of the peaks in the rugged Finisterre Range and the Huon Peninsula are over 4 000 metres (about 13,120 feet) high. This area is one of recent elevation, and earth movements are still common. Rivers coming from the mountains are unsuitable for navigation, and geologically recent coral is often found 70–100 metres (about 230–328 feet) above sea-level.

The islands

New Britain, the largest of the islands of Papua New Guinea, is structurally related to the northern mountains of New Guinea. Around its coast are numerous coral reefs and raised coral platforms; through the centre of the island run the Whiteman and Nakanai Ranges, which reach about 2 000 metres (about 6,560 feet). Volcanoes are quite common and many of them, such as Mt Ulawun, Mt Langila, and Mt Matupit, are still active. On the Willaumez Peninsula, Lake Dakataua is a vast caldera and there are many geysers and hot springs. At the north end of New Britain is the Gazelle Peninsula, which is the most economically developed area in New Guinea. Simpson Harbour, upon which Rabaul is situated, is one of the finest harbours in the southwest Pacific. It was formed when the sea breached and flooded the caldera of a former volcano.

All the other large islands, from the Admiralty Islands through New Ireland and Bougainville to the Solomon Islands and the New Hebrides, are probably the top of a submerged range running parallel to the Central Cordillera. The Ninigo group, the Hermit Islands, and many other small island groups are atolls which are probably growing on top of submerged mountains in the chain. Nearly all the islands in this chain contain some volcanoes and are surrounded by coral reefs.

Just off the north coast of the New Guinea mainland is a belt of volcanic islands known as the Bismarck Volcanic Belt. These islands are of volcanic origin and include the Schouten Islands, Manam, Karkar, Long, Omboi, and the Vitu group. The volcanic mountains of the west coast of New Britain are also part of this belt.

Volcanoes

The threat of volcanic outbreaks similar to those of 1878 and 1937, when Matupit and Vulcan erupted near Rabaul, is always present. In 1951 Mt Lamington, near Popondetta, erupted, killing nearly 3,000 people. Extinct or dormant volcanoes are evident throughout New Guinea, but the only recently active ones outside the Bismarck Archipelago are Balbi and Bagana on Bougainville, Mt Victory on the northern side of Collingwood Bay in the northern district of Papua, the Doma Peaks in the Southern Highlands, and Mt Lamington. North of the Central Cordillera, earthquakes and earth tremors are quite common and pose a serious hazard to buildings, particularly if the movement is large and the epicentre shallow.

Climate and vegetation

As New Guinea is very near the Equator, atmospheric temperature and humidity are uniformly high throughout the year in all lowland areas. Mean monthly temperatures reflect little seasonal change. Lae, for example, has an average mean temperature in January of 27·4°C (about 81°F) and in July 25·1°C (about 77°F). Diurnal temperature variation is often greater than seasonal change, but even the variation in temperature in any one day is usually less than 8°C (46·4°F). Mean maximum temperatures rarely exceed 32°C (89·6°F) for any lowland station, even during seasons of high sun; in the June–August period, when the sun's rays are almost oblique, mean minimum temperatures rarely drop below 20°C (68°F).

Temperatures become lower with increasing elevation, highland areas being much cooler than those near the coast. The town of Mt Hagen, which is 1 630 metres (about 5,347 feet) above sea-level, has an average mean temperature in January of 18·9°C (66°F) and in July 17·6°C (about 63°F). At about 3 000 metres (about 9,840 feet) frost is common and in 1972 caused severe food shortages in many of the intermontane valleys in the Highlands to the south and west

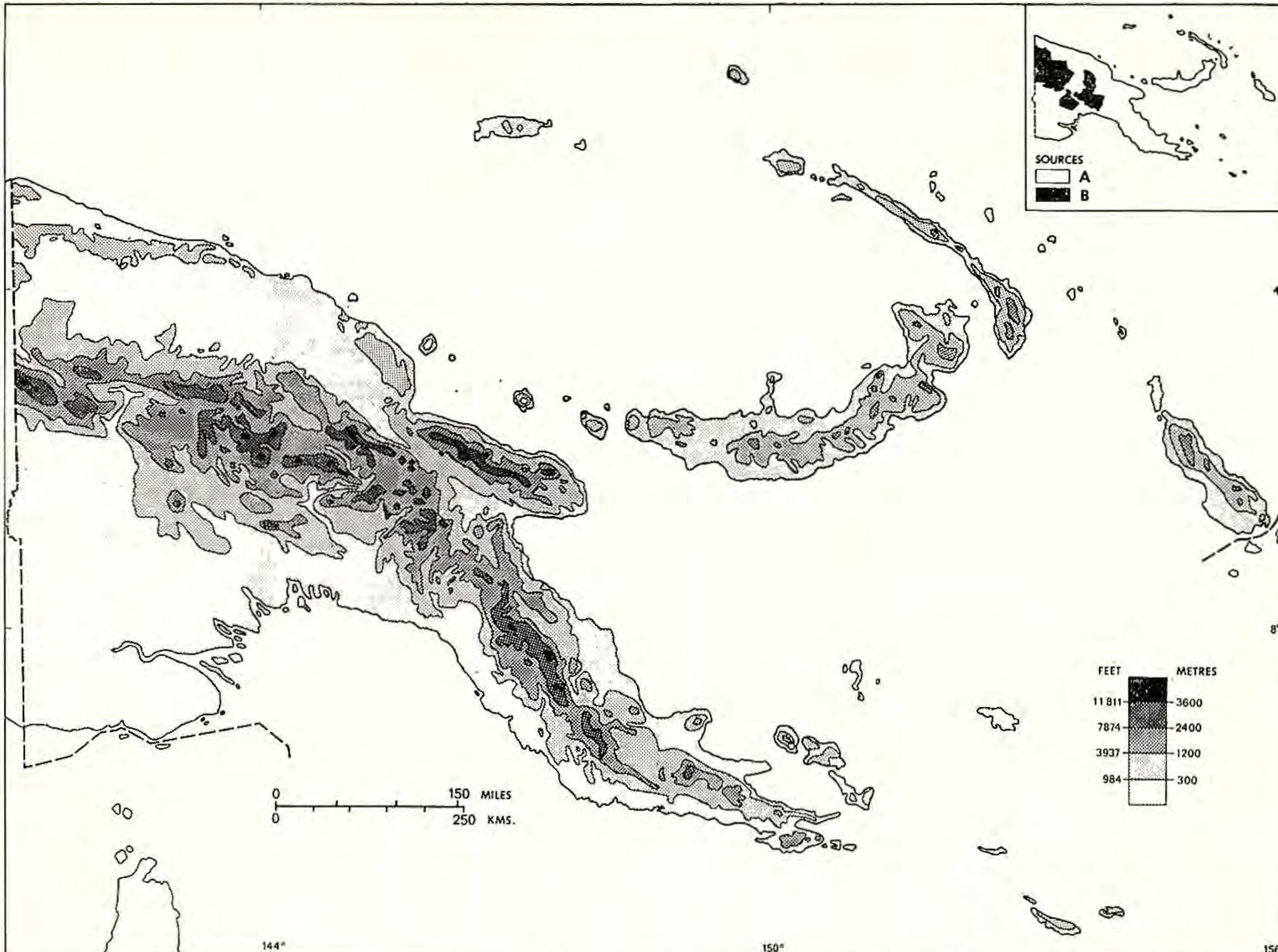

Figure 3.—The relief of Papua New Guinea. (From Ward and Lea, 1970, page 31. Source A is the Australian Geographical Series 1 : 1,000,000 and 1 : 250,000 maps, both available from the Division of National Mapping, Canberra. Source B indicates that use has been made of numerous small-scale maps).

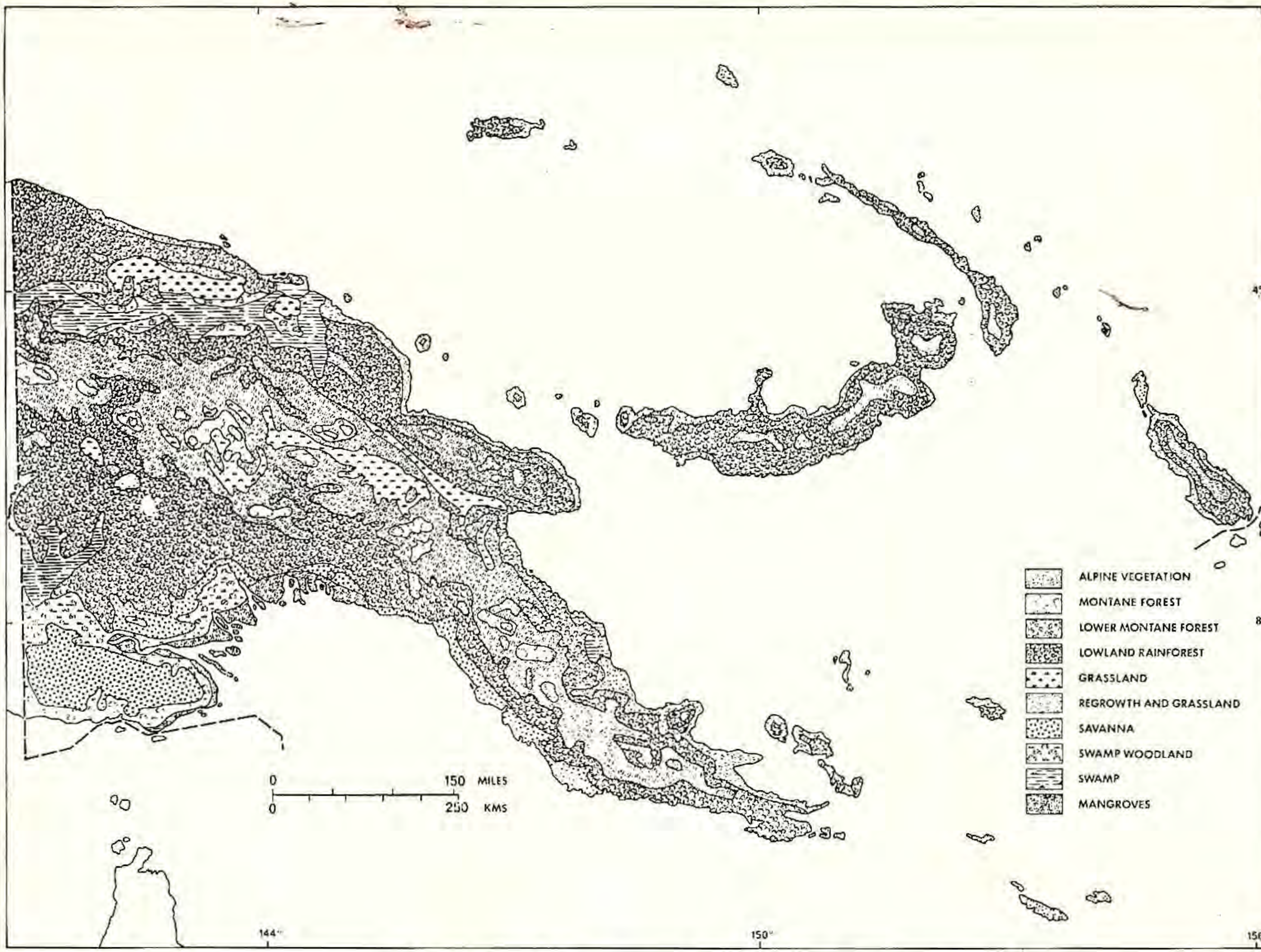

Figure 4.—The vegetation of Papua New Guinea. (From R. G. Robbins, in Ward and Lea, 1970, page 47).

of Mt Hagen. On Mt Wilhelm snow occasionally falls. Most parts of the country are exposed to saturated winds blowing from warm seas, and consequently nearly all areas have a high rainfall for at least part of the year. The area with the lowest rainfall is around Port Moresby, where the average annual rainfall is about 1 170 millimetres (about 46 inches) and open eucalypt savanna reflects a climate very similar to parts of north Queensland. Most of Papua New Guinea, however, has a rainfall of over 2 500 millimetres (100 inches) and on some of the mountains exposed to moisture-bearing winds annual rainfall probably exceeds 7 500 millimetres (300 inches).

Winds blow from the southeast fairly regularly from May to October, and the northwest winds blow more intermittently from December to March. Places exposed to the south tend to receive their maximum rainfall or "wet season" while the southeast trades are blowing, but places exposed to the northwest receive their maximum during the northwest season. In the period between changes of seasons neither of the winds systems are dominant: winds are gentle and variable and at such times the weather is humid and oppressive and thunderstorms are common.

The vegetation cover (see figure 4) is closely related to climate and altitude. About 80 per cent of the country is covered with dense tropical rainforest between sea-level and approximately 1 000 metres. Around the coasts are mangrove forests and saline mudflats, while inland are numerous freshwater and brackish swamp plant communities. Where there is a marked dry season there is usually semi-deciduous forest, especially where the rainfall is between 1 000 and 1 500 millimetres (about 40 to 60 inches). Where the rainfall is less than 1 000 millimetres and there is a pronounced dry season savanna woodland is common, especially in the areas around Port Moresby and south of the Fly River.

At about 1 000 metres (about 3,280 feet) the rainforest, which is usually between 30 and 45 metres (about 100 and 150 feet) high and made up of a great variety of trees, rattans, lianas, and epiphytes, changes to what is called lower montane forest. The lowland trees are replaced by mountain species which include laurel, oak, southern beech, and the commercially important *Araucaria* forest of klinkii and hoop pine. At about 2 700 metres (about 8,800 feet) the lower montane forest gradually changes to mist-shrouded montane or mossy forest. Here there are gnarled and crooked trees only about 10 metres high, and the trunks and branches are festooned with thick mantles of dripping mosses. At about 3 300 metres (about 10,824 feet), above the misty mountain forest, is the alpine zone, which is drier and sunnier. Here mountain conifers and shrubby heaths mark the limit of tree growth. Above 3 600 metres (about 11,800 feet) the vegetation consists of alpine tussock grasses. In this region are found yellow buttercups, deep-blue gentians, and many other plants which belong to temperate-zone plant families.

In densely populated areas, where man has cleared land for gardens, the scene is different, and the forest often looks like a patchwork quilt when viewed from the air. In some places it is thought that man has turned forest into "induced" grasslands by first cutting the forest for gardens then burning over the land and killing all the young trees so that only grasses which are ephemeral or are tolerant to fire can survive. With the advent of urbanization, road construction and new forms of agriculture, the face of Papua New Guinea is going through some interesting transformations, but these changes will have a much greater impact on the people than on the land.

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Acknowledgment: Much of this article is from Chapter 2 of Lea and Irwin, 1971, and the author thanks Mr Irwin and Oxford University Press for giving permission to publish this amended and revised version.

Figure 1.—A jet-boat negotiating a difficult rapid in the Yuat River, South Sepik region. These boats, which can travel in as little as 4 inches of water, penetrated the southern tributaries of the Sepik River into the southern mountains well beyond the limits of conventional craft. [Photo: Bureau of Mineral Resources.]

THE GEOLOGICAL EVOLUTION OF PAPUA NEW GUINEA

By D. B. DOW

Supervising Geologist, Bureau of Mineral Resources, Canberra, A.C.T.

UNTIL recently, the rugged interior of much of Papua New Guinea was so inaccessible that the geology of large areas remained unknown; this prevented all but the most superficial reconstructions of the geological history of the country. The situation has been transformed in the last few years by teams of geologists using modern means of transport to penetrate the mountainous hinterland and fill-in the blanks on the geological map.

These expeditions needed massive logistic support which only organizations such as the Commonwealth Bureau of Mineral Resources and the larger oil exploration companies could supply. One such expedition was the 1966 exploration of the mountains south of the Sepik River, of which I was the leader. This exceptionally rugged, jungle-covered, and virtually uninhabited area is approachable only by way of the Sepik swamps, which present a most formidable barrier even today. Shallow-draft boats driven by water jets were used for the first time in Papua New Guinea to carry men and equipment into the foothills (figure 1), and helicopters to ferry light, mobile geological parties into the mountains (figure 2). Once in the mountains, the usual difficulties of dense jungle, mountain torrents, waterfalls and gorges (figure 3) were compounded by the almost complete lack of population, which meant that the parties did not have the benefit of even the most rudimentary jungle tracks. Small isolated pockets of nomadic peoples were contacted for the first time, but, in the absence of any means of communication other than sign language, we were unable to enlist their help.

When one considers that these difficulties are found to greater or lesser degree in most parts of Papua New Guinea, it is little wonder that so much of the country remained unknown for so long; but geological knowledge has now reached the stage where at least the broad outline of the geological evolution of the country can be confidently reconstructed.

Figure 2.—A helicopter pad constructed by a Bureau of Mineral Resources traverse party (one geologist and five carriers) at the end of a week-long traverse in the headwaters of the Salumei River, South Sepik region. It was not always possible to find clearings at the end of a traverse, and often a full day's work was required to clear a pad in virgin forest. The hut belongs to the Bikalu people, who had never before been visited by white men. [Photo: Bureau of Mineral Resources.]

Unfortunately, the farther one goes back in time the less complete is the geological record, because in an area so strongly affected by earth movements the older rocks become transformed by heat and pressure, and the evidence of earlier events locked in the rocks becomes obliterated. This has happened to most of the Palaeozoic and older rocks (see geological time scale, figure 4), but knowledge of events since the beginning of the Mesozoic Era is fairly complete. During most of this time, Papua New Guinea has been the buffer zone between the northward-drifting Australian continent (Australian Platform in figure 5) and fragments of oceanic crust, each many thousands of square kilometres in area, that acted as rigid plates to the north and east. The net result has been an intensely folded and faulted geologically complex zone, called the New Guinea Mobile Belt, which forms the spine of mainland Papua New Guinea. Thus the geology, from south to north, falls into three broad divisions: the Australian Platform, the New Guinea Mobile Belt, and the Melanesian Oceanic Province (figure 5).

Australian Platform

During most of the Mesozoic and Tertiary, the Australian Platform was submerged beneath the sea and received a thick cover of sedimentary rocks; because the underlying continental crust was strong and stable, the whole area was protected from the forces which were acting to such effect farther north. Changes in sedimentation were therefore gradual, affecting the whole of the Platform, and as a consequence the sediments are uniform over a wide area. As far as is known sedimentation began in the early Mesozoic, and from then until the Tertiary, shale, siltstone, and sandstone, supplied by weathering and erosion of the Australian continent, were deposited over the whole of the Platform (figure 5). Many of the sandstone beds are good reservoir rocks for the accumulation of petroleum, but so far exploratory drilling has located only sporadic gas flows.

During the earliest Tertiary, most of the Australian Platform was above sea-level, and when the sea once more encroached in Oligocene time the supply of detritus from the Australian continent had virtually ceased, and the only sediment deposited over the whole of this large area was limestone. Great thicknesses accumulated in places, the maximum known being over 3 000 metres (about 9,840 feet) penetrated in a petroleum exploration well.

Near the margin of the Platform the limestone formed a barrier reef which can be traced southwards to the Great Barrier Reef of north Queensland. The Australian part of the reef has continued to grow to the present day, but the northern part was uplifted along with the spine of mainland Papua New Guinea several million years ago (in the Pliocene), and has subsequently been eroded to form the spectacular limestone cliffs of western Papua (figure 6).

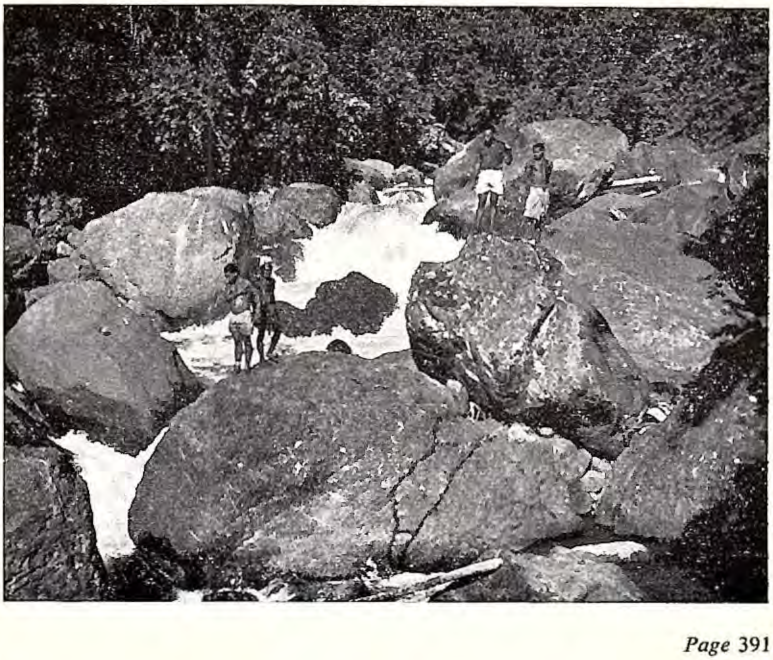
New Guinea Mobile Belt

An entirely different story is told by the rocks flanking the Australian Platform, which now form the mountainous backbone of the mainland. Here the rocks, almost without exception, have been crushed and highly deformed by the huge forces generated by the collision between the Australian continental block and the oceanic plates.

Knowledge of the rocks of the Mobile Belt is fairly complete because they have been uplifted and eroded, and so exposed to the geologist's hammer. Over most of the Australian Platform, on the other hand, the older rocks are covered by young sediments, and almost the only way of obtaining knowledge is from the few deep exploration wells put down by oil companies.

The oldest rocks in this Mobile Belt are thick sedimentary rocks deposited during late Mesozoic time in a deep ocean trough called the New Guinea Geosyncline, which wrapped around the Australian Platform (figure 7). Widespread volcanism occurred spasmodically in the geosyncline, probably as chains of island volcanoes whose products are preserved as thick sequences of lava and other

Figure 3. — Typical traverse conditions in mountainous parts of Papua New Guinea. The best rock outcrops are found in rivers, where the going is generally arduous and often dangerous. [Photo: Bureau of Mineral Resources.]



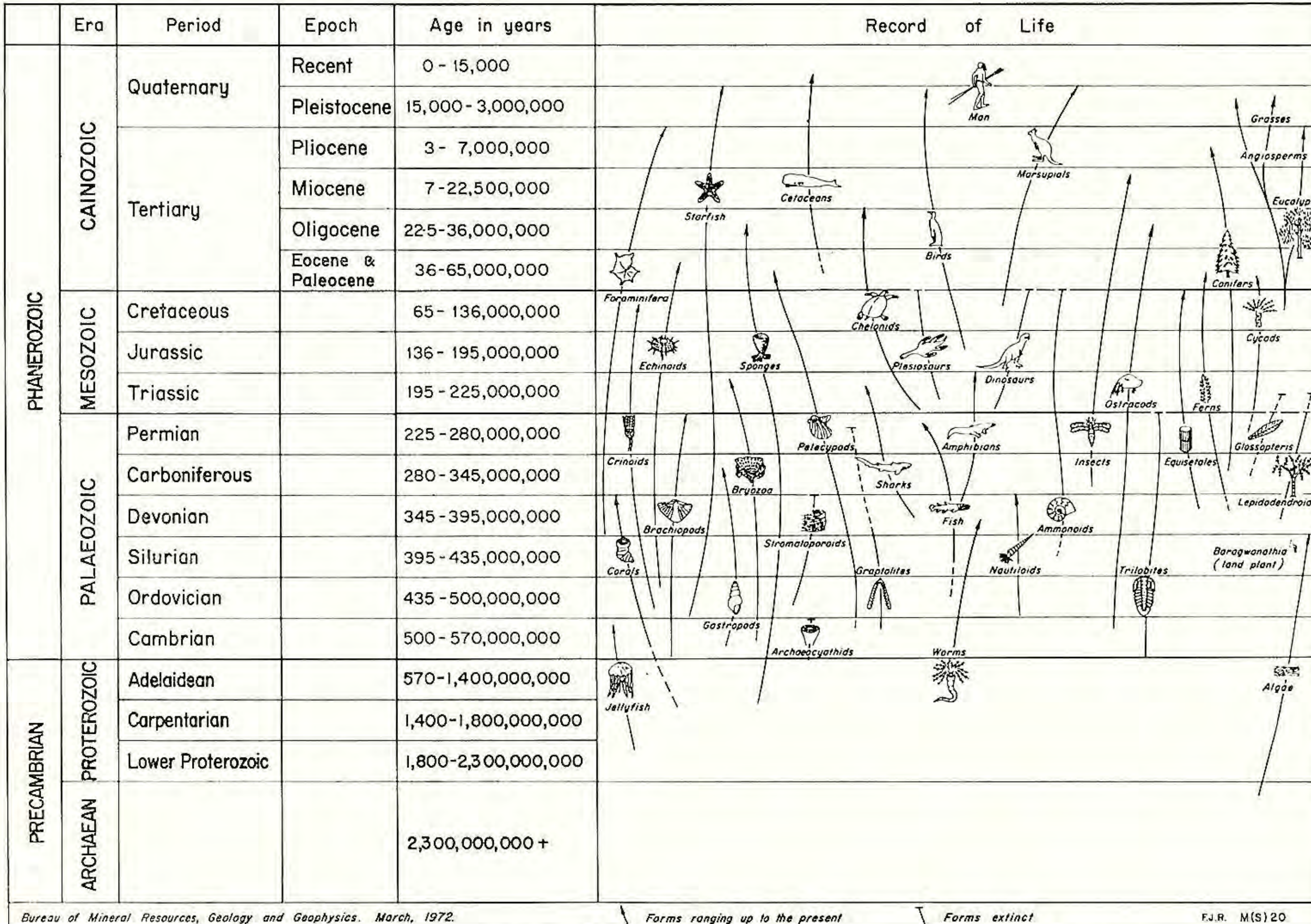


Figure 4.—Geological time-scale.

volcanic rocks interbedded with the sedimentary rocks. In view of the close proximity of these volcanoes to the Australian Platform it is perhaps surprising that volcanic detritus is absent from the Platform sediments. However, the deep trough probably acted as a sediment trap and prevented the volcanic detritus from being carried south to the Platform.

Early Tertiary (Oligocene) time was one of major earth movement during which the rocks of the New Guinea Geosyncline were crushed and deformed, and the whole of what is now mainland Papua New Guinea was raised above the sea. The effects of the earth movements were most severe along the outer (northern) margin of the Geosyncline, where the sediments were recrystallized to form metamorphic rocks which are now exposed in a zone extending from the West Irian border to southeast Papua.

Geosynclinal sedimentation resumed in the Miocene (figure 8), following closely the earlier pattern. There were two important differences, however: the outer margin of the Geosyncline was occupied by a chain of mountainous islands composed of the metamorphic rocks formed during the earlier earth movements, and the supply of detritus from the Australian Continent had almost ceased, so allowing shallow-water limestone to accumulate on the Platform.

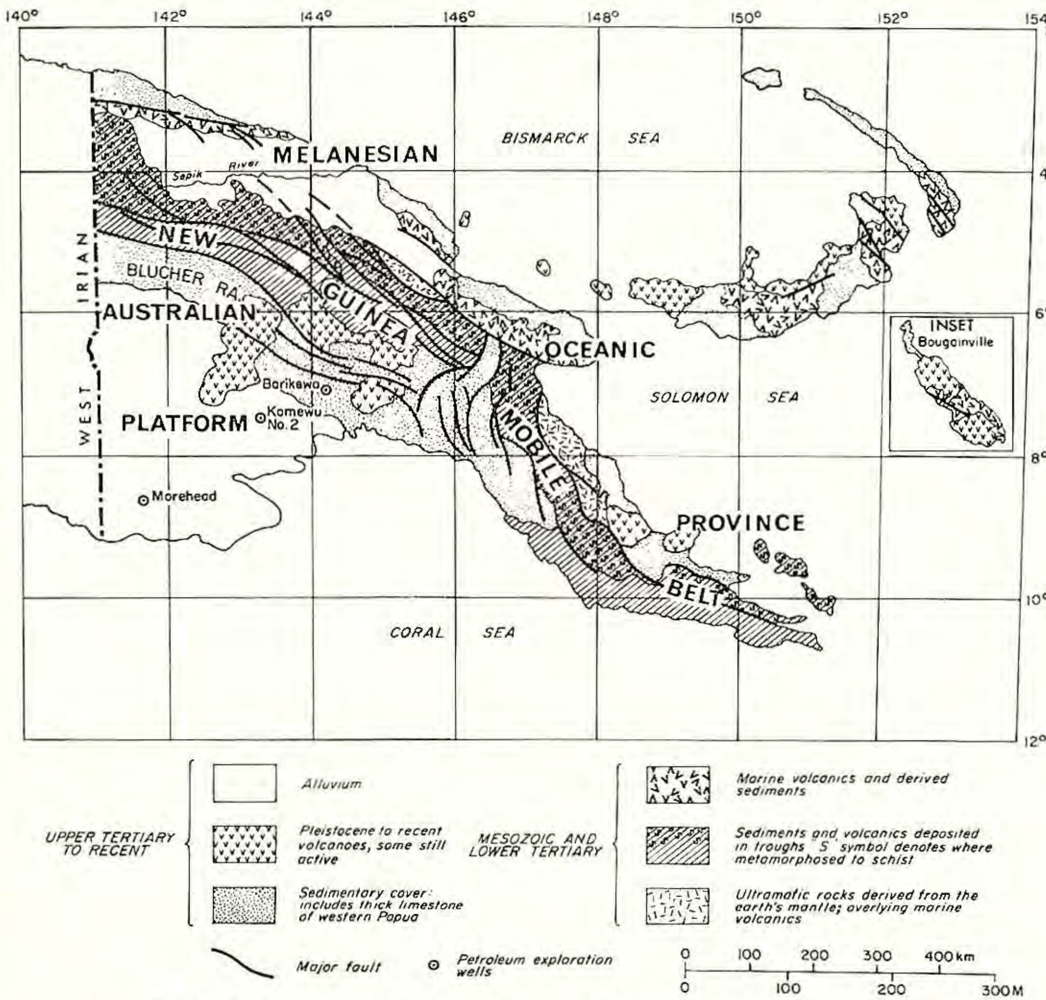


Figure 5.—Geological map of Papua New Guinea. [Map by Bureau of Mineral Resources.]

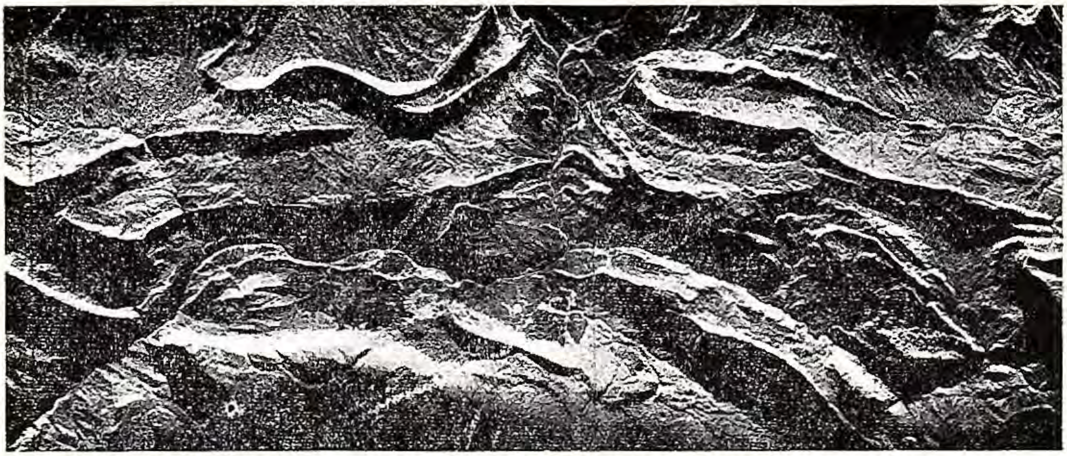


Figure 6.—Radar image of the middle reaches of the Strickland River, western Papua. The sharp sinuous ridges are the upturned edges of slabs of contorted Darai Limestone which are thought to have slumped down the flanks of the actively rising New Guinea mainland in Pliocene times. Radar images can be obtained even through heavy cloud cover, and are the only source of topographic data for many areas of western Papua New Guinea. [Imagery by Westinghouse Raytheon for the Department of the Army.]

The simplified stratigraphic columns shown in figure 9 are greatly generalized, but they illustrate the enormous contrast between the sediments laid down at the same time on the Platform and along the Mobile Belt. Thus from the early Jurassic until the upper Miocene, about 16 000 metres (about 52,500 feet) of sediments interspersed with marine volcanic rocks were laid down in parts of the Mobile Belt while no more than about 5 000 metres (about 16,400 feet) of monotonously uniform sediments were deposited on the Australian Platform.

Several periods of igneous intrusion (large-scale injection of molten rock deep in the earth's crust) during the Mesozoic and Tertiary are recorded in the Mobile Belt; the most important of these took place about 15 million years ago. None, however, is known from the Australian Platform. The rocks are largely granitic, and they are of economic importance because almost without exception they were accompanied by sporadic gold mineralization and, in some places, by important copper mineralization. The copper deposit being tested at Frieda River in the South Sepik region was formed during this phase of intrusion.

One of the most spectacular features of the New Guinea Mobile Belt is the presence of ultramafic rocks derived from the earth's mantle; submarine lavas which overlie them are considered to be part of the deep ocean floor formed in Cretaceous and Eocene times. These rocks were thrust up from a depth of thousands of metres against the Australian continental block, and it may have been this event that generated the huge compressive forces and great heat which metamorphosed the Mesozoic sediments of the New Guinea Geosyncline.

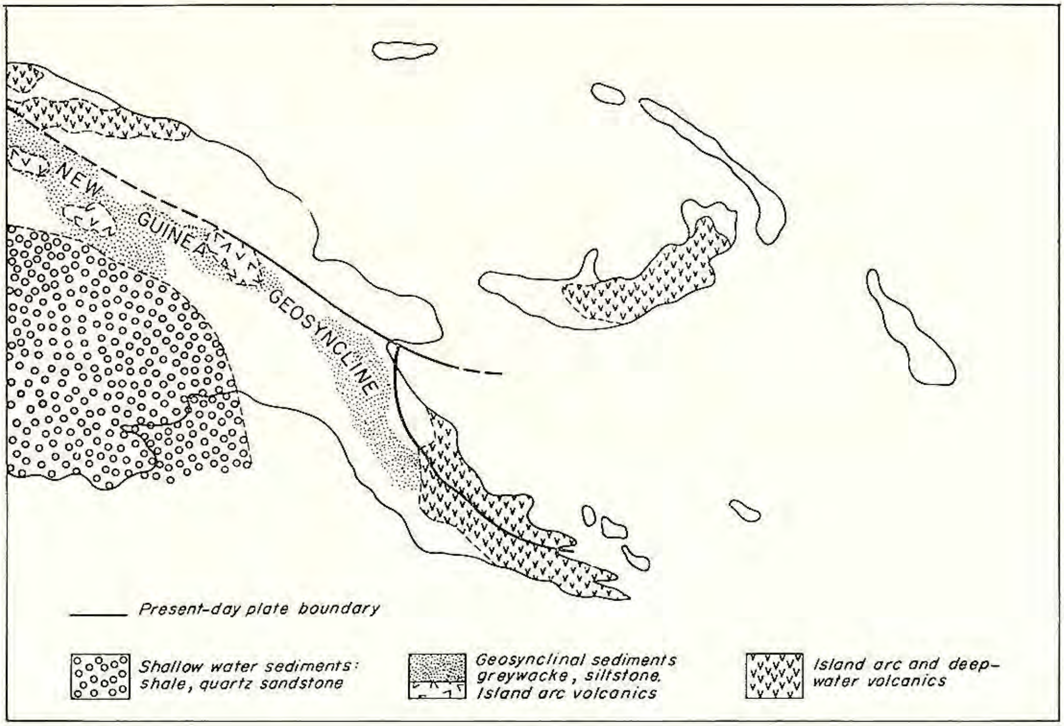
Melanesian Oceanic Province

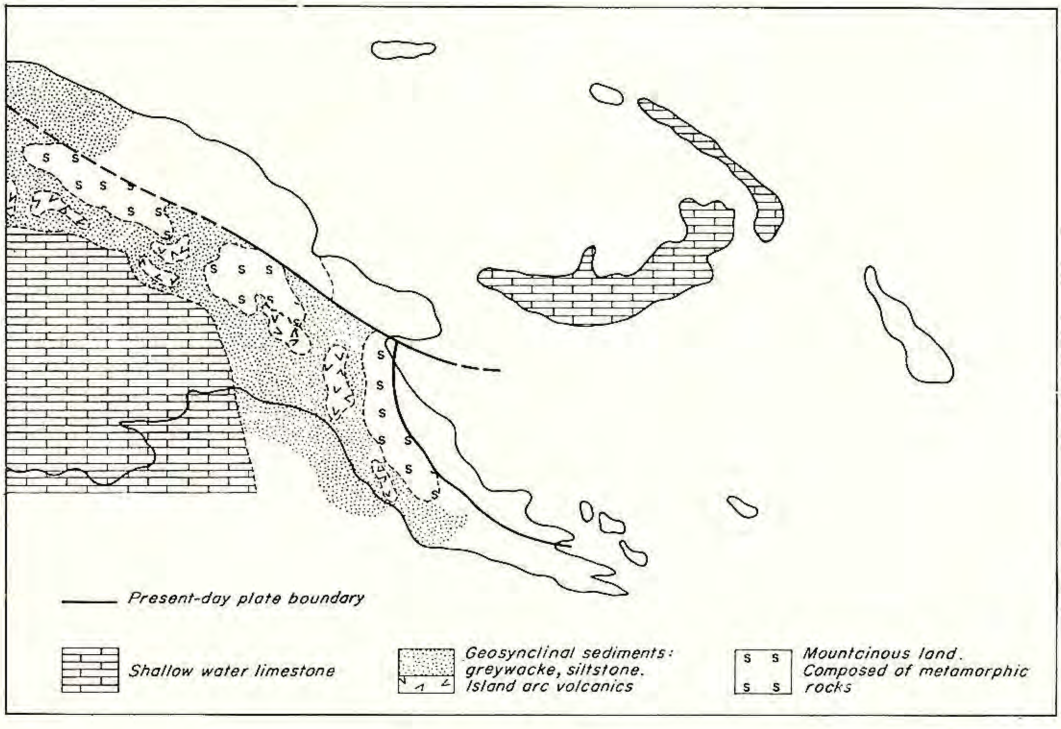
The northern coastal area of Papua New Guinea and the outlying islands belong to the Melanesian Oceanic Province, in which the land areas are made up almost entirely of the products of marine volcanism (figure 10) and reef limestones. There is no evidence to suggest that the conditions differed significantly from those of the present day, in which chains of active volcanoes are located along fundamental breaks in the earth's crust.

The volcanism was not continuous, and several breaks are recorded in the geological

OPPOSITE

Figure 7 (top).—Pattern of sedimentation, upper Cretaceous to Eocene. Figure 8 (bottom).—Pattern of sedimentation, middle Miocene. [Maps by Bureau of Mineral Resources.]


NEW GUINEA GEOSYNCLINE
Present-day plate boundary
Shallow water sediments: shale, quartz sandstone
Geosynclinal sediments greywacke, siltstone. Island arc volcanics
Island arc and deep-water volcanics


Present-day plate boundary
Shallow water limestone
Geosynclinal sediments: greywacke, siltstone. Island arc volcanics
Mountainous land. Composed of metamorphic rocks

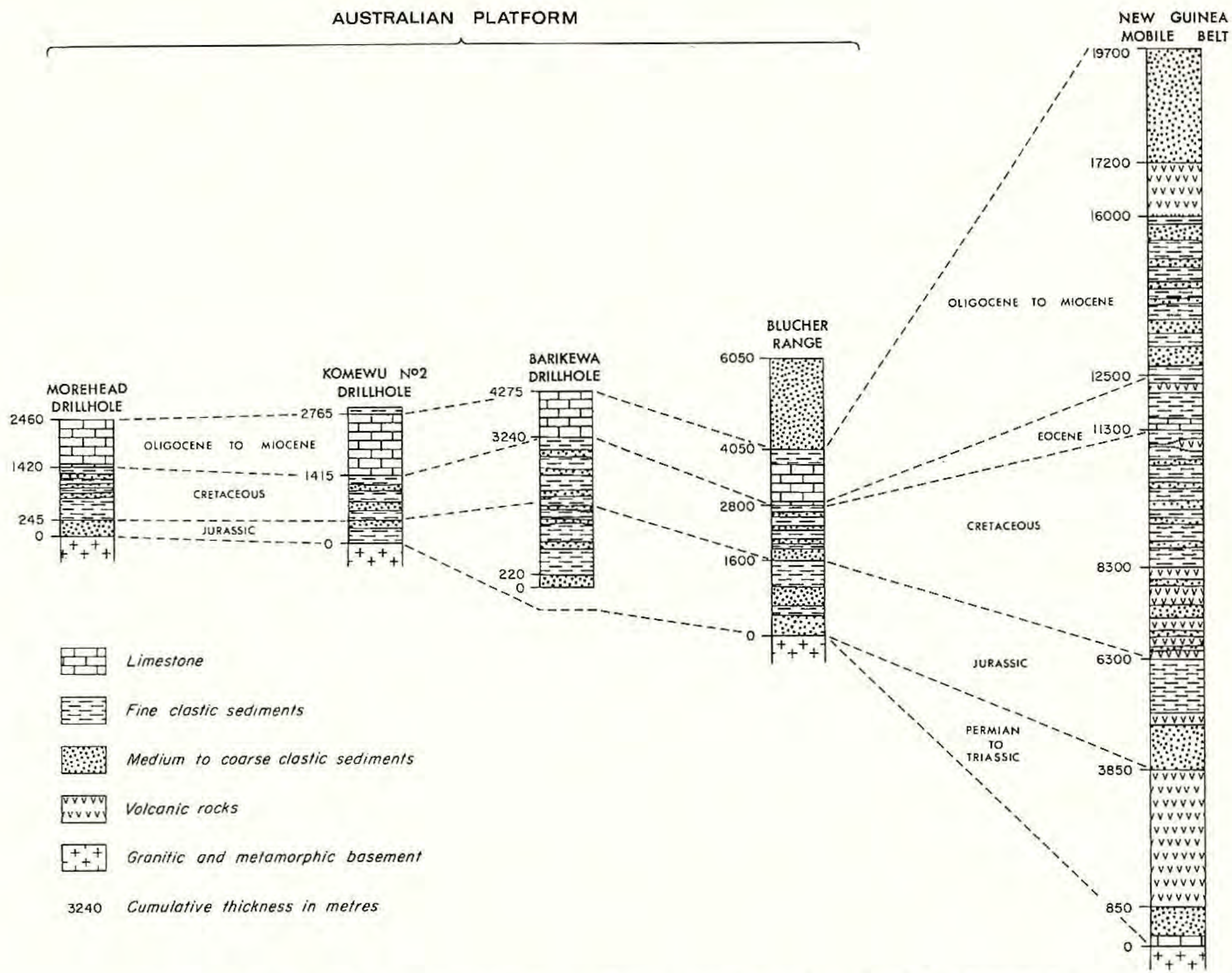


Figure 9.—Generalized stratigraphic columns, Papua New Guinea. See figure 5 for location of drillholes. [Diagram by Bureau of Mineral Resources.]

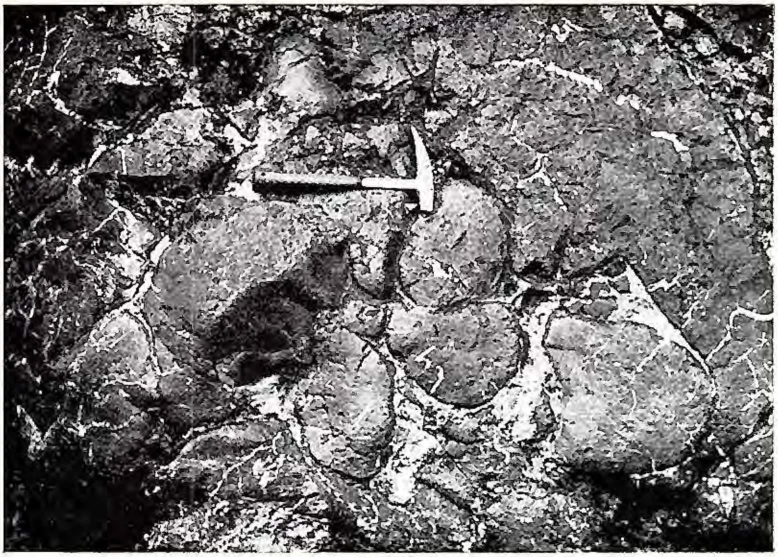


Figure 10.—Rock outcrops like this provide clues to past geological events. Here, in a stream draining the Torricelli Mountains north of the Sepik River, pillow lavas of lower Tertiary age are exposed. The rounded masses were molten globes (pillows) of lava extruded on the sea floor. The white material in the interstices was a calcareous ooze on the sea floor caught up between the pillows. The ooze contains microscopic fossil shells (foraminifera) which date the lavas as lower Tertiary. [Photo: Bureau of Mineral Resources.]

column, the main one being in the Miocene, when a thick blanket of limestone accumulated over most of the area (figure 8).

By late Tertiary time the stage had been set for the earth movements which determined the present morphology of mainland Papua New Guinea. For reasons not yet understood, the rocks of the Mobile Belt were uplifted many thousands of metres to form the mountainous backbone of Papua New Guinea. Most of the movement took place along faults, most of which stand out as prominent scarps flanking the highlands.

Radar imagery (figure 6) shows part of the Tertiary limestone on the edge of the Australian Platform, which was raised with the underlying basement rocks and formed an unstable cover over the actively rising mountains. Under the pull of gravity huge rafts of limestone slid off the flanks of the mountains, riding one over the other and crumpling, much like the snow crust in a slab avalanche—only in this case the sliding was inestimably slow, and may have taken hundreds of thousands of years before the movement ceased. The resulting contorted bed of limestone, repeated many times over, is well illustrated in the figure.

Volcanic activity has continued intermittently to the present day, but reached a climax in the Pliocene, when large volcanoes burst into eruption over much of mainland Papua New Guinea. Intrusive rocks which accompanied the Pliocene volcanism introduced gold and copper mineralization throughout the Mobile Belt and the Oceanic Province. The mine on Bougainville Island, one of the major copper mines in the world, occurs in an intrusive rock only about 3 million years old.

The earth movements which established the main landforms continue little abated to the present day, keeping pace with the rapid erosion caused by high rainfall and tropical weathering, and so maintaining the rugged mountainous character of Papua New Guinea.

Alluvial gold being worked in a small stream near Maprik, Sepik district. [Photo: Bureau of Mineral Resources.]

MINERAL RESOURCES

By N. H. FISHER
Director of the Bureau of Mineral Resources, Canberra, A.C.T.

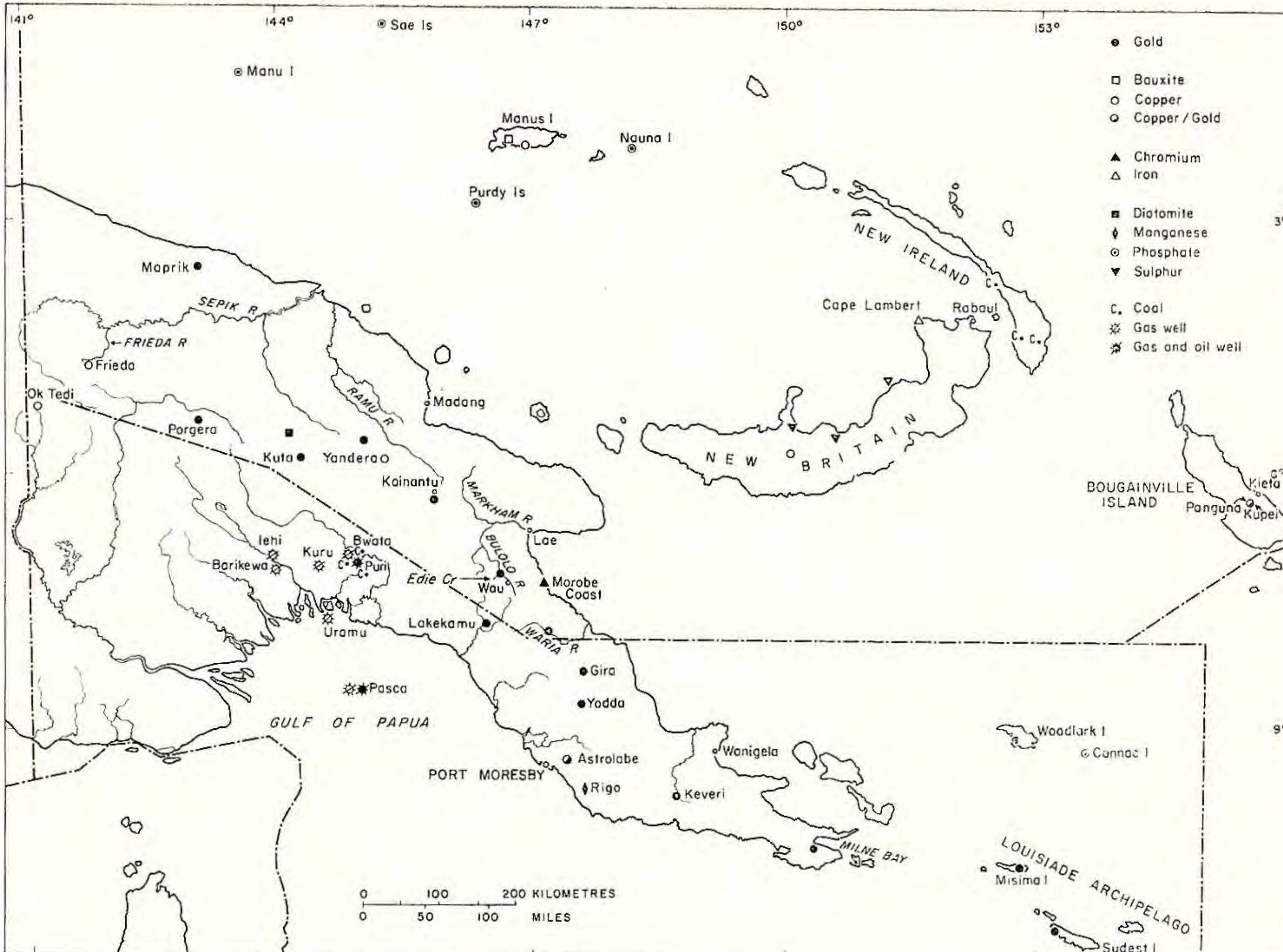
IN both geology and topography, Papua New Guinea offers a striking contrast to the mainland of Australia. New Guinea is a young country, geologically speaking, which has been subject to strong earth movements of comparatively recent age. Upthrust mountain areas have been dissected by deep gorges as the abundant surface waters unsuccessfully attempt to keep pace with nature's pulsations and wear the surface down. Much of the country is incredibly rugged, and easy access is limited to the coastal plains, which are usually of small extent, the upland open valleys, and the lower courses of some of the big rivers, such as the Fly, Strickland, Sepik, Ramu, and Markham. The oldest known rocks in New Guinea are late Palaeozoic and more than 80 per cent of the surface of the country is occupied by Tertiary formations, not more than 50 million years old.

Australia, on the other hand, has comparatively few Tertiary rocks; it has a large proportion of old, Precambrian terrain and much of its land area has been weathered down by continuous erosion during a long period of tectonic stability to a peneplaned surface. As in its physiographic and geological style, so in its distribution and occurrence of mineral deposits, and in the methods employed to locate them Papua New Guinea differs considerably from Australia.

The mineral resources of Papua New Guinea so far discovered fall mainly under three headings: gold, petroleum, and copper, though there are minor occurrences of many other minerals. The locations of the principal deposits are shown on the accompanying map.

Gold

The history of gold mining embraces the most romantic period of development of Papua and New Guinea—romantic in retrospect, but in actuality incredibly arduous and often hazardous. The natives were not always friendly and the only defence against malaria was quinine, which is not nearly as effective as modern anti-malarial medicines. Mining began in Papua before the turn of the



Minerality locality map of Papua New Guinea.

century, and several goldfields—Louisiade Archipelago (Misima, proclaimed in 1889), Woodlark Island, Milne Bay, Yodda, Gira, Lakekamu, and Keveri—were worked in Papua before World War 1. At that time, too, Australian prospectors surreptitiously entered what was then the German Territory of New Guinea across the Papuan border and worked gold on the Waria River.

It was not until about 1922, however, that prospectors really began to penetrate the hinterland of the now Mandated Territory of New Guinea and "Shark-eye" Park found the rich alluvials at the head of Koranga Creek, a mile-long streamlet deriving its precious concentrations from gold-bearing conglomerates dumped in the edge of the former lake that occupied the ancestral valleys of the Bulolo and Watut Rivers. And not until 1926, four years later, did Royal and Glasson manage to scramble up to the head of Edie Creek, only 4 miles away, and find the phenomenally rich alluvial gold deposits that made fortunes (mostly ephemeral) for a few and started the real gold rush to New Guinea, and, incidentally, the opening up and development of the highland valleys of the Territory.

Gold in the Morobe Goldfield—as the Wau-Bulolo area was proclaimed—occurs in association with porphyries and andesites, intruded in Pliocene time or later, and with granodiorite of Miocene age. Gold associated with the granodiorite is of fairly high fineness, 870 or thereabouts (87 per cent gold, 12 per cent silver, 1 per cent copper and other impurities); that associated with the deeper-seated porphyries is about 700–750 and that with the near-surface porphyries and andesites only 500–650.

The vast bulk of the production came from the wide and deep gold-bearing alluvial flats of the Bulolo and Watut Rivers downstream from Edie and Koranga Creeks. Gold-bearing lodes were worked at Edie Creek and at Golden Ridges near Koranga, but accounted for less than 10 per cent of the total production of 3,653,000 fine ounces of gold.

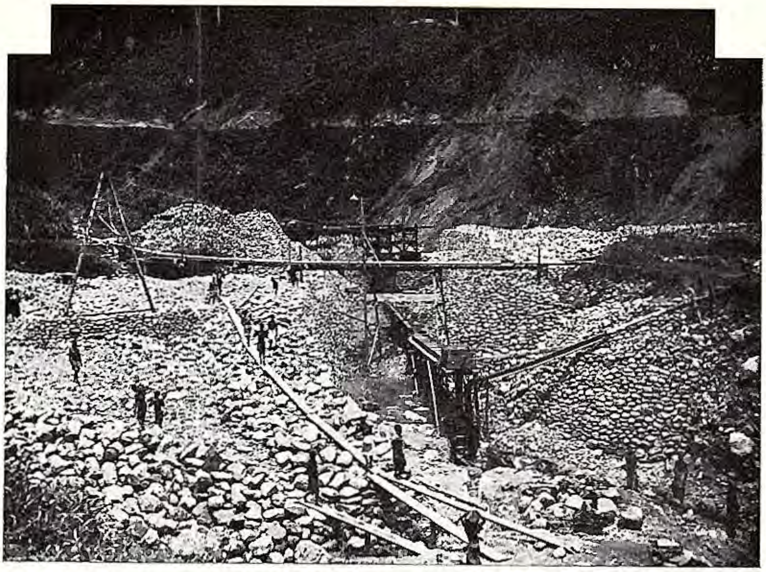
Other smaller fields in the Territory of New Guinea include Kainantu, Mt Hagen, and scattered small deposits in the Highlands, and the Sepik (Maprik) area. Gold was also found associated with copper on the Astrolabe field near Port Moresby and at Kupei on Bougainville Island, where about 2,300 ounces were produced prior to 1941.

Total production from the various fields to 30th June, 1972, as far as is known, is given in fine ounces in the following table:

Morobe Goldfield	3,653,000
Misima (including Sudest, 10,000 oz) ..	236,000
Woodlark	207,850
Yodda	81,000
Gira	67,900
Sepik	52,900
Lakekamu..	37,400
Eastern Highlands (Kainantu)	24,000
Milne Bay	15,000
Keveri	5,000
Kieta (Kupei)	2,300
Madang (Sinbai)	2,000

In many of the alluvial fields, especially in southeastern Papua, small amounts of platinum and osmiridium were found in the alluvials with the gold.

Deep alluvials being tested with a percussion drill at Koranga, Wau. The Koranga open-cut alluvial workings are in the background. [Photo: Bureau of Mineral Resources.]



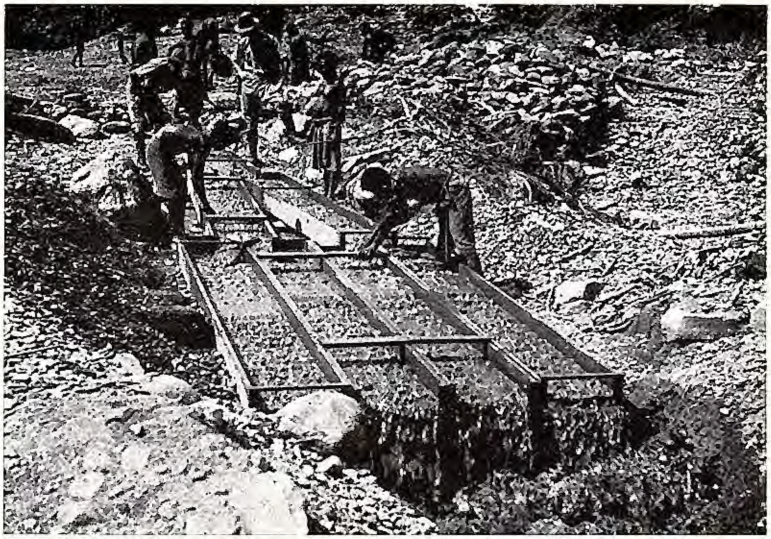
Working gravels in the bed of the Bulolo River at Cliffside, between Wau and Bulolo. [Photo: T. A. Olsson.]

Copper

Up to World War 2, prospecting in Papua New Guinea was mainly for gold. There are two reasons for this. First, transport costs were too high for anything but gold to be worked profitably, and second, it was extraordinarily difficult in New Guinea to prospect for anything but gold. Because of its durability and resistance to chemical attack, gold remains after its enclosing rock has disintegrated and has been washed away. Gold finds its way into the streams but because of its weight all but the smallest particles are trapped between the boulders and pebbles, leaving a trail for the prospector to follow to the source or to flat areas where large amounts of gold-bearing gravel have been able to accumulate without being scoured out by the roaring mountain floods. Thus gold is its own indicator, a peculiarity shared only by platinum, osmiridium and cassiterite, the oxide of tin, and because of its colour and weight it can be readily detected in the field by the simplest of all prospecting methods—just washing a dish. Also, it is still a valuable deposit after it has been removed from its original source, often made much more so because it has been concentrated by reason of its high density.

Other minerals, however, which have to be found in outcrop, are much more difficult to locate in New Guinea. The outcrop probably lies under deep forest or stream gravels or lacustrine deposits; there are few, if any, telltale gossans; surface traces have been washed downstream, and access is almost everywhere

Boxing alluvials in upper Edie Creek. [Photo: Bureau of Mineral Resources.]



Boxing alluvials on the Watut River. [Photo: Author.]

extremely difficult. Small wonder, then, that except for the massive outcrops of gold-bearing and copper-bearing sulphide ore in the comparatively barren area near Port Moresby, virtually no base-metal deposits had been found before World War 2, and, where they had been located, as in the gold-copper lodes of Kupei and Panguna, the copper was mainly regarded as a nuisance, because it inhibited the recovery of gold by amalgamation in the small battery that had been dragged in over the mountains from the coast to treat the ore.

The advent of geochemical prospecting, combined with the development of the helicopter for quick access, changed all that. A sample from the sediment of each tributary stream, tested by sensitive rapid methods more or less on the spot, could indicate the presence or absence within that comparatively small catchment area of anomalous amounts of copper or other metals. Once identified, it was a fairly simple matter to locate the source of the anomaly and define its extent, although the costs of testing remained extremely high. Also, as knowledge increased about the manner of occurrence of "porphyry coppers" (disseminated copper deposits in igneous rocks, commonly carrying gold or molybdenum as well) and discoveries were made in the Philippines and other areas of similar geology to New Guinea, it became obvious that New Guinea was an attractive prospecting target for this type of deposit. Geologists of the Bureau of Mineral Resources recommended the Panguna area of Bougainville Island as worthy of attention, a lead that was followed up by geologists of Conzinc Riotinto of Australia Ltd. This resulted in the discovery, testing and development of the huge Panguna deposit, now in full production at the rate of 180,000 tons a year of copper (in concentrate) and 700,000 ounces of gold.

Testing is being carried out on a number of other copper prospects: at Ok Tedi in the Western Highlands a large ore body has been proved; on Frieda River, a southern tributary of the Sepik, exploration is at an advanced stage; and other deposits on Manus Island and New Britain and in the Central Highlands are being investigated.

Other minerals

Other occurrences of minerals of the base metals that are worth mentioning in a brief account of this nature are: bauxite on Manus Island; chromite in beach and estuary sands along the Morobe coast; titaniferous magnetite sands on the shores of Bougainville and the Gulf of Papua; magnetite deposits on Suloga Peninsula on Woodlark Island and near Cape Lambert on New Britain; nickel minerals in the Papuan Ultramafic Belt between Wau and Wanigela on the northern side of Papua New Guinea; mercury (cinnabar) associated with gold in some of the epithermal lodes of the Edie Creek area; and battery grade manganese ore near Rigo, southeast of Port Moresby, of which 2,200 tons were exported between 1939 and 1964.

Of the non-metallic materials, Papua New Guinea has large deposits of limestone and of pumice; small deposits of sulphur occur around some of the volcanic centres; diatomite has been found at one locality in the central highlands; rocks of the ultramafic areas may contain asbestos; low-grade coal has been found at several localities in central Papua and on New Ireland; and there are small deposits of phosphate rock on Nauna Island, east of Manus, on several islands of the Purdy and Ninigo Groups, and on Cannac Island, east of Papua.

Petroleum

Southeastern Papua is regarded as being highly prospective and has been intensively explored for petroleum. Results, however, have been somewhat disappointing: much of the geology is complicated, overthrust faulting is present in many areas, and costs of exploration are extremely high. Despite the fact that numerous surface oil seeps occur, oil has been found (only a small amount), with some gas, in one hole at Puri, but several good flows of gas have been found at Kuru, Iehi, Barikewa, and Bwata, and offshore in the Pasca and Uramu wells.

Other prospective areas which have been and still are being explored include the northwestern part of New Guinea, north of the Sepik and Ramu Rivers, and the off-shore shelf areas around eastern Papua.

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ISLAND IS PART OF VOLCANIC BELT

Manam Island, a volcano just off the north coast of Papua New Guinea, is part of a great belt of volcanic activity extending in a long arc north of New Guinea and through the Bismarck Archipelago. Manam Island has been active several times in recent years. A mixture of cloud and a small amount of smoke from the crater is seen in this picture. [Photo: H. G. Cogger.]

The Vegetation of the Lowlands

By PETRUS C. HEYLIGERS
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THE vegetation of the island of New Guinea is among the richest in the world. The number of seed-plant genera is about 1,600, and the number of species has been estimated to be in the order of 12,000. These figures are in the same order of magnitude as those for Australia, which has a landmass about nine times the size of New Guinea. Figures for ferns, mosses, and other cryptogams are lacking because these groups are still too inadequately known for any reliable estimates.

The distribution of many seed-plant species is not only limited to New Guinea, but often also restricted within this area. The genera, however, are usually more widespread and point to a close relationship with the floras of the Indonesian and Philippine archipelagos and the southeast Asian mainland. Interesting ties are also found with the Australian, New Zealand, and New Caledonian floras, but numerically these elements form a minority, notwithstanding the fact that they are conspicuous in certain communities. Examples are the eucalypts in the seasonally dry country around Port Moresby and the emergent araucarias on forested slopes at mid-altitudes.

One of the main reasons for the wealth in species is the great variety of habitats available for plant growth. These range in Papua New Guinea from estuarine mudflats colonized by mangrove species to wind-battered and occasionally snow-covered mountain peaks where only some dwarfed plants hold out. At altitudes between 1 000 metres (about 3,280 feet) and 1 400 metres (about 4,592 feet) above sea-level the transition occurs between the tropical lowland forests and the montane forest types. The latter are less luxuriant due to a cooler and often more cloudy climate, and are more often dominated by one or a few tree species. This article gives an outline of the vegetation types of the lowlands, followed by a more detailed description of the climax vegetation—the tropical rainforest. Professor D. Walker deals with the vegetation types of the higher altitudes in another article.

Anastomosing roots of a strangling fig obstructing the secondary growth of the host tree and slowly killing it.

Climax and swamp vegetation

Evergreen, broad-leaved forest types with canopies between 30 metres (about 98 feet) and 45 metres (about 147 feet) high, rich in palms, epiphytes, and lianes, which collectively are often designated as tropical rainforest, cover most of the hills and mountain spurs, and large expanses of well-drained plains. They are indicative of a biologically optimal environment, characterized by an equable tropical temperature and sufficient soil moisture at all seasons.

Because of the seasonality of the rainfall most rivers periodically flood in their lower reaches. In the case of the large river systems, such as that of the Fly River in the south and of the Sepik and Ramu Rivers in the north, floodwater covers thousands of square kilometres for at least several weeks every year. In the low-lying parts of these plains drainage

An aerial view over the tall, evergreen, broad-leaved forests on the alluvial plains near Vanimo. The photo shows the variety in shapes and tones of the crowns forming the canopy.

is often impeded for long periods, giving rise to swamps and lakes in areas where drainage is permanently blocked. The deterioration in drainage conditions is clearly reflected by the change in vegetation types. The first sign is the occurrence of sago palms in the under-storey of the forest, the canopy of which is also less dense and more irregular than usual. Sago palms are easily recognized by their thick trunks and very large fronds, which are over 10 metres (about 33 feet) long and covered with rows of needle-like spines on the midribs. They are very important in the local economy, as the starch extracted from the pith in the trunks forms the staple diet for more than half the lowland population.

When drainage conditions further deteriorate, sago palms gradually take over from the forest and finally form pure stands. These are flooded every year for several months, and the water-table remains close to the surface for the remainder of the year. In swamps where water is permanently above the surface sago palms cannot survive, and there cane grasses, reeds, or tall sedges and herbs dominate the vegetation if a more or less solid substrate can still be reached by the roots. In deeper water, water-lilies, water-ferns, floating grasses, duckweed, and other water-plants are found.

In the estuaries where the mud brought down by the rivers settles out after coming into contact with the salt water, mangrove vegetation is at home. Only about twenty species of trees and a few herbs and ferns are adapted to the conditions in this habitat. The trees show the well-known features of stiltroots branching out from the lower parts of the trunks, and pneumatophores of various shapes protruding above the mud. The interface between freshwater and saltwater environment is indicated by the occurrence of commonly large stands of nipa palms. This palm has only a rudimentary trunk, but its fronds are huge and exceed those of the sago palms in size. If, due to the very low gradient of the country, the swamps behind the mangroves are extensive, the tidal action is also felt in the freshwater environment through banking-up the river flow. Some tree species, totally unrelated to the mangrove species, show very similar adaptations in the way of stiltroot formations, but little is known about the floristics and ecology of these rather unique freshwater tidal habitats because of the inaccessibility of the terrain.

Dry-season influences

The coastal lowlands around Port Moresby, the area south of the lower Fly River, the plains north of the lower Sepik River, part of the Markham Valley, and small areas along the northeast coast are subject to prolonged dry spells every year. These are most intense in the Port Moresby area, where the climate resembles that of the top end of the Northern Territory. The vegetation also has a typical Australian aspect. It is an open woodland of several species of gum trees with a ground cover of grasses, amongst which Kangaroo Grass is often dominant. Semi-deciduous scrub and forest occur along intermittent watercourses and on soils with a good moisture retaining capacity. In the scrubs, trees are often gnarled and several shrubs have long trailing branches, commonly with spines. In the forest, the trees generally remain thin, but some—for example, the native kapok tree and an endemic species of bottle tree—stand out above the canopy and can reach a considerable size. Many trees, especially the taller ones, are deciduous, some at the onset of the dry season, others only when the dry season intensifies. Several species develop spectacular red and golden "autumn" colours before dropping their leaves. It is a remarkable experience for somebody familiar with northern temperate zone conditions to see these colours and hear the fallen leaves crackle underfoot while the sun is straight overhead and the atmosphere is bright. The evergreen species normally have hard, roundish leaves, about 5 centimetres (about 2 inches) long.

Swamps and periodically inundated plains are the major habitats in the area south of the Fly River. The swamp vegetation is dominated by several species of paperbarks (*Melaleuca*) forming either open stands or a closed forest. A thick cluster of roots around the basal part of the trunks indicates the average inundation level during the wet season. Open woodland is the main vegetation on the plains. Besides paperbarks, several other "Australian" species form part of the flora. These include some wattles and *Banksia dentata*. Eucalypts, however, are rare or absent.

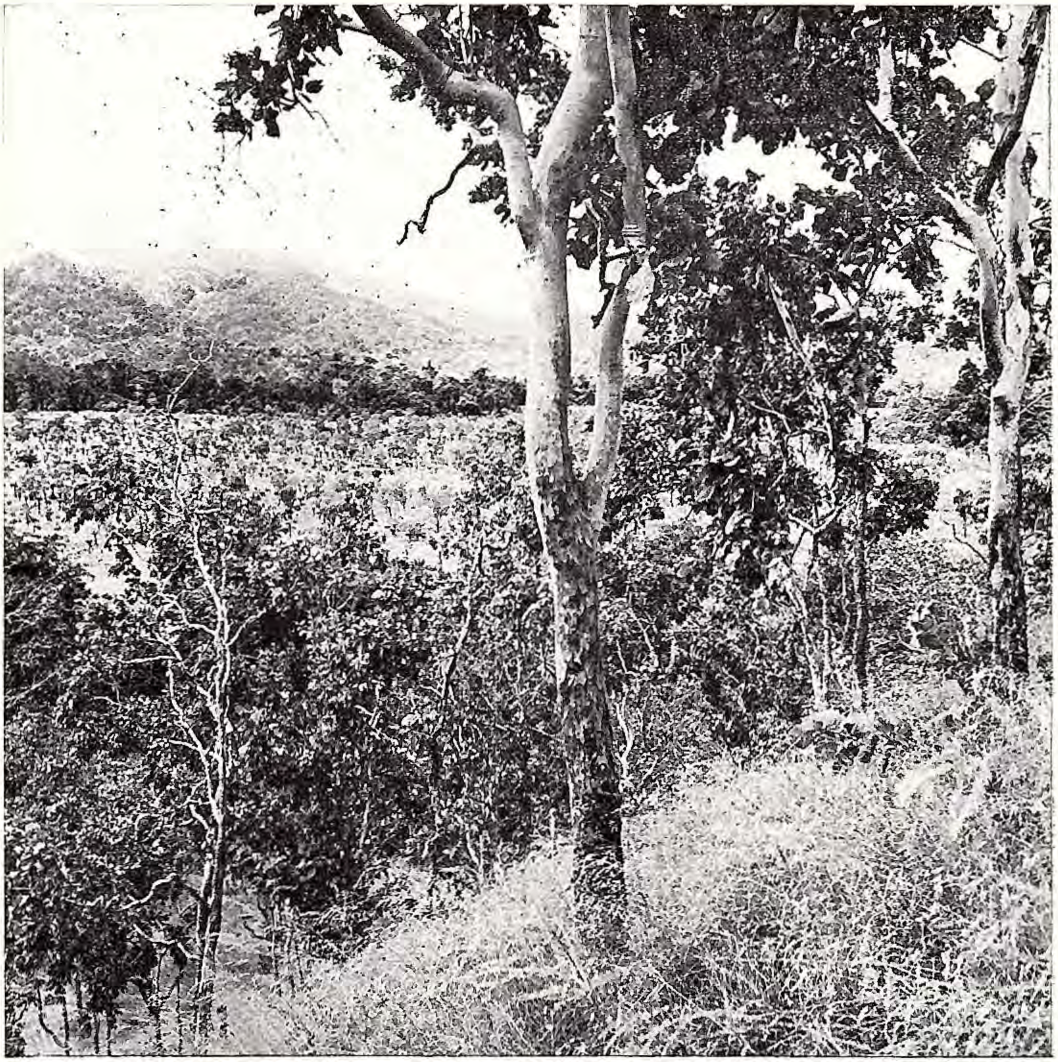
The seasonally dry areas north of the Sepik River are characterized by large tracts of grasslands, separated by gallery forests, often with sago palms, in the valleys. The origin of the grasslands is still a matter of controversy. Was man the primary cause, or, say, poor soil conditions? However, fire is essential to the maintenance of the grasslands. If it is excluded, woody regrowth establishes itself and one may assume that in due time the grasslands will revert to forest. The typical seasonal forest formations occurring near Port Moresby are not found in any of the drier areas north of the main range. However, some eucalypt species have managed to cross and occur in open woodlands around Safia and near Pongani, about 150 kilometres (about 93 miles) east of Port Moresby.

Rainforest

Seen from a vantage point the rainforest canopy looks like an undulating carpet composed of many shades of green. Differences in crown shape, branching habit, and size and colour of leaves are the reason for this striking variety in tree crowns. Lianes spread through the crowns, and often it is impossible to decide which part of the crown belongs to the tree proper. Woody epiphytes, clinging with their roots to the branches of the host tree, also spread their branches through and above the canopy.

Young strangling figs are amongst these epiphytes. Their anastomosing roots grow down the trunk of the host tree and in time reach the soil. As the fig grows these roots become thicker and finally coalesce. The host tree is slowly strangled in the process, because the fig roots do not allow the tree to expand, with the result that at last the sap flow in its bark is cut off. When the host tree decays the fig becomes a hollow, but independent, tree, and often has in the meantime developed an enormous crown conspicuously emerging above the forest canopy.

Conditions inside the forest contrast sharply with those above the canopy, as only a small fraction of the light which falls on the canopy penetrates to the lower layers. On the forest floor only seedlings and scattered shade-loving grasses, forbs, and ferns are found, while the struggle for light has forced most of the plants to extend towards the canopy. Saplings, still unbranched and bearing a cluster of leaves at their top, are common; their growth form is likely to be the result of this struggle.



View over open woodland country about 20 kilometres (about 12.4 miles) east of Port Moresby. *Eucalyptus confertiflora* and a ground cover of Kangaroo Grass (*Themeda australis*) occupy the foreground. Semi-deciduous forest occurs along a watercourse in the mid-distance.

An aerial view over the Laloki River meandering through the swampy coastal plain 20 kilometres (12.4 miles) northwest of Port Moresby. The trees grow on the higher levees and cane grass on the lower ones, while reeds and cane grass cover the swamps. Semi-deciduous forest occurs on the higher alluvial plains in the background. [Photo: J. G. Speight.]

Because of the low illumination the undergrowth is usually sufficiently open to allow one to walk through the forest without the use of a bush knife. However, locally progress can be barred by fallen logs and branches, by young rattans, or by tangles of lianes fallen from the canopy layers. Rattans are climbing palms with fronds ending in long multi-barbed whips, which are excellent devices not only for getting a hold on thinner tree branches but also on the hair and clothes of the unwary passer-by.

Many trees are adorned by climbing plants which root in the soil but seek foothold on tree trunks to support themselves. Trunks and branches also form the substrate for epiphytes, which extract all their nutrients from the rainwater that runs off the crown of their host tree and from the litter that settles between their roots. Some, for instance the staghorn ferns, have developed elaborate structures to collect water and humus. Many families of flowering plants, ferns, and mosses are represented among the species which make up the communities of climbers and epiphytes. Orchids feature prominently in the latter category. They form the largest family in New Guinea, and comprise about 130 genera with a total of probably about 2,600 species. The upper surface of older leaves of under-storey plants are often overgrown by so-called epiphyllous mosses, lichens, and algae. The algae are known to bind atmospheric nitrogen, possibly to the advantage of the host plant.

Palms occur at all levels of the forest. The smallest species are less than 1 metre (3·28 feet) tall and occur gregariously in the herb layer. Others are 2 to 4 metres-tall treelets, also commonly gregarious, and bearing a crown of "untidy", irregularly divided fronds. Taller than these, but usually remaining well below the canopy, are the members of the fan palm genus *Licuala*. Finally, there are the tall palms with large, pinnate leaves, some of which grow only in the sub-canopy, while other species penetrate into and occasionally through the canopy, reaching heights of 40 metres (about 131 feet). The trunk of such a tall palm is a really magnificent example of nature's engineering, because palms have virtually no means of increasing their girth after they have formed the basal section of the trunk during the seedling stage. Dicot trees of such height have added over the years secondary growth layers to their trunks, which often are reinforced by plank buttresses as well.

Finally, some figures on the species diversity in the lowland forests will be given by quoting from the work of a colleague of mine, Mr K. Paijmans. He investigated four plots, 0·8 hectare (about 2 acres) each, in the hills near Popondetta. In these plots all trees with a girth, at breast height or above the buttresses, of 30 centimetres (about 11·8 inches) and over were enumerated, which amounted to a total of 1,864 trees. Amongst these, 392 species were represented, but the four plots had only three species in common. Two plots on a plateau and less than 1 kilometre (about five-eighths of a mile) apart, with 116 and 145 species respectively, had 64 species in common. The two other plots, on hill slopes, but about 40 kilometres (about 25 miles) apart shared only 23 species out of the 122 and 147 present on the respective plots. Only 10 per cent of the species were represented by 11 or more individuals, and 35 per cent of the species occurred as a single specimen only. It should be realized that these figures pertain only to trees of girths of 30 centimetres (about 11·8 inches) and more. None of the other plants—e.g., small trees, palms and pandans, shrubs, small and large ground herbs, lianes, climbers, epiphytes, parasites, saprophytes, tree-ferns, other ferns, and mosses—were taken into account. In view of the staggering complexity of a rainforest community, it will not surprise the reader that no one has as yet produced a complete analysis.

The account of the lowland vegetation of Papua New Guinea has been, of necessity, sketchy and incomplete. More information can be found in publications of detailed studies of particular areas. Several short general accounts of the vegetation are also available; two of these are mentioned below under "Further Reading". An original vegetation map at scale 1 : 1,000,000 and a comprehensive description of the vegetation of Papua New Guinea are presently being prepared by Mr K. Paijmans.

[*Unless stated otherwise, the photographs in this article are by the author. All are made available by courtesy of CSIRO.*]

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NEW FORMAT FOR MAGAZINE

Commencing with the March 1974 issue, "Australian Natural History" will have bigger pages and an improved layout. This will give the magazine a more modern and attractive appearance and improved pictorial display, without, of course, reducing in any way the features which readers have always appreciated.

Mt Giluwe, from about 2 300 metres (about 7,550 feet). Gardens and grasslands on the lower slopes are separated from the grassland and herbfield summit area by a band of upper mountain forest. [Photo: E. Loffler.]

HIGHLANDS VEGETATION

By D. WALKER

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ANY visitor to the Central Highlands of New Guinea, flying up from Port Moresby to Goroka or Mt Hagen, must be impressed by two things. The first is the steepness with which the mountains rise from the soggy lowlands to ridges 3 000 metres (9,850 feet) and more in height; the second is that, whereas the mountains themselves are mostly forested, the large high-level valleys which lie amongst them are filled and flanked by grasslands, swamps, and gardens. In terms of species composition and physical structure, mountain forest replaces lowland forest between 1 000 metres and 1 500 metres, depending on such variables as temperature, rainfall, and soil type, but only rarely is the distinction sharp and transitional vegetation types are common. Only a few of the highest peaks (e.g., Mt Wilhelm and Mt Giluwe) emerge above the forest and may bear snow fleetingly.

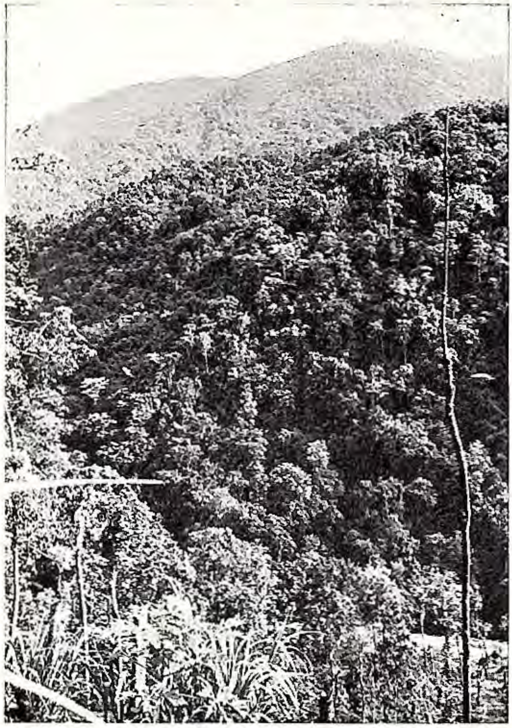
It would be intellectually comforting to be able to subscribe, as most commentators on New Guinea vegetation have done, to the notion that the mountain forests fall into a number of well-defined types which, after making allowance for the effects of aspect, soil, settling of cold air on the ground, and so on, lie in broad altitudinal bands. It is true that a general impression that this is the case may honestly be gained from experience in a particular region or by the wider experience of those who, like me, have only modest taxonomic skill. But the few adequately critical studies so far published certainly give the impression that the reality may be a great deal more complex. In the present state of knowledge the only break in forest type consistently correlated with altitude seems to occur at about 3 000 metres (9,850 feet), although this is much confused by the effects of prolonged cloud-lie, which is a dominating environmental factor about this altitude.

Lower mountain forest

The lower mountain forest, which is a simple portmanteau term for everything below the 3 000-metre (9,850 feet) level, is a very varied thing. Its canopy, which may be 10 metres (about 33 feet) deep and is usually continuous, often reaches to 30 metres (about 100 feet) or more above ground surface; the under-storey, which contains many juveniles of the canopy trees, is well-stocked but the lower undergrowth and ground cover vary very much from place to place. Very many tree species contribute to this forest, some of them notable plants geographically, ecologically, or aesthetically, such as the southern beeches (*Nothofagus* spp), the oaks (*Castanopsis acuminatissima*, *Lithocarpus* spp) and the conifers (e.g., *Podocarpus* spp, *Phyllocladus hypophyllus*, *Papuacedrus* spp). Quite commonly one or other of these plants is numerically so abundant in an area as to displace other species which grow with it elsewhere, so forming patches of rather distinct composition and appearance which have usually been treated as separate forest types. There are particular cases (e.g., small stands of very large southern beeches from which regeneration seems not to be spreading) for which this is well justified but, in general, transitional types are so common and the extremes themselves are so varied as to bring into question the validity of such a procedure. For the present, at least, it seems best to think of the lower mountain forest as a complex mixture in which, in response to ecological and historical circumstances, nodes occur in which particular components gain pre-eminence. Some of the plants involved have altitudinal limits which, of course, impose similar limits on the vegetation nodes their abundance typifies. For instance, no species of *Lithocarpus* or *Castanopsis* grows above 2 900 metres (about 9,500 feet), so that so-called oak forest is similarly limited; in fact, oaks rarely occur together in numbers sufficient to give special character to the forest above 2 500 metres (about 8,200 feet). The frost-tolerance of some of the conifers leads them to assume dominant roles in hollows into which cold air frequently drains. Because of the great environmental diversity of the New Guinea Highlands, there is nothing monotonous about the lower mountain forest even if pedantry prefers to unite its parts into a continuous, but continuously varying, whole.

Upper mountain forest

The upper mountain forest extends from about 3 000 metres (9,850 feet) to the altitudinal limit of closed woody vegetation which, undisturbed, lies at about 3 800 metres or somewhat below. There are very few critical descriptions of the transitions between the two main forest types, both of which are convergently modified in structure, and almost certainly in species composition, by the frequency with which cloud swathes this altitude day after day through much of the year. The upper mountain forest, however, is not so rich in species and has a canopy about 15 metres (about 50 feet) high, a thick shrubby undergrowth, and good litter accumulation. Oaks and southern beeches are absent but conifers remain, particularly *Dacrycarpus compactus*, whilst members of the myrtle, laurel, and rose families seem to become important. With increasing altitude the forest becomes lower and numbers amongst its shrubs several which also grow outside the forest in wet, cold, grassy places or above the maximum altitudinal limit. In many places the forest edge has a characteristic flora, in which daisy trees and rhododendrons figure largely, but it is at least possible that this is fire-induced and occurs only where hunting fires have been used in the neighbouring grassland until very recently. Although the forest limit is well above the highest level of normal human habitation (about 2 600 metres or about 8,530 feet) there are strong indications, such as wood charcoal in soil below grassland, which, together with the recollections and even present habits of indigenous people, conclusively demonstrate that the origin of some of the vegetation outside the forest was influenced by humans. This is



Lower mountain forest in the foreground merging into upper mountain forest on the distant slopes. Inbrum Valley. [Photo: G. S. Hope.]

particularly the case where the moraine-choked bottoms of formerly glaciated valleys inhibit the drainage of soil water but encourage the down-valley passage of cold night air, so opposing the establishment of trees well below their normal altitudinal limit and providing natural grassy corridors through which hunting parties can move easily up the mountains.

Immediately contiguous with the forest, the vegetation is dominated either by grass tussocks half a metre high and a metre across, compact mossy swamp plants, or low straggling shrubs amongst which figure both Northern and Southern Hemisphere heath families (Ericaceae, Epacridaceae). These shrubs may persist as high as about 4 300 metres (about 14,100 feet) in favourable localities, but the large tussocks usually give way to different, smaller, and more delicate tussocking grasses and herbs by about 3 900 metres (about 12,800 feet), and lichens and mosses become more important in the vegetation.

On the highest mountains the ice-smoothed slabs and frost-shattered edges of the summit areas above about 4 200 metres (about 13,750 feet) are interspersed with slopes on which the soil is frost-sorted into stone polygons, terraces and stripes bearing correspondingly patterned plant communities of small compact herbs and more diffuse moss mats.

Altitudes exceeding the natural limit of forest trees are relatively uncommon at low latitudes and the vegetation which occupies them is peculiarly interesting in a number of ways. Effects of aspect, which frequently determine the differential distribution of vegetation types in higher latitudes, can also be seen on equatorial high mountains; in spite of the perennially high elevation of the sun, the time of commonest cloud accumulation affects the radiation reaching opposite sides of the same mountain. Another interesting feature is that the same area of ground on the high mountains of New Guinea supports a considerably greater mass of living plant material than do places in higher latitudes which, although at lower altitudes, are otherwise ecologically comparable. This difference is probably the result of the high insolation and lack of seasonality of climate on the equatorial mountains.

Forest boundaries

The upper boundaries of the mountain forests are often disturbed, but their lower edges, where they abut the grasslands and gardens of the valley slopes, are almost everywhere unnatural. They lie between about 1 400 and 2 600 metres (about 4,600 and 8,500 feet)—that is, where human population densities are at their highest. Before the advent of the white man the indigenous people made their gardens by cultivating the grassland with digging sticks or nibbling at the forest with polished stone axes; now these are largely replaced by steel spade and axe respectively, but now, as then, fire remains an important adjunct to both processes. Because we can witness the conversion of forest to garden and of spent garden to grassland at the present day, it is tempting to suppose that *all* the grasslands of the great intra-montane valleys were formerly forest and are the product of horticulture. The very extent of the grasslands, coupled with the impression that the present horticultural system is related rather specifically to sweet potato growing and the supposition that this staple is an introduction of the last 500 years, leaves the jigsaw puzzle unconvincingly fitted together; but more of this later.

Cultivated crops

The grasslands inter-penetrate areas, usually fenced, in which cultivated patches are currently rotating. The main crop is sweet potato, usually grown on mounds of size and shape dictated by local tradition, sometimes interplanted with indigenous green vegetables and, increasingly, with recently introduced Irish potato, cabbage, peas, and so on. Another traditional garden type contains bananas, sugar cane, *Ficus dammaropsis*, winged bean and others and occupies a very much smaller total area than do the sweet potato gardens. Some groups of people have long practised monoculture forestry, planting *Casuarina oligodon* in fallow gardens in order to provide structural timber and firewood and, incidentally, nitrifying the soil. When sweet potato gardens have rotated with ephemeral grass fallow in an area for several years, long enough to evince a fall in yield or the loss of obvious organic content of the soil, it is abandoned to the rootling of domestic swine and often periodically burned. Depending on drainage, climate, pig-pressure and fire-frequency, the resulting grassland varies in composition but *Miscanthus floridulus* (cane grass), *Ischaemum polystachyuum*, and *Imperata cylindrica* are amongst the most common and obvious species. From east to west through the Highlands the valley vegetation is increasingly varied and patchy, so that driving along the highway in that direction one has a sense, probably quite unfounded, of approaching an agronomic frontier.

The Highlands people do not either clear-fell the forest or leave well alone; they harvest a great variety of animals and plant-products from it, such as *Pandanus* nuts, fibres from the nettle family for the fabrication of string bags, and so on. In these ways the forest has been altered by human activity to an unknown degree.

"The Observatory" (4 110 metres, or about 13,484 feet), a subsidiary peak of Mt Wilhelm, seen from Kombugomambuno (3 350 metres, or about 12,950 feet) in the Pindaunde Valley. Tree ferns (*Cyathea atrox*) grow amongst tussock grass (*Deschampsia klossii*) on a moraine blocking the valley, the sides of which are covered by upper mountain forest. [Photo: J. M. B. Smith.]

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Historical problems

Little though we know about New Guinea Highlands vegetation, it presents a number of problems which can only usefully be investigated in historical terms. One set of such problems is associated with the Highlands' position as a major link in the interrupted mountain chain between the two hemispheres through Indonesia. It is very striking that predominantly Southern and Northern Hemisphere sections of single families, or whole families so distributed, meet in New Guinea. Amongst the trees, the northern *Castanopsis* and *Lithocarpus* grow alongside the southern *Nothofagus*, all representatives of the family Fagaceae. Shrubs of the northern heath family Ericaceae grow with plants of the southern equivalent family, Epacridaceae. Clearly, patterns on such a grand scale must have needed large chunks of geological time in which to develop, and argument as to their origins is inevitably bedevilled by the inadequacy of the fossil data. If as has been increasingly asserted during recent years, the flowering plants as a whole first evolved somewhere in the western tropical or subtropical Pacific region, the simplest explanation might be that the New Guinea Highlands are a refugium for some of the earlier products from which geographical and biological radiation have gone hand in hand. Opponents of this kind of idea, however, can point to the probability that the mountains themselves are geologically recent, perhaps even the product of collision between migrating continental plates. Without taking up the question of the ultimate origin of the families involved, this geological basis suggests that we are now witnessing a reunion of closely related plants anciently separated.

Another historical problem is that of the stability, or otherwise, of the vegetation we see in the Highlands at the present day. Two rather striking phenomena prompt the supposition that there might be something worth investigating. The first is the altitudinally anomalous position of the valley grasslands and the clear association of human activity with them. The second is the positive evidence of glaciation on the high mountains and down the valleys to about 3 000 metres, a glaciation which we now know to have been waning as recently as 10,000 years ago; surely the climatic change which this implies must also have affected the vegetation pattern. The twin techniques of mud stratigraphy and pollen analysis, backed by radio-carbon dating, have allowed the partial reconstruction of vegetational and some related environmental events in the Highlands during the past 20,000 years. It happens that many plant genera, and even a few species, can be identified by the shape and ornamentation of the walls of their pollen grains. These walls fall in large numbers on accumulating mud and peat surfaces and are there preserved at the appropriate levels as the sedimentary body continues to grow upwards. Their recovery and identification, layer by layer, can therefore provide some hint as to the directions and rates of vegetation change in the past.

Present indications from this currently active research are that major vegetational shifts contemporary with the glaciation of higher altitudes took place down to about 1 500 metres (about 4,920 feet), if not beyond. If we are correct in interpreting pollen data from about 2 000 metres (about 6,560 feet) and 25,000 years ago as evidencing vegetation now found at about the altitudinal tree line and if, with extreme caution, we allow that our record may come from what was a singularly frigid frost hollow, we can hardly escape the conclusion that a vegetational shift of about 700 metres (about 2,300 feet) is implied between then and now. Indeed, since forests presently appropriate to that

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OPPOSITE

One of the most spectacular members of New Guinea's diverse reptile fauna is the Green Python (Chondropython viridis). It is widely distributed throughout the island (with an outlying population in Cape York Peninsula), and occurs in a range of habitats from primary forest to garden areas. The adults are normally rich emerald green, although occasional blue specimens are seen; the young, on the other hand, vary from rich yellow (as in the specimen shown opposite) to red or orange. The change from juvenile to adult colour may take place in only a few weeks, and may occur between sloughing cycles. [*Photos: H. G. Cogger.*]

Birds-of-Paradise

Among the numerous and diverse animals and plants which have evolved under New Guinea's conditions of tropical climate and varied topography, no group has so captured man's imagination as the birds-of-paradise. With habits as bizarre as their plumage, these birds have come to symbolize the strange and distinctive beauty of this large island.

Except for two species found only in the Molucca Islands, two rifle birds found only in eastern Australian rain forests, and one rifle bird and one manucode common to both eastern Australia and New Guinea, the remainder of the forty-two known species of birds-of-paradise are found only in New Guinea. They appear to be relatives of the crows and jays, which they resemble in size and the possession of stout bills and harsh voices.

In no other family of birds do the males show such bright colours or such great modifications of various feathers; both are used in their complex displays, which take place at special dancing trees. Like bower birds, many males are polygamous and take no part in nest-building or rearing the young. These are done by the dull-coloured females.

Young males are similar to females; they take several years to attain full adult male plumage, although before this occurs they are quite capable of mating successfully. In those species where the adult male and female are similar in plumage, normal pairs are formed and the male helps the female to raise her brood. Birds-of-paradise are forest-dwellers, and feed on fruit, insects, tree-frogs and lizards.

Left — King Bird-of-paradise, *Cicinnurus regius* (Linnaeus). This is the smallest of the birds-of-paradise, the body, excluding the long central tail feathers, being only 5 to 8 inches long. The male selects and displays on its own special tree in the forest, while the dull-brown female, unlike most other birds-of-paradise, makes a nest in a hole in a tree. Small flocks consisting of a single adult male in full plumage and several brown females and young males are commonly seen moving low through the forest.

Upper right — Magnificent Bird-of-paradise, *Diphyllodes magnificus* (Pennant). This is slightly larger than the King Bird-of-paradise, being 6 to 8 inches long without the central wire-like tail feathers. The male's display area is a clearing about 20 feet in diameter, with several bare saplings on which he displays and may mate with the female. Both females and young males are brown, and are more often seen than the adult males. This species has the usual type of stick cup-nest.

Lower right — Multi-crested Bird-of-paradise, *Cnemophilus macgregorii* De Vis, also called the Sickle-crested or Crested Golden Bird. These birds look rather like bower birds, and were originally placed with that group. However, later anatomical studies have shown them to be true birds-of-paradise. No display area has yet been found. The nest, which is domed, made of moss and fern stalks, and built in a decayed tree stump, is different from the nests of all other birds-of-paradise.

[*Photography by W. Peckover*]

(*Continued from page* 414)

altitude seem to have become established round the site at least 5,000 years ago the change must have been quicker. In the glaciated and periglacial areas themselves there is evidence that the forest moved up the final 1 000 metres (about 3,280 feet) to its present natural altitudinal limit in about 1,000 years. Given these changes at high altitudes one cannot help wondering how effective the causative environmental changes were in modifying what is now lowland rainforest. The sea-level was lower during glacial times and the lowlands were thereby more extensive, which is another reason for anticipating that the lowland tropical rainforest, in common with that of the Highlands, has since had little chance to gain long-term stability.

Origin of Highlands valley grasslands

The origin and age of the Highlands' valley grasslands are still unknown but a solution of the problem is now much closer than it was a decade ago. Horticultural implements of types still in use in the Highlands have been unearthed from pollen-analysed deposits and dated to about 2,300 years old. The vegetation of that same period and region, at about 1 500 metres (about 4,920 feet), was certainly disturbed and grasslands were present. Indeed, at altitudes as high as the present limit of human occupation, there is pollen analytical evidence that forest disturbance and grassland initiation had begun almost 5,000 years ago, although there is no positive association of artefacts which would prove beyond all doubt the significance of human activity in this process. Yet the presumption that, long before the introduction of the sweet potato, horticulture had become established in the Highlands must now be very strong. Until we have some evidence of the crops being grown and the human populations being supported we can only guess at their impact on the forest itself. Certainly it was different from that of earlier people who, presumably, were totally dependent on forest products for a livelihood. But, almost equally certainly, it most probably made more specialized demands on natural resources, so threatening particular links in the ecological chain with irrevocable disruption.

Travelling through the New Guinea Highlands at the present day it is hard to believe that horticultural man has been there as long as he has been in, say, the British Isles. Yet, in places where the steel axe, the chainsaw, and the bulldozer have already made their marks, it is clear that, whatever the environmental differences may have contributed, the relative destruction of British vegetation compared with that of the New Guinea Highlands has been chiefly due to the imposition of metal technologies on Britain during the past few thousand years. The vegetation of the New Guinea Highlands was saved this until about 40 years ago but by now the whole armoury of the modern developer can be brought to bear on, and certainly destroy, what some scientists believe may be the nearest thing, perhaps even the closest place, to the very cradle of flowering plants, without which, it is reasonable to suppose, man would never have been.

OPPOSITE

The male Rainbow Wrasse (Paracheilinus) is the underwater counterpart of the majestic bird-of-paradise. This species, which was recently collected at Madang, Papua New Guinea, was previously unknown to science. These fish inhabit the rich coralliferous areas of the outer reef slope at depths between 10 *and* 50 *metres. The female does not possess the elongate fin rays, which the male erects during courtship displays. The fish fauna of New Guinea is one of the richest on earth. At least* 2,500 *species inhabit the marine and freshwater habitats of the world's second-largest island.* [*Photo: G. R. Allen.*]

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LAND MAMMAL FAUNA

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THE New Guinea mainland shares with Australia the distinction of being home to all three subclasses of mammals—the monotremes, the marsupials, and the placentals. Prior to the inundation of Torres Strait by rising sea-levels at the close of the last glacial period, New Guinea and Australia were part of the same landmass. Reflecting this, the faunas are not markedly different at the higher taxonomic levels. New Guinea shares with Australia one family of rodents, one of monotremes, six of bats, and six of marsupials. Seven Australian families missing from New Guinea contain specialized forms adapted to sclerophyll forests or more arid habitats. The faunas of the Bismarck and Solomon Islands have been derived from the New Guinea fauna, but deep-sea barriers between the mainland and these islands have prevented all but a few groups from spreading there. The successful forms include one bandicoot, one wallaby, two cuscuses, several rodents, and a considerable number of bats.

The major component of the Papuan fauna of New Guinea and the North Melanesian fauna of the Bismarcks and Solomons consists of rainforest species. The speciation that has occurred within the marsupial and rodent stocks in the rainforests will be discussed in more detail later.

A much smaller component of the fauna consists of several typically Australian forms occurring in the drier savannah areas of southern New Guinea opposite Cape York Peninsula and the Port Moresby area. Of these, the Sugar Glider (*Petaurus breviceps*) and the Short-beaked Echidna (*Tachyglossus aculeatus*) have spread widely through forested areas. The Brindled Bandicoot (*Isoodon macrourus*), the Agile Wallaby (*Macropus agilis*), and the Dusky Field-rat (*Rattus sordidus*) have extended their range around the southeast tip of New Guinea, colonizing extensive areas of man-made secondary grasslands in higher rainfall areas. The Red-legged Pademelon (*Thylogale stigmatica*) and the Brush-tailed Tree-rat (*Conilurus penicillatus*) are limited in distribution to the trans-Fly area of southern Papua. The Red-cheeked Dunnart (*Sminthopsis rufigenis*) and the New Guinea Planigale (*Planigale novae-guineae*) occur in both the Port Moresby and Western District savannahs.

Female and young Mountain Cuscus (*Phalanger vestitus*). This common species replaces the Grey Cuscus (*P. orientalis*) in the mid-mountain and lower montane forests. The fur is usually a dark chocolate-brown. The contrasting white abdomen is obscured in this photo. [Photo: Author.]

The third component of the present-day fauna consists of those exotic species that have become established recently with the help of man. The Polynesian Rat (*Rattus exulans*), the New Guinea Wild Dog (*Canis familiaris hallstromi*), and the pig *Sus scrofa papuensis* arrived in New Guinea with Melanesian man or his predecessors. The Polynesian Rat is widespread but commensal with man, living in his houses and gardens, while the wild dog has found a niche for itself in the alpine grasslands of the main mountain ranges. Western civilization has more recently endowed New Guinea with the ubiquitous Ship Rat (*Rattus rattus*), Norway Rat (*R. norvegicus*), and House Mouse (*Mus musculus*). Domestic cats (*Felis catus*) have become feral in some areas. Three species of deer have been introduced. The Rusa Deer (*Cervus timorensis*), introduced into southern Irian Jaya from Indonesia, has crossed the border and colonized the expansive plains between the Morehead and Bensback Rivers in western Papua, where it now dominates the fauna.

Tree-kangaroos

Tree-kangaroos are basically terrestrial browsing mammals that are adapted to sheltering in trees. Of the five species usually recognized from New Guinea, four occur in Papua New Guinea. Two species are found in the Cape York rainforests, but the genus has not reached the Bismarcks or the Solomons. Goodfellow's Tree-kangaroo (*Dendrolagus goodfellowi*) occurs only in the hill and mountain forests of eastern New Guinea. Matschie's Tree-kangaroo (*D. matschiei*) is related to *D. goodfellowi*, but is a shorter-tailed, stockier animal, and is the only species found on the isolated mountain ranges of the Huon Peninsula. Doria's Tree-kangaroo (*D. dorianus*) is a large, heavily-built species, partly sympatric with *D. goodfellowi* in the main ranges of the east and extending into the west-central highlands. The Grizzled Tree-kangaroo (*D. inustus*) is a long-tailed, large-footed western species, occurring in Papua New Guinea along the north coastal ranges bordering the Sepik River. It is sympatric with the White-throated Tree-kangaroo (*D. ursinus*) in far-western New Guinea.

Cuscuses

The cuscuses are a very successful group widespread in tropical Australasia and occupying habitats from sea-level to the tree-line in alpine areas in New Guinea. More than one species frequently co-exist sympatrically, and where they do the species differ in body size and utilization of the habitat. The widespread Spotted Cuscus (*Phalanger maculatus*) of the lowland forests shelters among dense tree-foliage during the day. The Grey Cuscus (*P. orientalis*), also widespread in the lowlands, is much smaller and inclined to seek tree-holes for shelter. A third species, the Ground Cuscus (*P. gymnotis*) is sympatric with the previous two species in the lowlands, but also ranges into the montane forests. It feeds in trees during the night, but shelters in terrestrial dens during the day, choosing holes under tangled tree-roots, among rock clefts, or in caves. This habit restricts the species to the more rugged terrain, where suitable den sites occur. Two other species occur in the montane forests, where they variously choose tree-holes or tree-roots for shelter. The Mountain Cuscus (*P. vestitus*) is perhaps the commonest game mammal in the lower montane forests between 2 000 metres (about 6,500 feet) and 2 800 metres (about 9,000 feet). At higher altitudes this species is replaced by the long-furred Silky Cuscus (*P. sericeus*).

The rarest of the New Guinea cuscuses is the Black-spotted Cuscus (*P. atrimaculatus*), known only from a few museum specimens collected in the northern lowlands, where it is sympatric with *P. maculatus*. Races of the Spotted and Grey Cuscus occur in north Queensland and the Bismarck Islands. The Grey Cuscus also occurs in the Solomons, where a brown-coated form has developed in the mountains.

Wallabies

The most widespread wallaby is the Brown Pademelon (*Thylogale bruijni*), occurring throughout New Guinea and the Bismarck Archipelago. Various subspecies of this wallaby are distributed from the lowland forests near sea-level to the remnant patches of montane forests in the alpine grasslands at 4 000 metres (about 13,000 feet).

An interesting group of rainforest wallabies now confined to New Guinea but formerly occurring on the Australian mainland are the Forest Wallabies. The Brown Dorcopsis (*Dorcopsis v. veterum*) is common in the lowlands west of the Fly River, and the Grey Dorcopsis (*D. v. luctuosa*) is common to the east. In the northern lowlands these two forms are replaced by the White-striped Dorcopsis (*D. hageni*). Both species are rather sparsely furred, almost naked on the inner aspects of the limbs, an apparent adaptation to the humid climate in which they live. Neither species has been recorded above 400 metres. A third species, the Black Dorcopsis (*D. atrata*), occurs only on Goodenough and possibly Fergusson Islands off southeast Papua. This dark wallaby lives in the cooler mountain forests on Goodenough and is more thickly furred.

The Mountain or Little Forest Wallaby (*Dorcopsulus vanheurni*) is widely distributed in mountain forests. In appearance it is rather like a small pademelon. Its activities in captivity indicate that it may be more at home in rough, rocky country and thus avoid competition with the larger Brown Pademelon, with which it is sympatric. Macleay's Forest Wallaby (*D. macleayi*) is a rare species of the mid-mountain forests of the southeast and is larger than *D. vanheurni*.

Ringtail possums

The mountain rainforests of New Guinea contain the majority of the living species of ringtail possums (*Pseudocheirus*). The three larger species belonging to the subgenus *Pseudochirops* are superficially similar to the smaller cuscuses whose habitat they share. The two largest species, the Copper Ringtail (*P. cupreus*) and the Woolly Ringtail (*P. albertisi*), replace each other geographically, the former occurring in montane forests of the eastern half of the central ranges, and the latter in the west. The Copper Ringtail utilizes tree-holes for shelter. Its smaller relative, the Golden Ringtail (*P. corinnae*), is reported to shelter among foliage and epiphytes.

The relationships and distribution of the small ringtails of the subgenus *Pseudocheirus* are still rather poorly known. Of five species recorded for New Guinea, the common one in eastern New Guinea is the Painted Ringtail (*P. forbesi*). This is a mid-mountain and lower montane forest species, reported to be a nest-builder, and favouring the forest edge and areas of regrowth. A similar but smaller species is the Hoary Ringtail (*P. canescens*), of the lower-altitude hill forests in the southeast and far west. The Pygmy Ringtail (*P. mayeri*) is the smallest of the group, living in the high-altitude mossy forests. Though widespread in the mountains of central-western New Guinea, it occurs no further east than the Hagen Range in the central highlands of eastern New Guinea.

Insectivorous possums

Two striking genera of possums are adorned with bold patterns of black and white stripes. The Common Striped Possum (*Dactylopsila trivirgata*) is widespread in lowland and hill forests of New Guinea, and the rainforests of Cape York Peninsula. A closely related species, *D. tatei*, has been described from Fergusson Island. A third species, the Fluffy-tailed Possum (*D. megalura*), occurs in far-western New Guinea. The Long-fingered Possum (*Dactylonax palpator*) replaces the Common Striped Possum at higher altitudes. The Striped Possums are strictly nocturnal and spend daylight hours in tree-hollows.

Two genera of pygmy-possums occur in New Guinea. The Long-tailed Pygmy-possum (*Cercartetus caudatus*) is regarded as being the most primitive of the pygmy-possum family that has radiated more extensively in Australia. *C. caudatus* occurs in the lower montane and montane forests and is reported to be commonest towards the tree-line on the mountain tops. Its ecological equivalent in the lowland forests is the

A young Painted Ringtail (*Pseudocheirus forbesi*) from the Wapenamanda area of the Western Highlands. None of the ringtails has adapted to the tropical lowland forests, but one species occurs in hill forests. [Photo: Author.]

Feather-tailed Pygmy-possum (*Distoechurus pennatus*), a widespread but uncommon species that has been taken from holes in dead trees.

Bandicoots and dasyurids

The Spiny Bandicoots (*Echymipera*) are found throughout the lowlands. They are long-snouted, short-eared and short-tailed, with rather spinous fur. The Kalubu Bandicoot (*E. kalubu*) is widespread along forest margins and secondary grasslands throughout lowland New Guinea and the Bismarck Archipelago, and is one of the few marsupials to have crossed the water barrier between New Guinea and New Britain. The Rufous Bandicoot (*E. rufescens*) is rather longer snouted than the Kalubu Bandicoot and seems to prefer forested areas. Both species are sympatric throughout mainland New Guinea. The Rufous Bandicoot also occurs on Cape York Peninsula.

The Clara or White-lipped Bandicoot (*E. clara*) is one of New Guinea's rarer mammals. The skull and teeth are much more heavily built than those of its relatives, possibly indicating a more carnivorous diet. It is known only from the Irian Jaya lowlands and various tributaries of the Ramu and Sepik Rivers.

The New Guinea Long-nosed Bandicoots (*Peroryctes*) are rather similar to the Australian Long-nosed species (*Perameles*). Of these, the Broadbent Bandicoot (*P. broadbenti*) is the largest known bandicoot and has only recently been recognized as a distinct species. It is known from the lowland rainforests of southeastern Papua. The Raffray Bandicoot (*P. raffrayanus*) is a brown-furred species of foothill and mid-mountain forests of New Guinea. The smaller Striped Bandicoot (*P. longicauda*) occurs in both forest and tall canegrass areas in highland regions above 1 200 metres. The Papuan Bandicoot (*P. papuensis*) is smaller and more brightly coloured than the Striped Bandicoot and is limited in its distribution to the mountains of southeast New Guinea.

The largest dasyurid in New Guinea is the New Guinea Quoll (*Dasyurus albopunctatus*), geographically and altitudinally widespread over the mainland and on some offshore islands, but not an abundant animal. Six species of medium-sized phascogales are placed in four endemic genera. *Myoictis melas*, of the lowland rainforests, has three dorsal stripes. *Neophascogale lorentzi* is a long-clawed arboreal species of montane forests which hunts for insects on heavily-mossed tree branches. Two species of *Phascolosorex* and two of *Murexia* are a little smaller in size. All are limited to the forests of mainland New Guinea.

There are three species of small phascogales of the genus *Antechinus* related to eastern Australian members of the genus. The Black-tailed Phascogale (*A. melanurus*) is widespread in lowland hill forests and mid-mountain areas and is replaced at higher altitudes by the larger Mountain Phascogale (*A. naso*) and the Little Red Phascogale (*A. wilhelmina*).

The old endemic rodents

The New Guinea mainland has six diverse genera of rats whose relationships are not at all clear. They are evidently remnants of an early radiation of murids that have survived because of various specializations. Four of these genera are monotypic. Two are the largest rats in New Guinea, approaching 3 feet in length. The Black-eared Giant Rat (*Mallomys rothschildi*) and the White-eared Giant Rat (*Hyomys goliath*) are sympatric in the montane forests of the New Guinea mainland. *Mallomys* is a vegetarian, known to feed on the soft shoots of scrambling bamboo and the fleshy-stemmed fern *Marattia*. The diet of *Hyomys* is unknown. A little smaller than these two giant rats, but still a large rat, is the short-furred Narrow-toothed Giant Rat (*Anisomys imitator*), characterized by its deep but narrow lower incisors.

New Guinea's smallest endemic murid is Lorentz's Mouse (*Lorentzimys nouhuysi*), a wide-ranging species of the mainland. Though often called a hopping mouse, evidence for its hopping ability is scanty. *Macruromys* has two species, the larger one, *M. major*, being found in scattered mid-mountain areas of eastern New Guinea.

The sixth genus has nine species. The prehensile-tailed tree-mice of the genus *Pogonomys* form a distinct group of long-tailed arboreal murids. All have a scaleless tactile area on the dorsal surface of the tail-tip, paralleling the condition seen in the unrelated *Pogonomelomys*. Three mainland

The Long-beaked Echinda (*Zaglossus bruijni*) is now quite rare in the central highlands due to hunting pressure, but remains in reasonable numbers in parts of the more remote mountain ranges of the mainland. [Photo: Author.]

species are placed in one sub-genus, *Pogonomys*. These are all different in size. The largest, *P. mollipilosus*, and the smallest, *P. sylvestris*, co-exist in the lower montane forests, and the medium-sized form, *P. macrourus*, occurs in the lowland forests. All three are communal species living in underground burrows during the day. A fourth species has been described from Fergusson Island. The subgenus *Chiruromys* contains five species, distributed through the eastern lowlands. The largest species, *P. forbesi*, lives communally in tree-hollows. Little is recorded about the others.

The water-rats

A second radiation in New Guinea has given rise to the water-rats, classified as the subfamily *Hydromyinae*. Nine genera containing thirteen species occupy a variety of habitats, not all aquatic. The Elegant Rat (*Leptomys elegans*) is usually considered the most primitive of the subfamily and has a lengthened hind foot which suggests that it may be saltorial. Though widely distributed, little is known about it. Two species of *Paraleptomys*, with normal hind feet, occurring in the mountain forests of western New Guinea, have not been recorded in the east.

The Broad-nosed Water-rat (*Parahydromys asper*) is externally like the Common Water-rat and has a similar white-tipped tail but rather coarser fur. The hind feet are partially webbed, indicating that the species may be semi-aquatic. It occurs in mountain forests near streams. The nasal region of the skull of this species is unusually broadened, and the lips are swollen.

The Common Water-rat (*Hydromys chrysogaster*) is an aquatic carnivore widespread in lowland streams up to 2 000 metres (about 6,500 feet). It has a number of variable geographic races throughout the

Australasian region. Closely related to this is the New Britain Water-rat (*H. neobritannicus*), not surprisingly one of the small number of mammal species to have colonized New Britain from mainland stocks.

The Earless Water-rat (*Crossomys moncktoni*) is remarkably specialized for aquatic life. Widespread in mid-mountain streams, it is almost blind, having very small and weak eyes, an ear pinna reduced to 1 millimetre (about a 25th of an inch) in height, fully-webbed hind feet with the toes splayed sideways, a fringe of stiff hairs on the underside of the tail acting as a keel, and protruding nostrils for breaking the surface of the water when it surfaces for air. The fur is very fine and dense.

The small Mountain Water-rat (*Hydromys habbema*) occurs in high-altitude streams and alpine lakes in the central highlands of Papua New Guinea and the highlands of Irian Jaya. This species has the soft fur of *Crossomys*, but other characteristics of *Hydromys*.

The moss-mice are all small, soft-furred species inhabiting the mossy forest floor of montane forests, where they burrow below mossy banks and, presumably, feed on insects. Though externally very similar to each other, being miniature versions of *Hydromys habbema*, they are divided into four genera on cranial and dental characteristics. *Pseudohydromys murinus* occurs in the east-central highlands and is a little smaller than *P. occidentalis*, of the west-central highlands. *Neohydromys fuscus* is sympatric with *P. murinus* in the east-central highland forests. These three species and the following one have the usual hydromyine complement of two molar teeth. *Microhydromys richardsoni* is distinguished by longitudinal grooves on the upper incisors. It was originally collected in the Idenburg River basin of Irian Jaya, and remains one of New Guinea's rarest and least-known mammals.

Shaw Mayer's Moss-mouse (*Mayermys ellermani*) retains only one molar in each tooth row, these being rather small and probably not functional. This species was discovered in 1950 at high altitudes on Mounts Wilhelm, Hagen and Giluwe, of the east-central highlands.

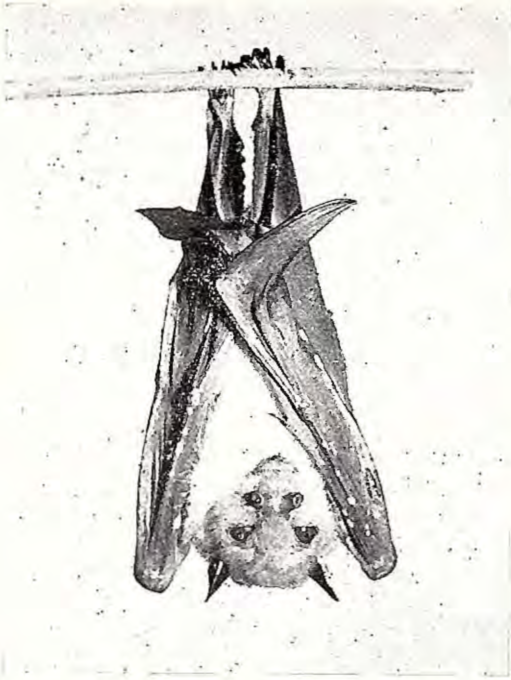
Mosaic-tailed rats

A more recent radiation has occurred among the mosaic-tailed rats, a group of four or five genera centred in New Guinea that has spread to New Britain, the Solomon Islands, and Australia. The mosaic-tailed rats are characterized by relatively hairless tails with the tail scales set edge-to-edge rather than overlapping as is the case with most other rats. The classification of the group is not at present well understood and some revision appears necessary. The smaller members of the group are placed in two genera. The genus *Melomys* contains about eighteen species of small to medium sized rats, generally with tails approximately the same length as the head and body. Eleven of these occur in Papua New Guinea. Some species are terrestrial, others are arboreal, or partly so, and one or more species are usually quite common in various habitats and at various altitudes throughout New Guinea. Four long-tailed species which have a dorsally prehensile tail are currently placed in the genus *Pogonomelomys*. However, some *Melomys* species, though shorter-tailed, are now known also to have dorsally prehensile tails.

Along with other large species, large members of the mosaic-tailed group of rats are conveniently known as giant rats. The Mottled-tailed Giant Rat (*Uromys caudimaculatus*) is a common species of lowland New Guinea and northeastern Australia. It is replaced in the mid-mountain and lower montane forests by the Black-tailed Giant Rat (*U. anak*). The genus is represented in New Britain by *U. neobritannicus*.

The Solomon Islands have been a centre of diversification for this group. Early stocks that reached these islands have given rise to two endemic types, *Solomys* and *Unicomys*, whose relationships to each other and to *Uromys* are still in question. Poncelet's Giant Rat (*Solomys* [*Unicomys*] *ponceleti*) is a striking and large animal, with long black fur, known only from a few specimens collected on Bougainville Island. *Solomys salebrosus* is a smaller species, also on Bougainville, and also poorly known. In addition, three species of *Uromys* and a second species of *Solomys* have been recorded for the south Solomon Islands.

Dental characteristics suggest that the rare giant rat *Xenuromys barbatus* of the New Guinea mainland may be an early offshoot of this group, though it has normal overlapping tail scales.



Paranyctimene raptor, one of the Tube-nosed Fruit-bats, is a small species common in mid-mountain forests, where it associates with the Blossom Bat (*Syconycteris crassa*). *Paranyctimene* and *Nyctimene* species have spots of yellow, orange, or lime scattered over the ears and wings. [Photo: Author.]

The recent invaders

Typical rats of the genus *Rattus* have made several invasions of New Guinea and the islands and are common in all habitats. *Rattus niobe* and *R. verecundus*, of the mountain forests, represent the earliest invaders. *R. niobe* is extremely common in montane forests and the alpine grasslands. A more recent invasion has given rise to a group of large and medium-sized rats whose taxonomy is still in doubt. *R. ruber* occurs in a puzzling variety of sizes along the north coast and islands, and *R. leucopus* along the south and southeast lowlands and into north Queensland. Relatives occur on some of the Bismarck and Solomon Islands and throughout the mountains, preferring disturbed areas and grasslands. This successful group is obviously in the early stages of a radiation.

Echidnas

When taking pride in their country's monotremes, Australians tend to forget that New Guinea is home to a third genus of these remarkable egg-laying mammals—the Long-beaked Echidna. Only one species, *Zaglossus bruijni*, is currently recognized. *Zaglossus* is much larger than *Tachyglossus*, has a much longer and curved snout, and shorter spines usually hidden in the fur. The Long-beaked Echidna occurs through the mid-mountain and montane forests, where it feeds on earthworms beneath the litter on the forest floor.

The Short-beaked Echidna (*Tachyglossus aculeatus*) appears to be extending its range out of the savannah areas of southern Papua, with which it was presumably once associated, and through the forested river valleys into the highlands. In at least one area it has crossed a low-altitude gap in the ranges, and is now found in northern-draining river valleys.

Bats

The bats of New Guinea are most abundant and most diverse in the tropical lowland forests, and decrease both in density and number of species with increasing altitude. This is the opposite of the situation with the marsupials and rodents, which show a greater diversity in the temperate mountains. Even though the bat fauna is rich in the lowlands, it is not greatly different to the faunas of neighbouring regions, and there are few endemic genera. The ease with which a large number of colonizing stocks have been able to fill available niches has lessened the amount of adaptive radiation that has occurred.

In keeping with their greater mobility, the bats have been much more successful than the marsupials and rodents in colonizing the Bismarck and Solomon Island groups. Two endemic genera and a number of endemic species and subspecies have evolved in these areas and are derived from mainland stocks.

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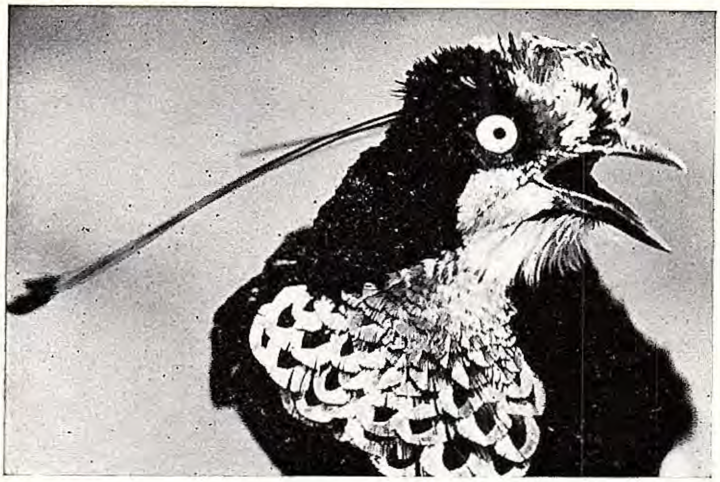

White-flanked Flag-bird (*Parotia carolae*), a bird-of-paradise.

REMARKABLE BIRD LIFE

By RICHARD SCHODDE
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NEW GUINEA is justly known for its rich and peculiar bird fauna. Characteristic of it are the birds-of-paradise, flightless cassowaries, great crowned pigeons, many-coloured parrots, and jewel-like kingfishers. These, together with honeyeaters, malurid wrens, fruit pigeons (*Ducula*, *Ptilinopus*), mound-building megapodes, flycatchers, whistlers (Pachycephalidae), flowerpeckers (Dicaeidae), and swiftlets (*Collocalia*), are its dominant elements.

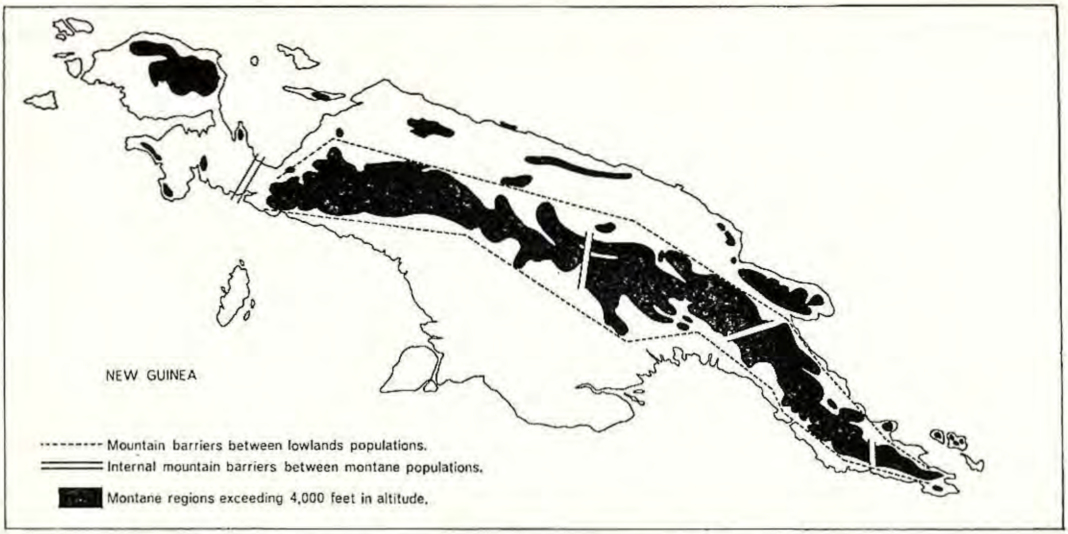
The diversity in many of these groups is extraordinary. In the birds-of-paradise, the bizarre modifications of plumage are common knowledge. But the remarkable variety in other groups is less widely realized. Those close relatives of birds-of-paradise, the bowerbirds, are just as well represented in New Guinea as in Australia. Among them are the gardener-birds (*Amblyornis*), which build the largest and most highly-decorated of all bowers: one of the species in West Irian constructs a small house-like shelter up to a metre or so high.

Both the largest and smallest of all members of the large Southern Hemisphere parrot family are all but endemic to New Guinea: the huge slate-black Palm Cockatoo (*Probosciger aterrimus*), with its great bill specially adapted for cracking the nuts of *Canarium* trees, and the minute pygmy-parrots (*Micropsitta* spp.) that have spine-tipped tail feathers which are used as a prop when the birds perch to feed on lichens on tree trunks.

Kingfishers are richer in number of genera and species in New Guinea than anywhere else in the world. Perhaps the strangest is the kookaburra-like Shovel-billed Kingfisher (*Clytoceyx rex*) that digs for worms with its bill on the forest floor and is partly nocturnal. But kingfishers are known for their bright colours, and the brightest of them are undoubtedly the iridescent Midget Kingfishers (*Alcedo*) of the lowland forests and the racket-tailed Paradise Kingfishers (*Tanysiptera*) which, except for one breeding migrant species in Queensland, are confined to the New Guinea region.

About 670 species in New Guinea

In New Guinea itself some 670 species of birds are found. This compares with about 660 in the whole of Australia. Moreover, whereas sea and immigrant non-breeding wading birds make up a significant proportion of the Australian bird fauna, the very great majority of species in New Guinea,



Mountain barriers between bird populations. [Map by the author.]

approximately 570, are breeding land and freshwater birds. Of these, about 190 are shared with Australia; most of the remainder, some 320, are endemic. In the entire Papuasian region—that is, New Guinea, its offshore islands, and the nearby Bismarck Archipelago and Solomon Islands—there occur some 860 species of birds. This compares with 800 in North America and some 1,100 in the whole of Eurasia.

Dr Ernst Mayr, in many papers on the birds of the Papuasian region, has shown that the affinities of New Guinea's birds lie with those of Australia rather than with those of the Orient in the Malay Archipelago further west. Such affinities are manifested most clearly in the honeyeaters (Meliphagidae) and parrots and cockatoos (Psittacidae). These two families, the largest in both Australia and New Guinea, are very poorly represented in the adjacent Indonesian islands. Conversely, bulbuls, woodpeckers, vultures, tits, and emberizid and fringillid finches, so characteristic of the Orient, do not occur in New Guinea or Australia, and only one species each of the diverse "Old World" families of hornbills (Bucerotidae) and shrikes (Laniidae) have reached New Guinea to stay.

If the bird fauna of New Guinea is so similar in affinity to the Australian, why does it appear so different to visitors at first sight? To be sure, the Black-faced Cuckoo-shrike, Blue-winged Kookaburra, and White-breasted Wood-swallow found commonly in the savannah woodlands about Port Moresby are the self-same birds that extend widely across northern Australia. But in the rainforest, everything seems different. The difference is actually illusory, heightened by the fact that the Australian land-bird fauna is largely open eucalypt forest-adapted and dry country-adapted while that of New Guinea is overwhelmingly rainforest-adapted. Another factor is the self-introduced bird fauna of secondary growth and garden areas especially obvious to visitors about towns and villages. Here are itinerant immigrants from other areas of the Malay Archipelago as well as Australia, like the Pied Stone Chat (*Saxicola caprata*), Dollar-bird (*Eurystomus orientalis pacificus*), Schach Shrike (*Lanius schach*), Grey Warbler (*Locustella fasciolata*), and swiftlets (*Collocalia* spp.) which hawk in great numbers over open spaces. In the primary forest, the "Australian" character of the bird fauna is more noticeable, particularly in the mountains above 1 200 metres (about 4,000 feet).

Six principal habitats

The distribution of birds in New Guinea can be more easily understood if it is related to habitat. For birds there are six principal habitats in New Guinea: marine and shoreline; freshwater swamplands (excluding forested swampland); anthropogenous (man-made) grasslands; alpine meadowland; eucalypt-paperbark woodland; and rain-forest, including primary, secondary, monsoon (partly deciduous), and mangrove forests. These and their birds are reviewed briefly here.

Marine and shore-line. There is nothing distinctive or diverse about the bird life of New Guinean beaches and adjacent seas. With its terns, frigate-birds and wading birds (thick-knees, sandpipers, whimbrels, dotterels, and egrets and herons of several species), it is just like that of the shores of Australia or any of the islands in the southwestern Pacific. Many of the birds are over-winterers or visitors; of the twenty-eight or so sea birds recorded from New Guinea, only six breed there.

Freshwater swampland. Comprising, in the main, open waters, lakes, and reedy and grassy swamps along the major rivers (e.g., the Fly, Sepik and Mamberamo drainages), this habitat has a rather more varied fauna than the beaches and seas. Predominant groups are herons and bitterns (fifteen species), ducks and geese (thirteen species), cormorants and darters (four species), and rails, crakes, and water-hens (eighteen species). There are few endemics, the most noteworthy of which are a large, flightless rail (*Megacrex inepta*) of forest swamp edges and Salvadori's Teal (*Anas waigiuensis*) of mountain streams.

Anthropogenous grassland. Though wide-spread in both lowland and mid-mountain regions, anthropogenous grasslands are apparently recent in origin and impoverished in bird life. Most birds represent wide-spread "Old World" forms and may have arrived recently—e.g., the Pied Stone Chat, Pipit (*Anthus novaeseelandiae*), and Schach Shrike. There is little endemism or diversity. The only endemics are one bower-bird, *Chlamydera lauterbachi*, and six of the twelve New Guinean mannikin finches (*Lonchura* spp.), all of which appear to have evolved recently in response to newly-created niches.

Victoria Crowned Pigeons (*Goura victoria*).

Eucalypt-paperbark (*Melaleuca*) *woodland*. Confined to dry monsoonal regions of limited area along the southern coast and about the Hydrographers Range, these woodlands are an extension of the eucalypt woodlands of northern Australia. Of the approximately thirty-six species of birds peculiar to them in New Guinea, almost all are widespread in northern Australia. Characteristic examples are the Peaceful Dove (*Geopelia striata*), Blue-winged Kookaburra, Black-faced Cuckoo-shrike, and Black-backed Butcher-bird.

Alpine meadowland. The alpine meadowlands, which cap the high mountains of the main New Guinean cordilleras above the tree-line from about 3 200 to 4 100 metres (about 10,500 to 13,400 feet) altitude, are basically natural. Their bird fauna is impoverished like that of the man-made grassland, but is relatively rich in endemics. Not only are endemic races of mannikin finches, the Island Blackbird (*Turdus poliocephalus*), and Brown Quail (*Syncicus ypsilophorus*) found there, but also endemic species and genera. These are a large alpine pipit (*Anthus gutturalis*), the great Snow Quail (*Anurophasis monorthonyx*), and Alpine Fire-tail Finch (*Oreosthruthus fuliginosus*) of the tree-line edge. The geographical affinities of these species are diverse, suggesting that colonization of the meadowlands by birds has been itinerant, sporadic, and in operation for a long time.

Rainforest. The vast rainforests that clothe New Guinea hold the core of the region's bird-life. Some 45 per cent or more of the land and freshwater birds are confined to primary forest and another 25 per cent live mainly in this habitat. In other words, 70–75 per cent of the island's bird fauna are essentially rainforest forms.

Micro-habitats

The seemingly uniform expanses of rainforest that support this rich fauna are, in reality, a complex of micro-habitats. This is reflected in three major partitions in rainforest habitats for birds. The primary partition is altitudinal. The great mountain ranges and cordilleras, rising to 3 200 metres (about 10,496 feet) and above in many parts, have had the effect of zoning the bird fauna altitudinally. Some birds are confined to very narrow altitudinal belts, like the crowned pigeons (*Goura*) and Twelve-wired Bird-of-Paradise (*Seleucidis melanoleuca*), which are usually found in lowland alluvial forest up to 200 metres (about 700 feet), and also Wilhelmina's Lorikeet (*Charmosyna wilhelminae*) and Striped Gardener-bird (*Amblyornis subalaris*), which are confined to mid-mountain forests between 600 and 1 200 metres. Other species are more ubiquitous, notably the Giant Cuckoo-dove (*Reinwardtoena reinwardtii*), Harpy Eagle (*Harpyopsis novaeguineae*), and Fantail Cuckoo (*Cacomantis pyrrhophanus*), which range through almost the whole gamut of forested altitudes.

The secondary partition distinguishes between primary and secondary forest. Secondary forest is found throughout New Guinea wherever rainforest has been disturbed or partly cleared, or is regenerating. Its bird fauna is relatively poor, and though many forest birds move into secondary growth at one time or another, few are confined to it. Typical residents are two species of Cuckoo-doves (*Macropygia*), the Brush Cuckoo (*Cacomantis variolosus*), White-eyes (*Zosterops* spp.), and Superb Bird-of-Paradise (*Lophorina superba*).

The tertiary partition is manifested in the segregation of different birds to different vegetation strata within the rainforest. Here in lowland New Guinea, an observer may see fifteen to twenty species at once or up to thirty in several hours at different levels in and around a single flowering or fruiting food tree: parrots, fruit pigeons, and honey-eaters of various species in the crown; flycatchers, shrike-thrushes, and several birds-of-paradise in the mid-stages; babblers, wrens, and kingfishers towards the ground, and pittas (jewel thrushes) and megapodes on the forest floor.

Why is the New Guinean birdlife so rich and diverse? To answer this question we must turn to the origin of the region's bird fauna and the environmental factors that have affected its evolution since then. Notwithstanding the present marine barrier of Torres Strait, New Guinea is and always has been part of the Australian continental mass. Continuous land between New Guinea and Australia has been usual in the past, at least from the advent of the basic stocks of Australo-Papuan birds during early and mid Tertiary times (*c*. 60 to 20 million years

Superb Bird-of-Paradise (*Diphyllodes magnificus*), with ruff raised.

or more ago). The climate of those times appears to have been mainly cool and wet. According to fossil evidence, rainforests covered much of the Australo-Papuan continent. From mid-Tertiary times onwards, climate became gradually warmer and drier, punctuated only by the Ice Ages, which brought several short, colder, and wetter periods in the last 1 or so million years. In New Guinea, but not Australia, huge cordilleras were flung upwards to heights of 4 000 metres (about 13,000 feet) or more along the length of the island.

These changes must have had a marked effect on bird life. The multitude of genera and species that originally evolved and diversified in cool, humid rainforests contracted to peripheral refuges around the eastern seaboard of Australia and New Guinea. In flat Australia, extinction seems to have been widespread. Those forms that could not escape to coastal havens perished; they were replaced by rainforest-derived forms better fitted for life in savannahs, mulga (*Acacia*) scrub, and eucalypt woodland. Examples are platycercine parrots (rosellas, grass parrots) which appear to have been derived from parrot-forms represented today by King Parrots (*Alisterus* spp.) in the Australo-Papuan rainforests. In New Guinea, extinction was probably not nearly so general. To survive the onset of warmer or colder conditions, all a bird and its associated habitat had to do was move up or down several hundred metres on the sides of the great cordilleras. Thus, New Guinea emerges as the main refuge for what is left of the old Tertiary Australo-Papuan bird fauna.

Compounding the historic diversity of the New Guinean bird fauna are the great mountain ranges and cordilleras which control the distribution of birds and bird habitats through their influence on temperature, rainfall, and hence general environment. In particular, they effectively separate populations of the lowland and hill-slope levels along opposite scarps and isolate montane populations on high mountain massifs by intervening valleys and passes. As a result of such disjunctions, local evolution and speciation appear to have proceeded at a remarkable rate in birds. Lowland groups, which encircle the mountain ranges, comprise forms which replace each other in a classical "ring" species configuration. Thus, the three lowland species of "true" birds-of-paradise alternate geographically around New Guinea: the "red" bird (*Paradisaea raggiana*) in the southeast and northeast, the "lesser" bird (*P. minor*) in the north and northwest, and the "greater" bird (*P. apoda*) in the southwest and Aru Islands. In the crowned pigeons, megapodes (*Talegalla*, *Megapodius*), lories (*Chalcopsitta*) and many others, the pattern of speciation is similar. Montane groups, by contrast, are frequently represented by chains of replacement forms strung out along the ranges. Typical are the long-tailed *Astrapia* birds-of-paradise, represented by five species, each occurring in different sectors of the main cordilleras, from the Arfak Mountains to the Owen Stanley Range and mountains of the Huon Peninsula.

[*The photos in this article are by courtesy of the late E. T. Gilliard.*]

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BOOK REVIEWS

GUIDE TO MINERALS

POPULAR PROSPECTING, A Guide to Australian Minerals, by K. J. Buchester; A. H. & A. W. Reed Pty Ltd, Sydney, 1972; 211 pages; price, $7.95.

Strong interest in minerals and rocks has produced a spate of popular and semi-technical books on the subject over the last few years. Any new books inevitably appear repetitious, with similar drawings and photographs of crystals and similar lists of their properties and localities. This is true of *Popular Prospecting*, but the layout of the book is its great grace.

Not plunging directly into hard facts, the book pleasantly phases them in after some broad, general, historical and geological chapters. The reviewer particularly liked the approach introducing the Aborigines as the earliest Australian prospectors. After fifty pages the book gets down to detailed descriptions of rocks, alluvial deposits, mineral identification and forms and surveys of metallic and non-metallic mineral groups. It finishes up on prospecting for gemstones and amateur mineral collecting, and closes with a geological time table, glossary, bibliography and index.

Clearly printed, the text aims for simplicity of style. Occasionally this is carried too far, as when iron is listed as one of the three main minerals, giving the wrong impression that native iron and not the hydroxide is the common species. The chapter on building and ornamental stones seems hardly worth its separate writing, being merely half a page; more elaboration would have been desirable here, particularly as sandstone is not mentioned. The early chapter on "Some Geological Observations" provides good background for the main subject, but should be read with some reservations in mind. Although the ranges in hypotheses for some of the major geological questions are made clear, the hypotheses chosen for more elaboration are not always those currently put forward by scientists. For example, Gondwanaland and continental drift are presented as alternative hypotheses, but they are not mutually incompatible concepts, and there is no mention of any of the modern sea-floor spreading concepts.

The script is largely free from typographical errors, but a few statements are questionable. Australian Aborigines are stated to have never seen any volcanic eruption, when in fact some native legends and radio-active dating of the youngest Australian volcanics indicate otherwise. Again, reference to uraninite as uranium ore and pitchblende as radium ore (p. 39) is a little misleading as they are varieties of the same mineral and are both essentially uranium oxide.

The book is well illustrated with a good balance between black and white and colour plates, figures, maps, and drawings. Of the forty-eight colour photographs set out six to a page, about three-quarters are shots of mineral specimens, but their standard is variable and no scale is given. Some are very good, but in others the lighting appears dull and does not always bring out crystal forms to best advantage. Different types of lighting appear to have been used, but are not specified in the captions. Pyrite, rather redundantly, is illustrated twice in the colour shots; the second specimen shows a strong blue colour most uncharacteristic of the normal colour and its crystal form seems closer to cube than pyritohedron as stated.

At $7.95, this book will meet competition from some of the cheaper Australian mineral guides, and, unlike some, it is too large to pocket easily in the field. On the other hand, it is cheaper than more detailed books such as those of Talent and Chalmers, aimed for more experienced collectors, and it is recommended as an interesting and useful introduction to the subject—*Lin Sutherland, Curator of Minerals and Rocks, Australian Museum.*

WILDLIFE PHOTOGRAPHY

PHOTOGRAPHING WILDLIFE, by J. M. Baufle and J. P. Varin, translated from the French by Carel Merongen; first English edition published by Kaye and Ward, 1972; 157 pages; price, $10.95.

In this book we are introduced not only to the adventurous prospect of stalking our subject with a camera but also to some of the intricacies of the technical world of equipment and materials.

With over 100 illustrations, the majority in colour, the reader is taken on a survey of wildlife photography in Europe and Africa. The principles explained are equally applicable to most Australian conditions, so the book would form a worthwhile addition to any library.

The authors achieve their object in providing a "practical and technical introduction to wildlife photography", and the beginner will find much of value. The more experienced will probably be disappointed with the lack of information in specialized areas, while the serious student will miss not having a proper index for easy reference. However, the novice should have his appetite thoroughly aroused to delve deeper into the many specialized aspects of this fascinating branch of photographic activity.

Nature-lovers will be disappointed that more emphasis was not placed on the important duty of every photographer to leave the field as he found it, with stones and leaves replaced, empty film packs collected, animals unharmed, and nests undamaged.

As an introduction, the book is excellent.—*Howard Hughes, Photographer and Visual Aids Officer, Australian Museum.*

A BIT ABOUT THE BUSH

A BIT ABOUT THE BUSH, by George N. Baur; Forestry Commission of New South Wales, Sydney, 1972; 87 pages; price, $2.50. G35254—1.

The title of this book is slightly deceptive. It is not really about the "bush". Rather, it is about forests and forestry in New South Wales—and an excellent account it is.

When Europeans first landed on the coast, forests covered 100 million acres of the eastern half of New South Wales. Since 1788, that vast expanse of forest has been cleared, burned, and grazed until only 40 million acres remain. Of this, 8 million acres are reserved as State Forests and Timber Reserves for the production of timber and wood products and are controlled by the Forestry Commission of New South Wales.

Book Reviews

A Bit About The Bush is about these State Forests, how they are used and managed to ensure wood products for the future, and why they are important to Australia. There are good descriptions of the trees (native and exotic) and of the forest types which are most important to forestry in New South Wales. There is also mention of the foresters—how they work and what they do, and one can even get an idea of the sort of persons they must be.

George Baur is to be commended for an excellent job. He tells us about the bush as a forester sees it. At a time when people are increasingly concerned about the environment, it is important to understand how the people who manage our forest lands think, and to know what sort of job they are doing. They appear to be doing a good job. The State Forests are not only vital for the wood they produce but are an important part of wildlife conservation in New South Wales.

This is a book for all ages and for anyone who is interested in nature and the environment.—*Harry F. Recher, Curator of Environmental Studies, Australian Museum.*

NEW ZEALAND FISHES

FISHES OF THE NEW ZEALAND REGION, by Wade Doak, 1972; Hodder and Stoughton, Sydney; 132 pages, 122 colour photographs; $13.50.

The rocky-reef fishes of the Poor Knights area of New Zealand have been given good treatment in this work by New Zealand diver-naturalist Wade Doak. Although the title is misleading (80 species from the New Zealand total of about 400 are covered), those species included are depicted by an excellent colour photograph, a small sketch, and a discussion of the New Zealand distribution and behaviour. Doak's reputation as an underwater photographer is fully justified by the illustrations. But the book is more than a picture book, as many hours of diving observations have gone into the natural history notes. An assimilation of other scientific literature has resulted in much of the discussion being relevant and thought-provoking.

Half of the species covered also occur in eastern Australia, and any worker on rocky-reef fishes here will find the book useful. Some of the Australian common names are in error or lacking: *Hoplostethus elongatus*, the Violet Roughy; *Epinephalus dameli*, Saddled Rock Cod; *Chrysophrys auratus*, Snapper; *Parma microlepis*, White Ear; *Coris picta*, Banana Fish.

I find this book both readable and useful. In the future there will doubtless be more erudite and comprehensive books on New Zealand fishes, scientific treatises, and identification handbooks; may they be written with the same sense of discovery that fills these pages.—*John R. Paxton, Curator of Fishes, Australian Museum.*

BOOK ON SHELLS

SHELLS OF NEW GUINEA AND THE CENTRAL INDO-PACIFIC, by Alan Hinton; Robert Brown and Associates Pty Ltd and Jacaranda Press, 1972; pages xviii-94; 44 colour plates; suggested price, $4.50. ISBN 0 7016 8114 4.

One would think that the recent spate of popular books on shells appearing in publishers' lists would discourage both publishers and authors from attempting to get much more out of what might appear to be an apparently limited market. There are probably at the most 1,000 serious shell-collectors in this country. This alone is not a large enough market for any book.

Luckily for publishers and authors alike, Australia and New Guinea are the source of a great many of the species most prized by collectors throughout the world, so that books on the molluscs of this region command a much larger audience than one would otherwise expect. World-wide, collectors number many thousands, and most have eyes turned towards this region of the Pacific for their glass-case exhibits.

This has enabled Robert Brown and Jacaranda Press to accept for publication Alan Hinton's *Shells of New Guinea and the Central Indo-Pacific*, a most worthy exercise that should enhance not only the shelves of bibliophiles but, more importantly, those of amateur and professional malacologists as well. Nomenclature is up-to-date (e.g., Vexillidae being treated as a family distinct from the Mitridae), and, on the whole, accurate. Some of the species shown are often excluded from other books because the area covered is not well known by most authors. The photography, by the author, is excellent, considering that before this venture he had never attempted this difficult exercise.

If I have any criticism it is that perennial one that this book only covers a few families of the class Gastropoda. Why don't authors of such books show some interest in the other classes? Or is this volume to be followed by another covering the other classes? The only other criticism is that this book, sadly, is only half the thickness it ought to be. However, with over 650 species discussed, including many with several forms shown, all in colour, and with all accompanying notes placed on the facing page, this book is certainly worth the moderate price its publishers suggest.—*Phil Colman, Molluscs Department, Australian Museum.*

This tiny tree frog, *Litoriairis*, is adult at about an inch in length. Its body is bright green, with orange areas and black markings. There are also orange areas on the legs. Pattern details vary greatly, however. This frog is found in the highlands of Papua New Guinea. [Photo: Author.]

REPTILES AND AMPHIBIANS

By RICHARD G. ZWEIFEL

Chairman and Curator, Department of Herpetology, American Museum of Natural History, New York, U.S.A.

TROPICAL lands are alive with snakes, or so goes a popular misconception. But if you go to New Guinea, be prepared for some disappointment (if you are like this author) or for a pleasant surprise (if you are one of the unenlightened with a more biblical view of serpents!) On a good day in the suburbs of New York I have caught more snakes—my record rate is one every three minutes for more than an hour—than in a typical week of tramping the forests of New Guinea. This is not to say that New Guinea is short of fascinating reptiles and their distant relatives, the frogs; it is merely that many of these animals are secretive or nocturnal and not likely to come to the attention of tourists, even those whose interests lead them afield from the markets and anthropological sights.

In contrast to Australia, where the majority of species of snakes belong to the family (the Elapidae) that includes the infamous cobras of Africa and Asia and the coral snakes of the Americas, New Guinea can boast more non-venomous than venomous forms among its more than 100 species. New Guinea shares the Death Adder (*Acanthophis antarcticus*) and Taipan (*Oxyuranus scutellatus*) with Australia, and the Papuan Black Snake (*Pseudechis papuanus*) is a close relative of an Australian species. These three are perhaps the best known Papuan species that constitute a deadly danger to man, but another species, the Small-eyed Snake (*Micropechis ikaheka*), endangers more people because of its island-wide distribution combined with large size (up to 8 feet in length); the Taipan and Papuan Black Snake are found only in Papua, and not the rest of of New Guinea, and the Death Adder is a smaller species. It speaks for our slow growth of knowledge of the fauna of New Guinea that a book on dangerous snakes of New Guinea printed as recently as 1963 does not mention the Small-eyed Snake, and another published in 1968 suggests only that it is "likely to have a lethal potential". The lethal potential has, unfortunately, been demonstrated.

Sea snakes

Colourful sea snakes of several species live in the warm coastal waters around New Guinea. All are highly venomous, but they constitute scarcely any danger to man because, with the exception of two species that must come ashore briefly to lay eggs (the others produce living young), they spend their entire lives in the ocean or in tidal rivers.

Venomous snakes (and harmless ones, too) want nothing to do with man, and if given half a chance will disappear without you ever knowing they were there. The danger—and it is statistically slight, even for the bush-walker—lies largely in inadvertently stepping on one. Even in the event of a bite, the odds are vastly in favour of survival, given the potent antivenenes now available.

Great variety of species

New Guinea snakes come in a wide variety of sizes, from the tiny "Flower-pot Snake" or Blind Snake (*Typhlops braminus*), well under a foot in length and resembling an earthworm, to the Amethystine Python (*Liasis amethystinus*), which attains a length of 22 feet. Between these extremes there is a great variety of species of divers habits and habitats. Small, venomous forms burrow in the soil and leaf mould, but use their tiny fangs only on earthworms, frogs, and lizards. Several species of the genus *Amphiesma*, with relatives among the commonest harmless snakes of Europe and North America, hunt for fish and frogs in swamps and streams. The Cat-eyed Snake (*Boiga irregularis*), with its vertically oriented pupil that implies nocturnal activity, often inhabits the palm-thatch roofs of village dwellings, where lizards and other potential prey are also at home. The Cat-eyed Snake, incidentally, is one of the rear-fanged snakes, those species with enlarged, grooved teeth in the rear of the upper jaw that transfer venom into a wound produced by deliberate chewing. I know of no evidence that this species is dangerous to

The comfortably draped pose of this baby Green Python, still with its bright-yellow juvenile coloration, is characteristic of these snakes. [Photo: Author.]

Gonyocephalus nigrigularis is a fearsome-looking "dragon" of the New Guinea highlands. It is about 2 feet in length, most of which is tail. [Photo: Author.]

man (though I would not let one chew on me!); the venom apparatus is crude and inefficient compared to the hypodermic-needle bite with which the taipan and its relatives deliver their potent venoms.

Colourful python

Even such a brief survey as this would be incomplete without mention of New Guinea's most striking snake, the 5-foot-long Green Python (*Chondropython viridis*). A favourite of zoo keepers and snake fanciers because of its attractive colouring, it is celebrated among zoologists for other reasons. In colour and pattern, in morphology, and even in the way it drapes itself across a branch (these pythons are largely arboreal), the Green Python is so similar to the Green Tree Boa of South America that one who does not know specific details to look for would not recognize them as different species. They are alike even to the extent that the young of both species begin life as bright yellow or yellow-orange snakes, only later to assume the green of the adults. Yet evidence from the internal anatomy suggests that these snakes are not particularly closely related in an evolutionary sense. Their similarity of form may merely reflect independently derived adaptations to similar rainforest habitats.

Lizards

Lizards are the reptiles most likely to come to the attention of visitors to New Guinea. Several species of geckos, with their toes wonderfully adapted to clinging even to glassy-smooth surfaces, scurry about on walls or upside down on ceilings where lights attract the insects they relish. Almost without exception these "house geckos" are widely distributed in the tropics, for their close association with man's dwellings assures that they or their eggs will inadvertently be transported wherever people travel. But the "house geckos" are only a small portion of the abundant lizard life of New Guinea, where there may be as many as 200 species. Green Tree Skinks (*Lamprolepis smaragdina*) scramble among vines in sunny spots on tree trunks; small skinks of the genera *Emoia* and *Carlia*, dull-coloured except for the bright-blue tail that some sport, seek the infrequent patches of sunlight on the forest floor or slip off the trail into the kunai grass at your approach; Legless Lizards, genus *Lialis*, easily mistaken for snakes, pursue the skinks through the grass with the same snaky intent—a meal.

But not all the Papuan lizards are small and inconspicuous. One species of Monitor Lizard or Goanna (*Varanus salvadori*) may reach 11 feet in length, though most of it is tail, and another (*Varanus indicus*) at 5 feet is large enough to furnish the favourite material for drumheads—its skin.

Turtles

Although freshwater turtles may be abundant locally in rivers and swamps of New Guinea, there are only a few species represented, and there are no land tortoises at all. The largest freshwater turtle is a soft-shelled turtle called *Pelochelys bibroni*, an Asiatic species that may be 4 feet in length. It is not common in scientific collections, and I well remember the anguish with which an Australian colleague and I viewed the remains of one hanging from hooks in the market in Port Moresby. New Guinea's scientifically most renowned turtle is the Pitted-shelled Turtle (*Carretochelys insculpta*), which was known for years only from rivers in southern New Guinea but recently was discovered in northern Australia. It is of special interest to scientists as the sole survivor of an all-but-extinct family of turtles otherwise known only from fossils. The other Papuan freshwater turtles are the "side-necked" turtles, so-called because, when the head is withdrawn, the neck is folded in a loop alongside the anterior part of the body. Other turtles pull the head straight back into the shell, folding the neck in a vertical bend. The four species of side-necks in New Guinea are the same as or closely related to species of the genera *Chelodina*, *Emydura*, and *Elseya* living in Australia.

Marine turtles of six species inhabit the waters around New Guinea and some (how many is uncertain) come ashore there to lay their eggs above the high-tide line. The leatherback (*Dermochelys coriacea*), with its distinctive, ridged, leathery shell, is the world's largest turtle, reaching perhaps more than 7 feet in shell length and a weight of almost a ton. Other marine turtles have more conventional shells, but, in common with the leatherback, propel themselves swiftly through the water with feet converted into flippers, and must come clumsily ashore to lay their eggs (commonly more than 100 at a time) in nests dug in the sand.

Elseya novaeguineae is the most widespread species of turtle in Papua New Guinea, being found in freshwater rivers, lakes and lagoons. Its maximum length is 1 foot. [Photo: H. G. Cogger.]

A giant Saltwater Crocodile about 16 feet long, in captivity at Daru. [Photo: Author.]

Crocodiles

New Guinea has two species of crocodiles—the Saltwater Crocodile (*Crocodylus porosus*) and the New Guinea Crocodile (*Crocodylus novaeguineae*). The first of these, a giant said to reach 20 feet in length, belies its common name by living far from the sea, for example hundreds of miles up the Sepik River. It is generally associated with larger bodies of water, and the smaller *novaeguineae* (up to 9 feet long) with smaller rivers and marshes, but the distributions of the two species overlap. Much hunted for their valuable hides, the crocodiles now enjoy a measure of legal protection, and research is directed toward establishing conservation measures that will allow both the industry and the crocodiles to survive.

Frog-watching

Scientists have identified more than 150 species of frogs on the island of New Guinea, and many more species occur on the smaller islands associated with Papua-New Guinea. But few of this vast assemblage will ever be seen by a visitor unless he goes frog-watching, the nocturnal equivalent of bird-watching. Get an electric lantern with a well-focused spot (a head lamp is ideal), tune your ears for sorting out the variety of night noises, and be prepared to dismiss the annoyance caused by an occasional mosquito. The males of most species of frogs utter a mating call characteristic of their species, and the eyes of frogs reflect light shone into them. Thus, the essence of frog-watching consists of listening for the calls and shining the spot from your lantern (hold a hand lantern up by your face) in the vicinity of the sound until you detect the bright spots of light that are the frog's eyes. Of course, it is not all that simple. Adult males of many frogs are too small to reflect enough light, at least for my weak eyes, and although many frogs will continue to call when illuminated, others stop calling and may depart. The more frustrating frogs call from beneath leaf litter, from holes in the ground, or from high in trees. The eyes of spiders reflect light very efficiently and can be confused with frogs' eyes, though you soon develop a feeling for distinguishing them. Nocturnal lizards (geckos) have a beautiful eyeshine, and the eyes of some snakes and many mammals reflect light. Aurally, the chief offenders are insects, though you will be surprised how many supposed insect-produced sounds turn out to stem from tiny frogs.

The common concept of a frog as a creature that sits on lily pads and snaps up passing insects fits some New Guinea frogs, but frogs make a living in a variety of other ways, too. Tree frogs spend much of their time far above the ground, but descend to ponds and streams to breed. Some deposit their eggs under rocks in swift-running streams, and the tadpoles that come forth have the mouth formed into a sucker with which the tadpole clings to the rocks and avoids being swept away. Many species have done away with the free-living tadpole stage entirely: the eggs are laid in moist places on land or in trees, and fully formed, though tiny, frogs hatch from them. Frogs of this sort never need go near a pond or stream. This adaptation enables one or another species to inhabit regions from sea-level to over 10,000 feet on the mountain tops, just so long as the atmosphere provides enough moisture to the frogs' own immediate surroundings.

Giant toad

The frog most likely to be seen by the visitor is not even native to the island, though tourists from Queensland may know it well. It is *Bufo marinus*, the giant toad of tropical America, introduced widely throughout the Pacific islands (and a pest in Queensland) in an ill-advised attempt to control insects harmful to agriculture. Seemingly well adapted to man's disturbance of the terrain, the toads thrive around towns and cluster beneath lights at night to eat the fallen insects. Sometimes they are abundant enough to litter the roads with their flattened bodies.

What happens when a foreign species such as this toad is introduced into a region new to it is a matter of considerable interest from both scientific and strictly practical standpoints. But the interest New Guinea holds for scientists extends far beyond such isolated cases. New Guinea, an extremely large island with habitats ranging from mangrove swamps to montane glaciers, is a natural laboratory for the study of evolution. As a reservoir for material and ideas for research it is inexhaustible. I hope to return there often.

FURTHER READING

There are no popular or semi-popular books on reptiles or amphibians of New Guinea comparable to those, for example, on birds and butterflies, but the following will be of help:

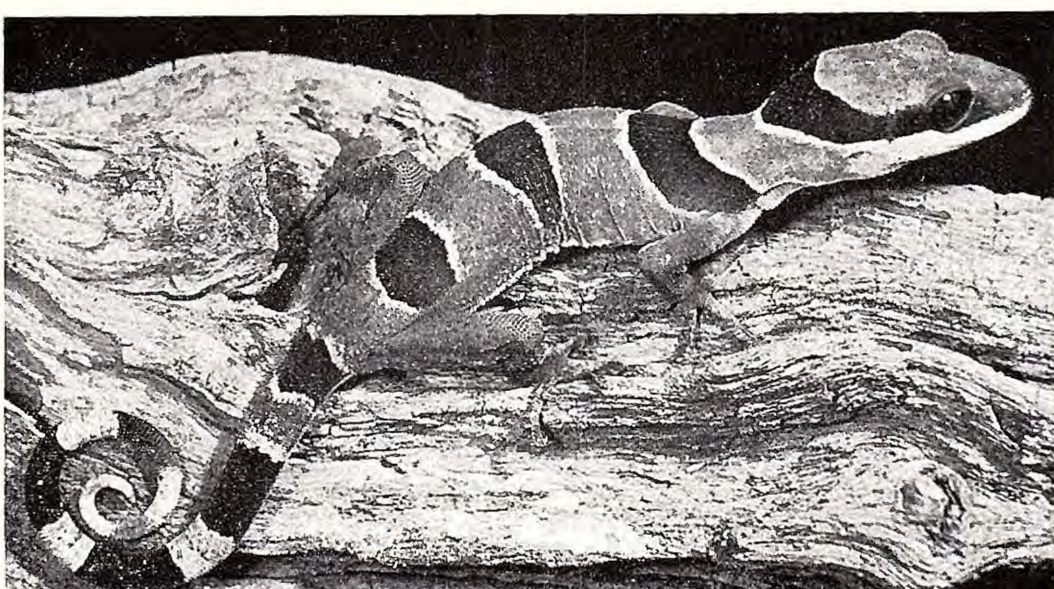
Cogger, Harold G., 1972: Crocodiles, Lizards, Snakes, Turtles, and Tortoises (separate articles) in *Encyclopaedia of Papua and New Guinea*, Melbourne University Press.

Loveridge, Arthur, 1946: *Reptiles of the Pacific World*, Macmillan Co., New York.

Slater, Kenneth, 1968: *A Guide to the Dangerous Snakes of Papua*, Government Printer, Port Moresby.

Zweifel, Richard, 1972: Frogs, in *Encyclopaedia of Papua and New Guinea*, Melbourne University Press.

HANDSOME GECKO

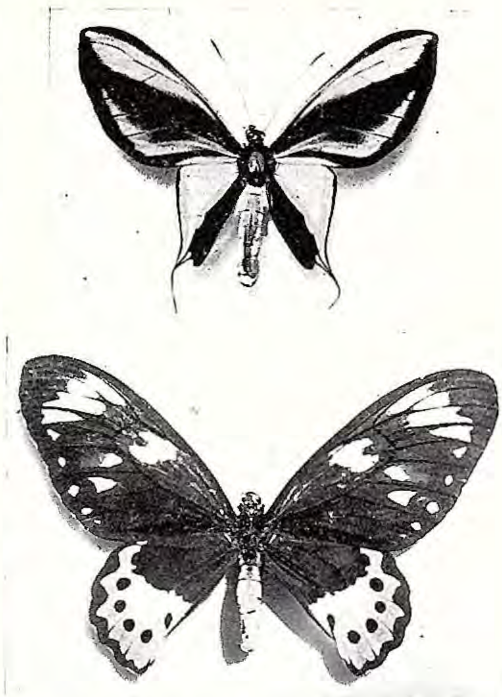


The large and beautiful forest gecko *Cyrtodactylus louisiadensis*, found in Papua New Guinea and the rainforests of far northern Queensland. It grows to nearly 30 centimetres (about 12 inches). [Photo: H. G. Cogger.]

INSECTS OF NEW GUINEA

By DAVID K. McALPINE
Curator of Insects and Arachnids, Australian Museum

THAT the insect fauna of New Guinea is a remarkable one has been known for over a century, but the diversity of this fauna is so great that new discoveries will continue to be made in it for many years to come. The broken, mountainous, largely forested terrain of the island has enabled populations of a great many different insect species to evolve and co-exist within this small area of the earth's surface. As the geological history of New Guinea as a separate entity is quite short, its fauna must have evolved its present diversity fairly rapidly and largely from immigrant stock. There is a shortage of isolated primitive or relict insect types; for instance, the primitive scorpion-fly families Choristidae and Nannochoristidae are apparently absent, though represented in Australia. This is no living fossil fauna; the processes of evolution and speciation are on the move—or were so until the last couple of decades.



Male (above) and female of the Paradise Birdwing Butterfly (*Ornithoptera paradisea*). The metallic lime-green wing markings of the male are absent in the dull-coloured, but larger, female. The forewing lengths are: male, 70 millimetres (nearly 3 inches); female, 95 millimetres (nearly 4 inches). This butterfly is an extreme example of sexual dimorphism, i.e., there is great difference between the sexes in addition to that of the sexual organs. [Photos: Author.]

Butterflies

Butterflies have attracted the most attention of all New Guinea insects, not only because of their variety of colour but because the largest of all butterflies live in this region. The birdwing butterflies (the name alludes to their size) have their greatest development in New Guinea, where the activities of commercial collectors have made it necessary to protect by law several of the rarer species. The Common Birdwing (*Ornithoptera poseidon*), which is found over most of the New Guinea mainland and some nearby islands, has not so far needed protective measures. It shows the extreme difference between the sexes characteristic of all true birdwing butterflies. The colouring of the male is brilliant metallic green and velvety black, while that of the female is dull brownish black with white or pale-grey spots and yellowish areas on the hind wings. Also, the female averages much larger than the male (length of forewing usually about 8 centimetres, or 3 inches, in the male, about 10 centimetres, or 4 inches, in the female) and the wings have a somewhat different shape. The butterflies are particularly attracted, for nectar-feeding, to red-coloured flowers. In gardens these include, particularly, hibiscus, poinsettia, and poinciana, but I have also seen them on flowers of other colours. The huge larvae, like those of other birdwing species, eat the leaves of poisonous vines of the genus *Aristolochia*. Like many plant-eating insects, their physiology is adapted to deal with the specific chemicals of their normal food, so that no poisoning results.

The largest of birdwings, and hence the largest of butterflies, is Queen Alexandra's Birdwing (*Ornithoptera alexandrae*), which is restricted to the Northern District of Papua in the vicinity of Kokoda and Popondetta. The wings of the exquisite male combine turquoise, mauve-blue, and black, but the colouring of the female is similar to that of the female Common Birdwing. The female of Queen Alexandra's Birdwing has the forewing usually about 13 centimetres (5 inches) long and the largest individuals have a wing expanse of 28 centimetres (11 inches).

One of the scarcest of all birdwings and the most prized by collectors is Allotte's Birdwing (known as *Ornithoptera allottei*). This is not found on the New Guinea mainland, but on the island of Bougainville. A specimen was sold in Paris in 1967 for £750 sterling. It had long been known that this butterfly was more or less intermediate between the two more common ones living in this locality—the Blue Birdwing (*Ornithoptera urvilliana*) and Queen Victoria's Birdwing (*Ornithoptera victoriae*). Recent study tended to confirm the intermediate nature of this butterfly to the point of providing strong circumstantial evidence of its hybrid origin from accidental crossing of the other two species. I have now been informed that collectors on Bougainville have known for some years how to produce the prized "*allottei*" by artificial hybridization. No doubt knowledge of this technique has proved remunerative.

The high mountains of New Guinea have their own particular butterfly fauna. At higher altitudes the birdwings are represented by the Highland Birdwing (*Ornithoptera chimaera*). The male differs from that of the Common Birdwing in having lime-green and yellow markings on a black ground above, and brilliant metallic golden-green markings on the underside of the wings. The female,

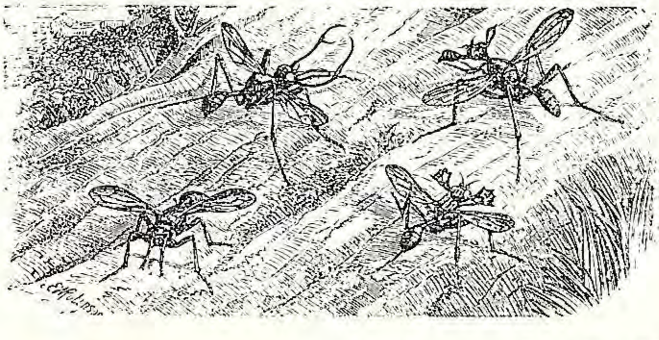
Two-brand Crow Butterflies (*Euploea sylvester*) feeding on nectar from flowers at Lake Murray, Papua. [Photo: Author.]

which averages a little larger than that of the Common Birdwing, is distinguished by the thickly furry abdomen with alternating rings of black and yellow. Where a mountain stream flows across a pathway or small clearing dozens of butterflies may often be seen drinking from the wet gravel at the water's edge. Among these are the incredibly alert and swift-flying Purple-spotted Swallowtail (*Graphium weiskei*) and numerous species of Jezebels (genus *Delias*). The Jezebels are medium to rather small butterflies, their colours including black, white, bright red, yellow, orange, blue-grey, or even pink—the last being one of the rarest colours in butterflies.

Protective mimicry

One more butterfly should hold our attention here. This is Laglaize's Swallowtail (*Papilio laglaizei*), which resembles closely in colour and shape the more common day-flying uraniid moths (genus *Alcidis*). It is thought that this resemblance to a more common and perhaps distasteful insect affords the butterfly a degree of protection from predaceous birds. This kind of protective resemblance of an edible species to a distasteful one is known as Batesian mimicry. It is brought about by evolutionary processes acting on an insect species which at first only faintly, by coincidence, resembles the distasteful model. The predator at first may only occasionally mistake the mimic for its model but these mistakes exert a selective pressure on the population of the mimic, which favours those individuals most resembling the model. The degree of resemblance to the model is therefore gradually strengthened over very many generations until even the trained entomologist has to look twice to distinguish the two species. There are several other examples of Batesian mimicry among New Guinea insects. Another form of it is the mimicry of wasps by flies, a very common occurrence in New Guinea. As is well known, stinging wasps have often acquired conspicuous warning colours, black and orange being the commonest combination. In New Guinea flies of at least eight different families have evolved definite mimicry of wasps. These generally repeat the warning (aposematic) coloration of the wasp model in addition to having a modified body form. The fly may have a slender wasp-waist or may be coloured so as to give an illusion of a wasp-waist. Sometimes the antennae of the fly are greatly lengthened to resemble those of wasps. In the hover-fly *Ceriana* the antennae are borne on a horn-like process on the front of the head, which gives them an illusion of greater length. Other wasp-mimic flies which have normal, short antennae hold their front legs out in front of the head and vibrate them like the antennae of wasps. Some of the New Guinea wasp-mimicking flies have acquired the ability to fold the wings longitudinally like those of the vespid and eumenid wasps. Many of those that cannot fold the wings have a darkened strip along the leading edge of the wing. By contrast with the glassy remainder of the wing this gives the appearance of a narrow, folded wing of intensified colour, much as in certain wasps.

New Guinea has many other remarkable and grotesque flies. There are the Antlered Fruit-flies (*Phytalmia*), in which the males have a pair of large horns on the head arising from just below the eyes. These are often branched, when they resemble the antlers of a deer. They are not to be confused with the paired antennae which are present on the heads of both sexes in all kinds of flies. The "antlers" are probably

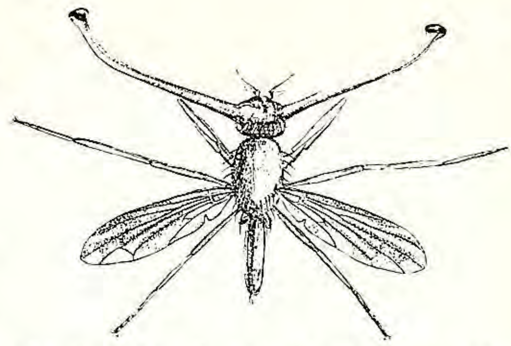


Males of four species of Antlered Fruit-flies on a fallen log, shown about natural size. Upper, *Phytalmia cervicornis* and *Phytalmia megalotis;* lower, *Diplochorda brevicornis* and *Phytalmia alcicornis*. [Drawing from A. R. Wallace's *The Malay Archipelago*, 1869.]

used in courtship display and are differently shaped in each species. In New Guinea, as in other countries, only a few of the large number of fruit-fly species ever damage cultivated fruits. The habits of the larvae of Antlered Fruit-flies are unknown.

Stalk-eyed flies

Three different categories of flies in New Guinea carry their eyes on rigid stalks projecting from the head. Of these the flies of the family Diopsidae, the familiar stalk-eyed flies of Africa and tropical Asia, are represented by a single very small species only in New Guinea. The conspicuous stalk-eyed flies of New Guinea are the males of two different genera, *Achias* and the less common *Laglaizia*. These genera both belong in the large family Platystomatidae, which includes many brightly coloured or intricately patterned insects. Possibly New Guinea has a larger concentration of platystomatid species than any other part of the world of similar area. *Achias* and *Laglaizia* belong in different sections of this family and have each evolved the stalk-eyed condition independently from different kinds of normal-headed ancestors. The females of *Achias* and *Laglaizia*, and also the males of some *Achias*, have the eyes merely bulging or on very short processes. The first specimen of *Achias* to reach Europe was supposed to have come from Java and belonged to L. A. Bosc, of Paris, who possessed a large and important insect collection. In the year 1805 the famous entomologist J. C. Fabricius published a description of the insect, choosing for it the name *Achias oculatus*. On the death of Bosc in 1828 this specimen, with the rest of Bosc's collection, passed to the Paris Museum of Natural History. In 1843 Macquart published an illustration of the fly in his large work on flies entitled *Diptères exotiques nouveaux ou peu connus*, and indicated that it was taken from Bosc's original specimen, then in the Paris Museum. After this date there is no further record of the specimen and it appears to have become lost or destroyed by insect pests. At this time no other specimens of *Achias* were known, though several other kinds of flies were confused with *Achias* by some naturalists. Perhaps the next specimens of *Achias* to come into the hands of an entomologist were four distinct species collected by Alfred Russell Wallace in the



A male *Laglaizia* fly, with the eyes protruding on long stalks. Its general colouring is brownish-yellow, including the wings. The length of the head and body is 9 millimetres (about two-fifths of an inch), and the width of the head across the eyes is 22 millimetres (nearly 1 inch). The specimen illustrated, from Hollandia, West Irian, was presented to the Australian Museum by Mr R. T. Simon Thomas. [Drawing by F. J. Beeman.]

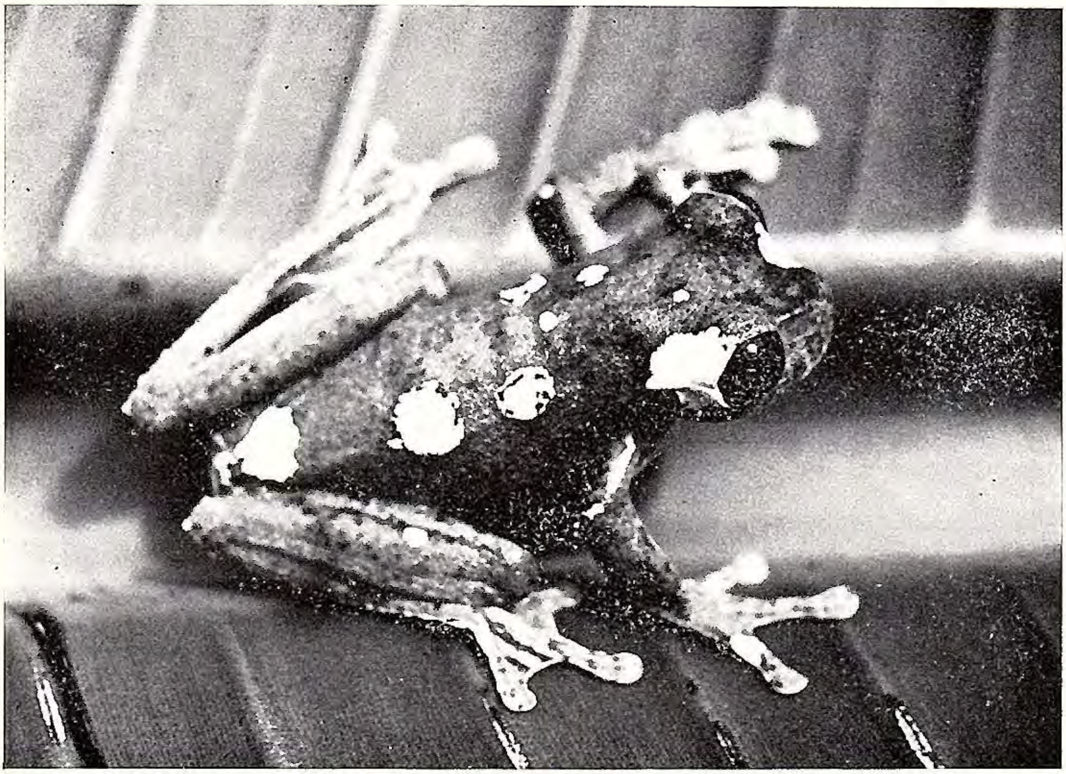
Aru Islands near the southwest coast of New Guinea in 1857 and an additional three at Dorey, West New Guinea, the following year. These were named and described by Francis Walker in 1859, 1861, and 1865, who, through a characteristic oversight, only recognized five of the seven as being true *Achias* species. These are now preserved in the British Museum (Natural History). More than twenty species of *Achias* have now been named, and several unnamed ones have been collected, but it has never been possible to re-identify the original *A. oculatus* of Fabricius with any certainty. It is fairly certain that it did not come from Java. The known species of *Achias* live in New Guinea, the nearby islands of Aru, New Britain, and Waigeo, and also in northeastern Queensland. They are generally found on tree trunks or foliage in wet forest but nothing is known of their life-cycle and little of the habits of the adults. [Since this was written, I have had the opportunity of rediscovering Bosc's long-lost specimen in the Paris Museum. It has proved to be distinct from any other known *Achias* species.]

Giant insects

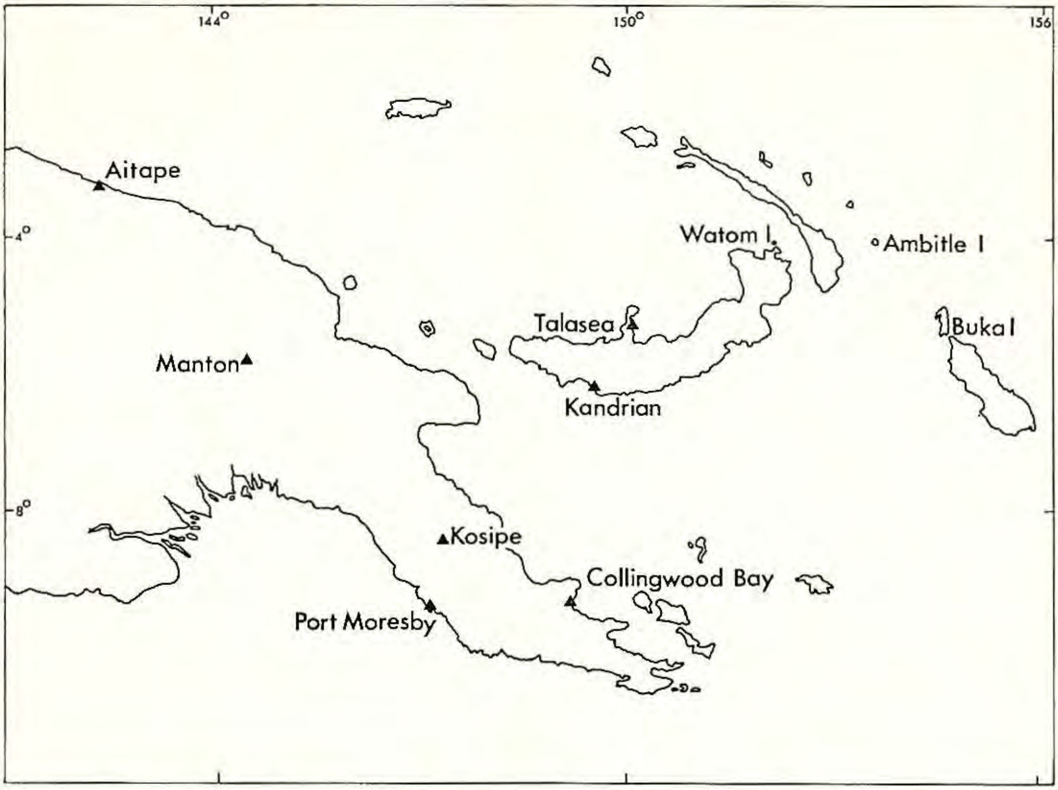
The largest insects in New Guinea, as in other warm countries, are stick insects or phasmids. Some individuals in New Guinea measure about 35 centimetres (14 inches) in length, which places them among the largest known insects. New Guinea also possesses one of the largest cicadas in the world in *Pomponia gigantea*. The female measures 164 millimetres (about 6½ inches) in wing expanse; the male is probably larger still. W. L. Distant, who first described this species, thought it could prove to be the largest of all cicadas when better known. It should not, however, be thought that most insects in New Guinea are large. Undoubtedly, the number of small and minute species is many times the number of the large ones like those just considered, and they no doubt play a more important role in the forest ecology.

In an article of this length only a few kinds of insects can be touched on, and many equally interesting ones are omitted. Our present knowledge of the New Guinea insects is only a minute fraction of what remains to be discovered about them. It is a pity that, with the present rate of destruction of primary forest, particularly in the lowlands, many insects will probably be lost before anything significant is known about them. Conservation measures aimed at limiting the activities of scientific or amateur collectors are likely to have little or no effect on the rate of loss. The only hope for the preservation of this fascinating fauna lies in the setting aside of sufficiently varied tracts of natural forest—particularly the primary rainforest.

Papua New Guinea Tree-Frog



The small tree-frog *Nyctimystes kubori*, widely distributed in many of the mountainous regions of Papua New Guinea. It is variable in colour and pattern, and many specimens (like the one above) have patches of white pigment greatly resembling patches of fungus. These apparently increase the frog's ability to camouflage itself. [Photo: H. G. Cogger.]



Some important archaeological sites in Papua New Guinea. [Map by the Author.]

Prehistory Poses Many Problems

By JIM SPECHT
Assistant Curator of Anthropology, Australian Museum

WITH less than 15 years of field research by trained archaeologists, the prehistory of Papua New Guinea is imperfectly known. Research to date has concentrated on two areas, the Highlands and the coastal zone around Port Moresby, with minor forays into the islands and along other parts of the New Guinea coast. Thousands of square miles have yet to be visited by archaeologists, while the complexity of the evidence that can be expected from areas such as the Sepik will prevent quick, easy answers to the multitude of questions that can be asked. The vast size of New Guinea, with its extensive swamps and rugged mountain ranges, is itself a major obstacle to rapid results. Therefore, this brief review of current and completed research can only be provisional, and is likely to be modified extensively by the end of this decade.

Early hunter-gatherers

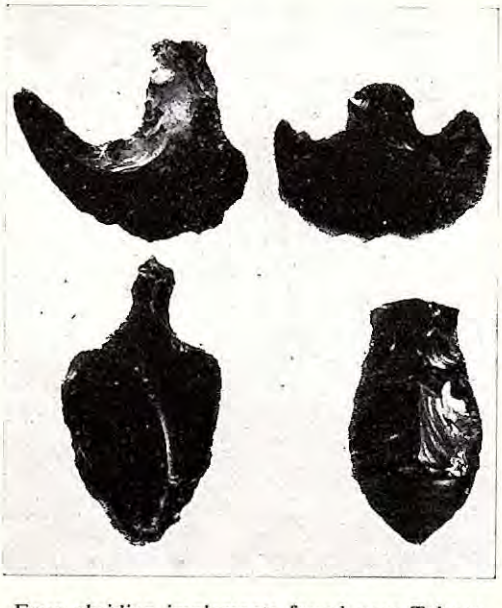
At the height of the Ice Ages, when world sea-levels dropped 100 metres and more below their present levels, New Guinea and Australia formed a single landmass. Even at its lowest level, however, the sea continued to separate them from the lands of southeast Asia. We do not know just when man constructed the first water craft capable of making this sea crossing, but the earliest recorded dates for human occupation in Australia suggest that this took place over 35,000 years ago. Research into this phase of human history in Australia-New Guinea is hindered by the drowning of the coastlines of that period by the rise of the sea to its present level following the end of the Ice Ages, and so our knowledge of the first settlers will always be incomplete.

These first settlers, dependent on hunting and gathering for food, encountered in New Guinea a fauna that was more restricted in both variety and size than that of southeast Asia, but the vegetation presented fewer problems since the two regions share many elements in common. However, any adjustments in food habits that were necessary had been made by 23,000 years B.P. (before present), when a camp site was occupied at Kosipe in the Papuan Highlands. This site stands on a ridge top at 1 800 metres (about 6,000 feet) altitude, though at the time of its first occupation its local environment and climate were more comparable with those of higher altitudes today. Its occupants were probably searching for forest products, such as pandanus fruit, though the only materials recovered in the excavations were flaked stone tools. Among these is a distinctive group of artefacts known as waisted blades, which are axe/adze tools with notches flaked on each side. The function of these tools is not known, but wood-working and food acquisition activities are obvious possibilities.

Unfortunately, the Kosipe site is unique, and there is a long time-gap before the next evidences of human activity, found in rock shelters in the Highlands and dated about 10,000 to 12,000 years ago. The waisted blades continued in use, though grinding appears on some ordinary axe/adzes. By the time they ceased to be made, around 6,000 years B.P., the waisted blades also were finished by grinding. In these shelters were found many bones of marsupials and other animals, the remains of hunting exploits, but the plant content of the diet is not represented.

There is some doubt whether these early hunter-gatherers managed to cross to New Britain and the other islands to the east of New Guinea, and if so at what date. A series of undated flaked stone tools found in stream beds near Kandrian in southern New Britain have been compared with the Highlands' waisted blades, though the comparisons, based on a few aspects of morphology, are tenuous to say the least. In 1972 a new flaked obsidian industry was discovered on the north coast of New Britain at Talasea, one of the most important obsidian sources in the western Pacific in recent times. These artefacts, also undated, have yet to be analysed, but they seem to be unrelated to the Kandrian forms. They include tanged blades similar to the knife and spear points used in the Admiralty Islands at the time of contact, though comparable forms are totally absent from the ethnographic record for Talasea itself.

If the first settlers on New Britain were hunter-gatherers, several important questions arise. We can assume that these settlers would have originated from the New Guinea mainland coasts, where they were probably less reliant than their Highlands counterparts on land animals for food, because they could include sea foods in their diet. New Britain is large enough to support hunter-gatherer bands living off both land and sea, but the colonization of the smaller islands of the region probably succeeded only after the



Four obsidian implements found near Talasea, west New Britain. The tanged handles suggest that the tools were hafted, perhaps as cutting tools and projectile points. [Photo: C. V. Turner.]

Front and side view of a stone figure from New Guinea. This figure was donated to the Museum by P. T. W. Black in 1972. It is 37 centimetres (14½ inches) high. The pointed base was probably stuck into the ground, and the figure may have been used in magic or some ritual performance. [Photo: C. V. Turner.]

replacement of the hunter-gatherer subsistence base by one of food cultivation. Whether or not these propositions are valid remains to be tested.

Crops and cultivation

Southeast Asia has long been regarded as one of the important "hearths" or centres of origin of agriculture, and recent excavations in Thailand have provided possible evidence for the earliest plant cultivation in the world at about 10,000 years B.P. We do not know just when cultivation was introduced to New Guinea, but on current evidence crops may have been grown in the Highlands by about 6,500–5,000 years B.P. Which crops were first domesticated in the New Guinea region remains a mystery, though there is some evidence for the sugar cane and probably some varieties of bananas. There is no doubt that the domestic animals of the region (pigs, dogs, chickens) were brought to New Guinea by man, since they are all forms native to the Eurasian mainland.

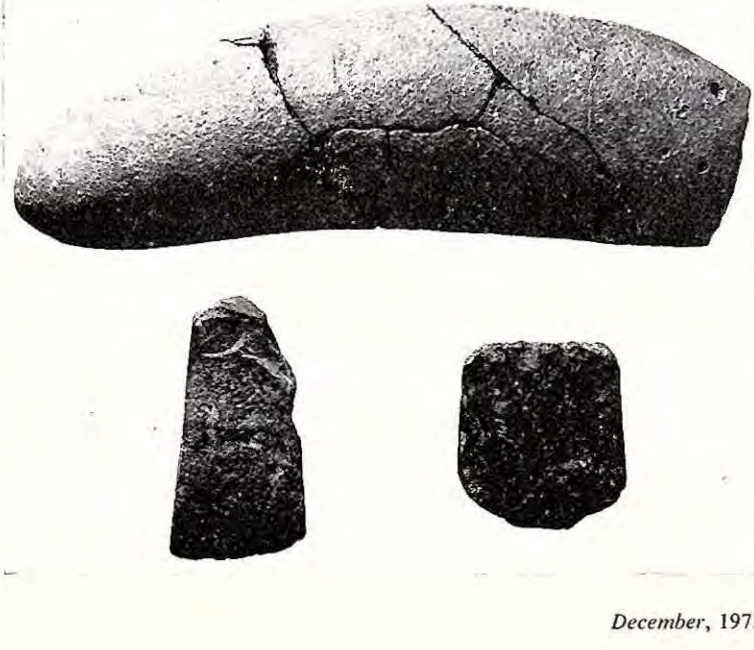
It is not known whether agriculture and domesticated animals were introduced at the same time, though the evidence suggests that this may have been the case. Research into the vegetation history of the New Guinea Highlands has shown a dramatic change from forest to grasslands at about 5,000 years B.P., and this change may reflect the clearance of forest for cultivation. However, until the actual remains of food plants or their pollen are recovered, this evidence cannot be regarded as conclusive. The first direct evidence for cultivation comes from the Wahgi Valley in the Highlands, where Professor J. Golson, of the Australian National University, Canberra, has excavated former garden systems buried in peat swamps. These gardens consist of series of intersecting ditches, now silted up, which were originally designed to control the flow of water through the garden plots. At the Manton site near Mount Hagen one such system has been dated about 2,300 years B.P., by which time the system was already well developed. Some remarkable finds at this site, and others in the Wahgi Valley, are wooden digging sticks and fence posts preserved in the waterlogged peat. Identical tools, and garden systems, have been recorded in use in various parts of the Highlands in the twentieth century.

Less direct evidence for cultivation may be implied by the presence of pig bones at several rock shelters in the Highlands dated between 5,000 and 6,500 years B.P. Since some modern New Guinea communities raise their pigs, regarded as the ultimate symbols of wealth and power in many communities, on cultivated crops, several authors have suggested that the archaeological pig bones are indicators of cultivation. This is not convincing, since the practice is a localized phenomenon and large populations of wild pigs survive without the benefits of such intensive care.

Before leaving the Highlands it is worth noting that the above summary is based on data from a few sites, some of them rock shelters. With limited archaeological data, most of which consists of flaked stone tools that show little change over several millenia, it is easy to gloss over the gaps and inconsistencies in the evidence. One point, however, that does emerge consistently is the impression of long-term stability, of little drastic change in the basic tool kits. Surprisingly, there seems to have been no major changes in the stone artefact inventory with the introduction of agriculture, even though the neolithic economy must have had a tremendous impact on population levels and daily activities. For hunter-gatherer bands throughout the world, with very few exceptions, are nomadic and have low population densities, whereas communities which cultivate their food tend to develop permanent settlements with much larger populations. The absence of major changes in the stone tools of the New Guinea Highlands following the introduction of agriculture may indicate that these tools were not primarily associated with the food quest, but were designed for tasks practised by both hunter-gatherers and cultivators. However, this picture of stability and continuity is in marked contrast with the evidence from the coasts of New Guinea and island Melanesia.

Maritime economies

Research in the lowlands has been dominated by the study of prehistoric pottery sites, particularly those belonging or related to the Lapita-ware complex. This complex, dated to between 3,200 and 2,000 years B.P., is now known to have extended from New Britain southwards through island Melanesia to the western edge of Polynesia. South of New Britain the richly decorated and very distinctive Lapita pottery seems to be associated with man's first entry into the southwest Pacific. Most Pacific archaeologists now agree that the descendants of the Lapita pottery people of Tonga and Samoa developed into the ancestors of the



Stone artefacts excavated from the Lapita pottery site on Watom Island, New Britain: a ground "pick" of unknown function (top) and two axe or adze blades. The pick is 19 centimetres (7½ inches) long. [Photos: C. V. Turner.]

present-day Polynesians, a question discussed by Professor R. Green in a recent issue of *Australian Natural History*.

From New Britain to Samoa the Lapita settlements are situated on or close to present or former beach lines. The tools and ornaments of shell and the remains of fish and molluscs taken for food emphasize their reliance on the sea. It is assumed that these people practised some cultivation and raised pigs, or imported much of their food, for many of the sites are on islands too small to support large settlements on the islands' natural resources alone. The immediate origins of the Lapita people are somewhat obscure, though the style of their artefacts implies a source in the Micronesian region rather than on the mainland of New Guinea, where only one Lapita sherd, found many years ago near Aitape, has so far been reported.

On New Guinea a cultural complex is being defined in the Port Moresby area which is clearly related to, if not derived from, the Lapita complex. The Papuan red-slipped pottery complex is younger than Lapita, dated between about 2,000 and 1,000 years B.P., but the artefacts and food remains reflect a similar reliance on the sea. The distribution of these sites coincides quite closely with that of the modern Motu and their trading destinations, and perhaps indicates a similar pattern of trading.

There is ample evidence that the Lapita people engaged in extensive trading activities. Obsidian from Talasea, on New Britain, has been found at Lapita sites on Watom and Ambitle Islands, and possibly also Buka Island. The most striking evidence for trade in this obsidian comes from the southern Solomon Islands, 2 000 kilometres (1,250 miles) to the south, where Professor Green found Talasea obsidian in the Santa Cruz Islands. It is possible that the Lapita pottery itself was also traded, though more work is needed on identifying the sources of the clays used to make the pottery.

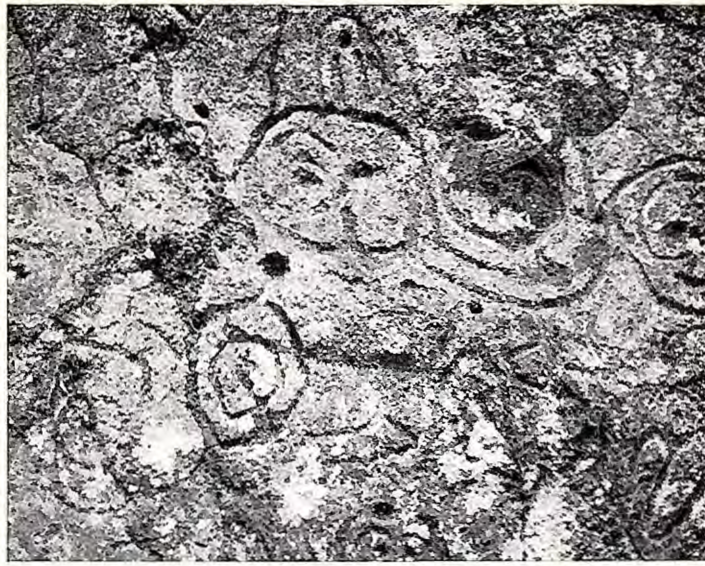
This early evidence for trade is not surprising, since in recent times many coastal peoples of the region were heavily dependent on imported food and other goods for survival. It is reasonable to assume that the factors necessitating this trade have operated for at least two millenia. What we do not understand as yet is just how material such as the Talasea obsidian was transported so widely. In recent times the Tolai people of Watom Island actually sailed to Talasea to obtain obsidian, and their Lapita predecessors on the island may have done likewise. The southern Solomons people probably received their obsidian through a series of exchanges between neighbouring groups, as it is unlikely that they would have sailed to Talasea itself. Whatever the method by which they obtained obsidian, it is clear that the Lapita people were competent sailors, well-equipped for life in the oceanic world of Polynesia.

In Melanesia, and around New Guinea in particular, the fate of the Lapita people is obscure. On Watom and Ambitle Islands their settlements seem to have ended at least 2,000 years ago, and the subsequent inhabitants of these islands possessed a very different material culture. Watom was totally devastated about 1,000 years ago by volcanic eruptions that created the Rabaul caldera, and was reoccupied, perhaps by the antecedents of the present Tolai inhabitants, about 750 years B.P.

On Buka Island to the south the culture history, as seen through changing pottery styles and other artefacts over 2,500 years, suggests a basic continuity of the original population, but interrupted by an event of some magnitude about 750 years ago. This is marked by a sudden change in pottery style that cannot be accounted for solely in terms of local development, and by an increase in the variety of stone artefacts.

At approximately the same time changes were occurring on the New Guinea coast, where the Papuan red-slipped pottery was replaced by pottery ancestral to that of the modern Motu. On the north coast at Collingwood Bay a very unique style of pottery appeared, flourished briefly, and then just as abruptly disappeared.

The period between 750 and 1,000 years ago emerges as a time of change in the coastal regions, but the archaeological evidence currently available does not provide us with a simple answer to the question of what these changes signified. The region-wide picture suggests movements of people to replace or to combine with existing populations, though better evidence is needed to demonstrate that the changes were contemporary and related. Some archaeologists would argue in favour



Rock engravings found on the north coast of west New Britain in 1972. The significance and age of such engravings are not known. [Photo: J. Kamminga.]

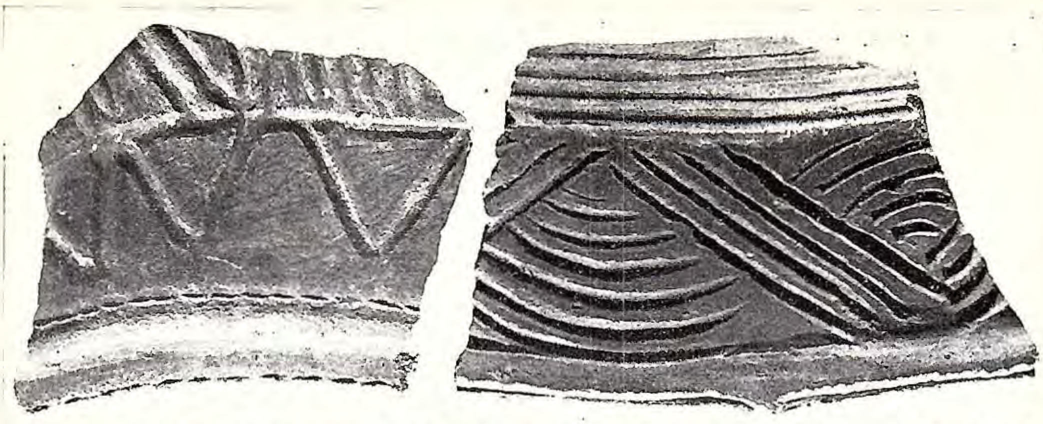
of a series of unrelated local developments that merely appear to be contemporary and connected. This problem must await better field evidence.

Languages and archaeology

In all of the areas where these changes can be identified the present populations speak languages belonging to the Austronesian (AN) family, which is found throughout the Indo-Pacific and to which the Polynesian languages belong. The AN languages account for over 200 of the 1,000 or so languages spoken in the New Guinea region, and the majority of them are found on or close to the coasts. In contrast, most of the other 700-plus languages of the region, loosely termed non-Austronesian (NAN), occur inland away from the sea. Whereas the Austronesian languages are quite closely related and form a single group, the NAN languages are more diverse, form several groups, and include some which currently appear to be unrelated to any other known languages. Linguists have interpreted these distributions and relationships as indicating that the AN languages are generally of more recent origin than the NAN languages.

The tracing of a language history by archaeological means is impossible if no written documents are preserved. Since there was no writing in Melanesia until the last century, following the arrival of Europeans, it is obviously impossible to discuss in detail the emergence of individual languages, though on at least one point the archaeological and linguistic evidences seem to converge. Some linguists believe that languages change at a fairly constant rate and have used this figure to calculate the date of the emergence of various languages. It may not be a coincidence that the linguistic estimate for the emergence of the Motu language of Port Moresby is about 750 years ago, about the time that the Papuan red-slipped pottery was replaced by pottery ancestral to the modern Motu pottery.

The coastal changes of about 750–1,000 years ago seem to have had repercussions in the New Guinea Highlands. Dog bones first appear in the region around 1,800 years ago at coastal sites on Buka and near Port Moresby, but are found in the Highlands only at about 800 years ago. At the same time pottery from a lowlands industry made its first appearance in the Highlands. Contact between the coasts and Highlands started much earlier than this, since seashells found in several Highlands rock shelters are at least 9,000 years old, but prior to about 800 years B.P. these contacts seem to have been minimal and intermittent. By the time Europeans entered the Highlands in the twentieth century, extensive trading networks linked the coasts and the Highlands. The development of these networks may have



Two pieces of prehistoric pottery from Collingwood Bay, Papua. This pottery style flourished about 1,000 years ago. Its origins are unknown. [Photo: C. V. Turner.]

been stimulated by the arrival on the coasts of new Austronesian groups in the period between 750–1,000 years ago.

In this brief review it is impossible to discuss the large body of prehistoric materials that cannot be fitted into our current interpretation of New Guinea's prehistory. Rock paintings and engravings occur throughout the region, but almost nothing is known of their age or significance. One style of engraving, based on curvilinear elements forming concentric circles, spirals and stylized human faces, is confined to coastal zones where AN languages are spoken, and may be connected with AN-speaking groups of the past. But more research is needed before such an interpretation can be accepted with confidence. Hundreds of stone pestles, mortars, and carved figures have been found over the years, but their cultural correlates, ages, and precise functions still remain unknown. For the New Guineans of today, most of these finds belong to the distant past which is not covered by their extensive myths and legends. It is one of the tasks of future archaeological research to fill these gaps in our knowledge and to provide some understanding of the factors which led to the development of such a culturally diverse region.

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MEET OUR CONTRIBUTORS . . .

DUNCAN BRUCE DOW graduated from the Auckland University College, University of New Zealand, in 1954, and joined the Commonwealth Bureau of Mineral Resources, Canberra, the following year to take part in the regional geological mapping of northern Australia. Subsequently, one of his main interests has been filling in the gaps in the geological map of Papua New Guinea. This work was interrupted for three years when, in 1968, he took up an offer by the Ethiopian Government to be the Foundation Director of the Geological Survey of Ethiopia. Since returning to the Bureau of Mineral Resources in 1971 he is again responsible for the Bureau's mapping in Papua New Guinea.

N. H. FISHER was educated at Toowoomba Grammar School and the University of Queensland, where he gained an honours degree in geology in 1931. He was then appointed mine geologist for Mt Isa Mines, and, after 3 years there, became Government Geologist of the Territory of New Guinea. Until 1942 he was concerned with the study of the mineral deposits of the Territory, particularly gold lodes and alluvial deposits, with broad-scale geological reconnaissance, and with vulcanology. He became a Doctor of Science of the University of Queensland in 1941. Dr Fisher designed and established a vulcanological observatory in Rabaul in 1939–40. He became Chief Geologist of the Bureau of Mineral Resources, Canberra, when it was established in 1946, and Director of it in 1969.

GRAEME G. GEORGE is Superintendent of the Wildlife and Bird of Paradise Sanctuary, Baiyer River, Papua New Guinea. Born and educated in Melbourne, he undertook teacher training at the Australian School of Pacific Administration in Sydney and went to New Guinea as an Education Officer at the end of 1962. He assisted with the establishment of the Sanctuary in 1967, and transferred to the Department of Agriculture, Stock and Fisheries to manage the Sanctuary in 1968.

PETRUS C. HEYLIGERS studied biology and majored in ecology at the University of Utrecht, the Netherlands. The same university awarded him the D.Sc. degree for a thesis on the vegetation and soils of a white-sand savannah in Surinam. Since 1961 he has been with the Division of Land Use Research, CSIRO, Canberra, taking part in land-resources surveys in Papua New Guinea. His research interests are the interpretation of aerial photographs with regard to vegetation characteristics and environmental factors, and the ecology of the woodlands and semi-deciduous forests in the seasonally dry areas.

DAVID LEA has been associated with Papua New Guinea since 1961, when he started a Ph.D. thesis on land-use and land-tenure problems in the Sepik district. In 1964 he became a Lecturer in Geography at Monash University, Melbourne, and had a sabbatical leave teaching in Canada and carrying out research in Guyana. In 1968 he returned to New Guinea as a Senior Lecturer in the University of Papua and New Guinea, and at the end of 1971 he succeeded Professor R. G. Ward as Professor of Geography.

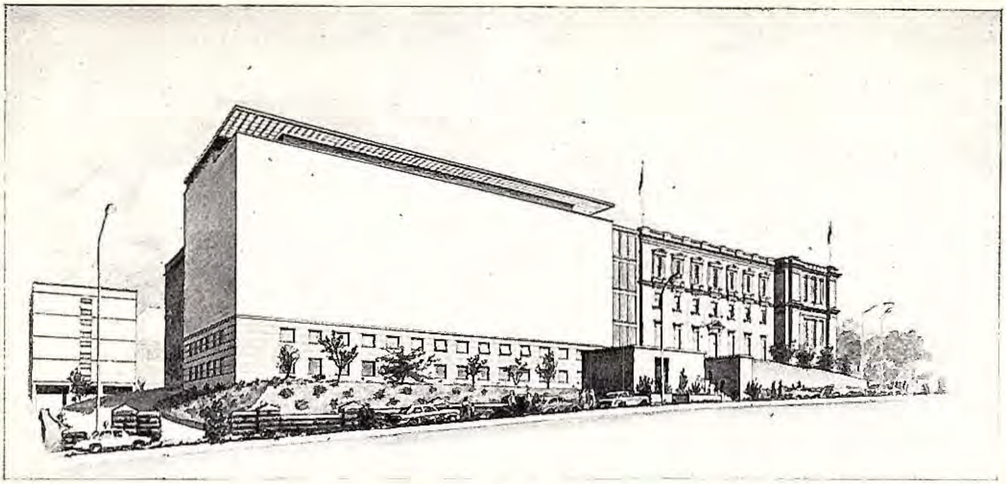
DAVID K. McALPINE is a Curator and Research Scientist in the Entomology Department of the Australian Museum. He was born in Australia and educated at Sydney Grammar School and the University of Sydney, receiving the degree of M.Sc. After joining the Australian Museum staff he studied at the Imperial College, University of London, where he received the degree of Ph.D., and at the British Museum (Natural History). He has a wide interest in natural history, but his special research interest is the systematics, biology, and evolution of the Acalyptrate Diptera (fruit-flies and related families), particularly those of Australasia.

RICHARD SCHODDE was born and educated in Adelaide. He graduated with honours in taxonomic botany from the University of Adelaide in 1960, and in the same year joined the CSIRO Division of Land Research, New Guinea survey group, as a botanist. He remained with the group until 1970, making frequent field trips to many parts of New Guinea and Bougainville Island. He was awarded a Ph.D. from the University of Adelaide in 1970 for his taxonomic research in the southern sassafrasses (Atherospermataceae). To satisfy his lifelong interest in Australo-Papuan birds and their geography, he took up the position of Curator of Collections at the CSIRO's Division of Wildlife Research at the end of that year. He is at present concerned with administering faunal surveys in various parts of Australia.

JIM SPECHT came to Australia from England in 1965. After completing a doctoral thesis on archaeology in the New Guinea islands, he taught for a year at Southern Illinois University, U.S.A., before joining the Australian Museum as Assistant Curator of Anthropology in June 1971. He has studied several modern pottery industries in New Guinea, and is currently working on the prehistory of trading in New Britain, with special reference to Lapita pottery period sites.

D. WALKER is a Yorkshire botanist who has lived in Australia since 1961 and is currently Head of the Department of Biogeography and Geomorphology at the Australian National University. Among other things he has been a night-shift labourer, a Royal Air Force officer, a Cambridge don, and President of the Botany Section of ANZAAS.

RICHARD G. ZWEIFEL entered the American Museum of Natural History, New York, as Assistant Curator in 1954 on receiving his Ph.D. from the University of California. The Museum had a long tradition of research on Papuan zoology, and he soon began research on collections of New Guinean amphibians and reptiles accumulated there over the years. Study of the preserved specimens whetted a desire to see the animals alive and in their natural habitats, a desire only partly appeased by three trips to the island, each of about 3 months' duration.



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