

# AUSTRALIAN NATURAL HISTORY

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# AUSTRALIAN NATURAL HISTORY

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● **FRONT COVER:** These carved human figures come from the Trobriand Islands, in the Massim region of eastern Papua. They are at present on exhibition in the new Gallery of Melanesian Art at the Australian Museum. Such black wood carving, with incised, lime-filled decoration, is typical of the art of the Massim region, where small decorated items were usually part of the wealth of chiefs and their families. These figures were probably used as stands for offerings to the clan ancestors. **BACK COVER:** A Geoffroy's Long-eared Bat (*Nyctophilus geoffroyi*), from New South Wales. Long-eared bats (*Nyctophilus*) are represented by about half a dozen species, confined to Australia and New Guinea. They rest in hollow trees or under loose bark during the day, and emerge at night to feed on insects. (Photos: C. V. Turner.)

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# Some Aspects of Recent Australian Mineral Development

By R. O. CHALMERS  
Curator of Minerals and Rocks, Australian Museum

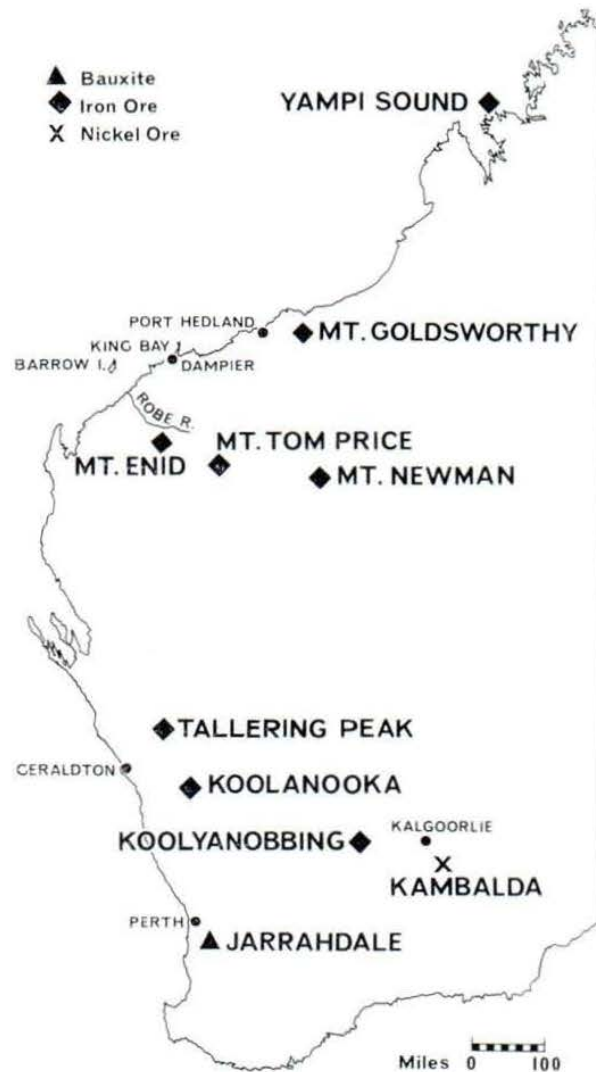
MANY notable mineral discoveries have been made in Australia. Many of these have been of great economic importance but, in addition, important development in many other directions has often resulted. There would be little or no settlement in many Australian regions generally considered unsuitable for human habitation had it not been for the discovery and exploitation of mineral deposits. In the 10 years following the first of the Victorian gold rushes in 1851 Australia's population increased threefold. The great wealth from the silver-lead-zinc deposits of Broken Hill, discovered in 1883, led ultimately to the establishment by the Broken Hill Proprietary Company in 1915 of an iron and steel industry in Newcastle that has now expanded into the largest private industrial concern in the Commonwealth.

In the latter half of the 19th century there were a number of other spectacular mineral discoveries, but between the discovery of gold at Kalgoorlie in 1893 and the year 1949 only three notable mineral deposits were discovered—the scheelite on King Island in 1904, the silver-lead-zinc and copper deposits of Mount Isa in 1923, and the Aberfoyle tin and wolfram deposits in Tasmania in 1926. Contrast the period between 1949 and the present, during which Australia's major deposits of uranium ore, bauxite, iron ore, manganese ore, nickel ore, phosphate rock, oil, and gas have been discovered.

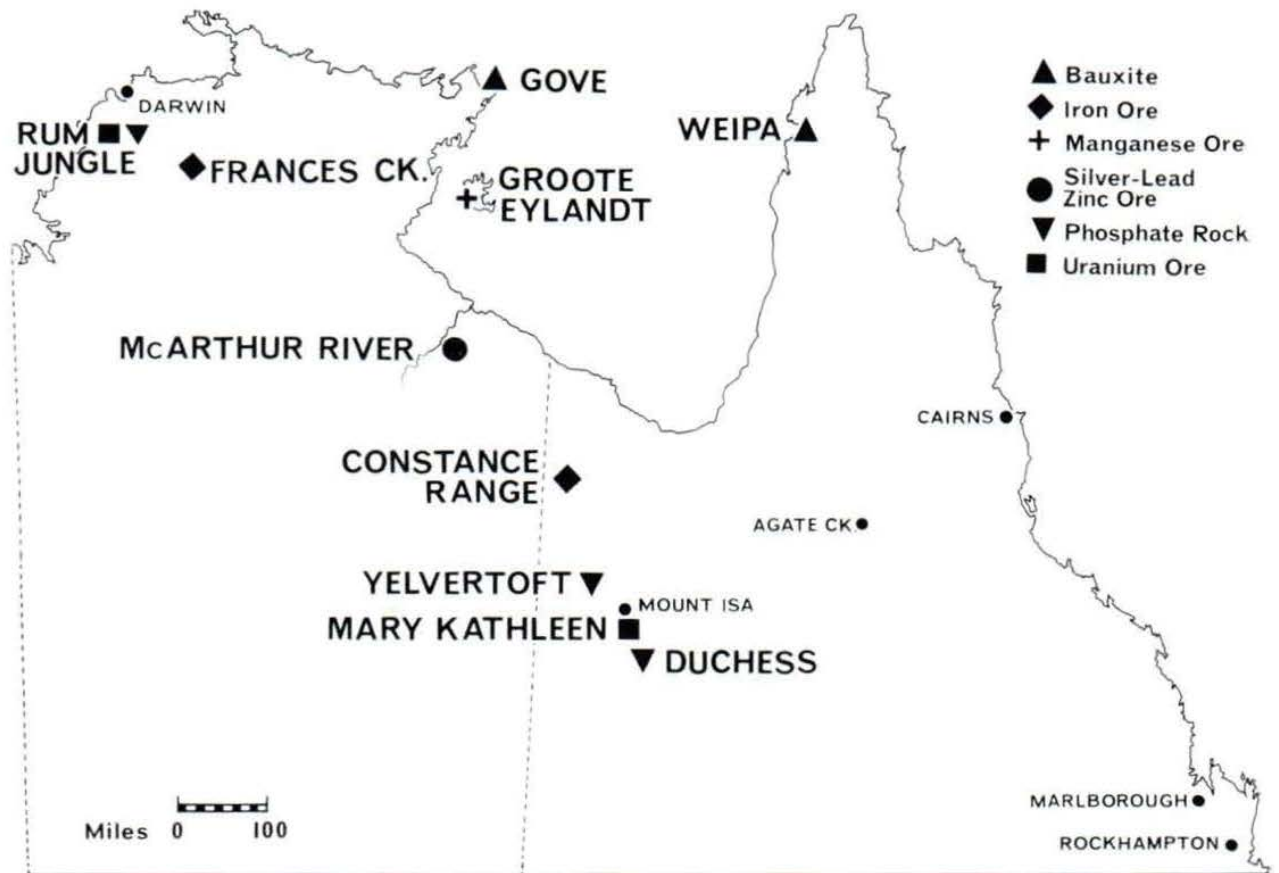
Almost every day the newspapers report negotiations between Australian and overseas mining, industrial, and business concerns to exploit many of these deposits, particularly bauxite, iron ore, and coal. Large sums of money are involved, a substantial part of which is contributed by both Commonwealth and State Governments.

## Iron ore

The most spectacular expansion in Australia's mineral production in the 1960's has been iron ore. In the belief that



Australia was deficient in iron ore, the Commonwealth Government had placed an embargo on exports just prior to the outbreak of World War II and this continued until 1960. By this time an extensive survey by the Commonwealth Bureau of Mineral Resources had established the reserves at 368 million tons, considerably more than had been previously estimated. The lifting of the embargo, and the indication of the willingness of Japanese interests to import



iron ore, initiated the extensive programme of exploration which is still continuing. By mid-1966 the iron ore reserves of Western Australia alone were estimated to be 15,000 million tons, most of these being in the Pilbara region in the northwest division of the State.

In the Hamersley Range in this region deposits of iron ore had been noted at widely spaced intervals in the past. H. P. Woodward, Government Geologist of Western Australia, wrote about them as early as 1888. In 1952 limonitic iron ore was discovered in the Turner Gorge, but it was not until 1961 that the first of the really important finds was made. In that year exploration geologists employed by Conzinc Riotinto of Australia Ltd found a massive high-grade hematite deposit, the reserves of which were estimated at more than 500 million tons. This was named Mount Tom Price after one of the principals of the Kaiser Steel Corporation of America, which, together with C.R.A., controls the company,

Hamersley Iron Pty Ltd, formed to work the deposit.

In addition to the development of a large open-cut mine to work the ore, a new port, Dampier, in King Bay, and two completely new townships, Mount Tom Price and Dampier, with all amenities for modern, comfortable living, have been built. These are linked by 182 miles of newly constructed railway. A plant for pelletizing the iron ore and a desalination plant to provide 400,000 gallons of fresh water a day have been built at Dampier. Regular shipments of iron ore have been made to Japan and Europe since August, 1966.

In a brief article such as this it would not be possible to give details of all the present-day new iron ore ventures in the Pilbara region and elsewhere in Western Australia.

Mount Goldsworthy, worked by a partnership of Consolidated Goldfields of Australia Ltd and two American organizations, is, like Hamersley Iron Pty Ltd, at the production and export stage. A new railway

line links the mine with Port Hedland, where harbour facilities have been improved.

Forty-five miles southeast of Mount Tom Price is a similar huge deposit of high-grade hematite at Mount Whaleback, in the Ophthalmia Range. The development of the mine and the laying of 265 miles of railway line to link the mine with Port Hedland have been started. Sixty per cent of the finance in this venture is controlled by the Colonial Sugar Refining Co. Ltd and Dampier Mining Co. Ltd, a subsidiary of B.H.P., and the rest by American, Japanese, and English interests. The general area is called Mount Newman after a nearby station property.

American and Japanese companies hold the leases and the entire financial interests in extensive iron ore deposits centred on Mount Enid, Robe River, but exploitation and development have not yet begun.

Outside the Pilbara region a consortium of Western Mining Corporation and American interests began to ship iron ore to Japan in March, 1966, from Tallering Peak, 80 miles

northeast of Geraldton, and Koolanooka, 80 miles southeast of Geraldton.

One of the conditions in the agreements between the Western Australian Government and the various companies is that, within 20 years of beginning to export iron ore, integrated iron and steel industries with a capacity of at least one million tons a year must be established in Western Australia.

Large-scale iron ore mining is not limited to the hot, arid regions of northwest Australia. The Savage River low-grade magnetite (magnetic iron oxide) deposits lie not far west of the Waratah-Corinna Road, west coast of Tasmania. Though these deposits were discovered in the 1870's it was only at the end of 1965 that, after an intensive survey, it was decided that the production of pellets could be an economic proposition.

The deposits are in typical rugged, heavily forested, high rainfall country on the west coast of Tasmania. At the inception of the exploration programme, all equipment, supplies, and manpower had to be taken in



An aerial view of the treatment area at Mount Tom Price, Western Australia. One of the iron ore stockpiles is in the centre. The big building in the left background is the primary crusher. [Photo by courtesy of Hamersley Iron Pty Ltd.]

by helicopter. An unusual feature of this project, which was completed and officially opened in March, 1968, is that the ore is pumped through a pipeline in the form of a fine slurry from the mill to Port Latta, 53 miles away on the north coast near Stanley, where a pelletizing plant and port facilities have been built. The American firm of Pickands and Mather and Company International is the managing agent for the company, which is a joint venture, the controlling interests being held by Japanese, American, and Australian organizations, in that order of importance.

### **Bauxite**

In 1606, the Dutchman Jansz in his little ship the *Duyfken* sailed into the Gulf of Carpentaria and down the western coast of Cape York Peninsula, and made anchorage at Duyfken Point, the northern headland of Albatross Bay, in which Weipa is situated. It was the first known landing by a European on the Australian continent.

In 1802, Flinders, when in the vicinity of Albatross Bay on his circumnavigation of Australia, wrote the following in his journal: "This land . . . is remarkable for having some reddish cliffs and deep water near the shore". These reddish cliffs are the now-famous bauxite deposits.

These deposits had been noted at various times and samples had been collected by geologists, but the full extent and colossal reserves were not realized until H. J. Evans, a geologist in the service of Conzinc Riotinto of Australia Ltd (C.R.A.), prospected the area in October, 1955. In his own words, as he saw mile after mile of reddish cliffs along the coastline he kept thinking that if all this was bauxite there must be something the matter with it otherwise it would have been discovered and appreciated long ago.

Before the decision to mine the bauxite was taken, much drilling and exploration had to be done to prove the extent and quality of the deposits. It was found that economic grade bauxite outcropped in the form of gently dipping beds over an area of several hundred square miles. The beds vary in thickness from a few feet to 30 feet and are covered by only a few feet of soil. The main bauxite beds are strongly pisolitic, consisting of a loose free-flowing mass of rounded pebbles, light reddish-brown in

colour and averaging about a quarter of an inch in diameter, in an unconsolidated clay matrix.

Comalco Industries Pty Ltd, equally owned by C.R.A. and Kaiser Aluminium of America, is the parent company controlling bauxite mining at Weipa. A small mission station had been the only habitation at Weipa prior to 1955, so that a port and township had to be built.

Extensive bauxite deposits were found in the Darling Ranges only 30 miles from Perth in 1955. The principal locality is Jarrahdale. Alcoa Australia Pty Ltd is the parent company mining the deposits. The Aluminium Co. of America holds a major interest. Western Mining Corporation is the largest Australian partner.

There are three stages in a completely integrated aluminium industry—mining of bauxite, manufacture of pure alumina (aluminium oxide) by chemical treatment of bauxite, and conversion, by smelting, of the alumina into metallic aluminium. At Gladstone, Queensland, an alumina plant, one of the largest of its kind in the world, began processing Weipa bauxite early in 1968. A similar plant at Kwinana, near Perth, produces alumina from Jarrahdale bauxite.

Bauxite deposits of similar magnitude to those already described were found at Gove in Arnhem Land in 1952. Nabalco Pty Ltd is a company formed to mine the bauxite, and part of the agreement with the Commonwealth Government is that a large alumina plant should be established by the end of 1971 on the site. Swiss Aluminium holds a 50 per cent interest in Gove, the remainder being held by the Colonial Sugar Refining Co. and a number of Australian insurance companies and banks. By about 1972 Australia will be one of the world's largest producers and exporters of bauxite and alumina.

### **Nickel**

One of the most spectacular of the recent mineral discoveries has been that of nickel. In January, 1966, Western Mining Corporation was drilling at Kambalda, an old and almost forgotten gold-mining ghost town. It is on the edge of Lake Lefroy, only 30 miles southeast of Kalgoorlie. The drill cores revealed the presence of rich nickel ore, actually an intimate association





The Savage River area, showing the iron ore open-cut mine in the foreground, the concentrator plant immediately behind it, and the town in the distance. [Photo by courtesy of Pickands and Mather and Company International.]

of pentlandite (sulphide of nickel and iron) and pyrrhotite (sulphide of iron) very similar to the ore at Sudbury, Ontario, Canada.

An intensive drilling programme has shown that the nickel mineralization is more extensive than was thought at first, and that a potential nickel province extends from Norseman, 100 miles south of Kalgoorlie, to Wiluna, 300 miles north of Kalgoorlie. Mining is now in progress at Kambalda.

Limitation of space will permit only bare mention of many other developments. The modern new mine on the site of the old C.S.A. mine, a few miles to the north of Cobar, New South Wales, has been producing copper and zinc concentrates since it began operations in 1965. The mine is owned by Broken Hill South and C.R.A.

Important deposits of manganese oxide were found on Groote Eylandt, Gulf of Carpentaria, in 1960. These are probably

submarine deposits of lower Cretaceous age. The annual output from these deposits has now reached the considerable figure of 270,000 tons and Australia is now a large-scale exporter of this valuable mineral.

The discovery and large-scale mining of uranium ores at Rum Jungle and Mary Kathleen are hardly recent developments, but it is worthy of note that, although mining ceased some years ago, both of these mines can begin operations again when the world demand increases, as it undoubtedly must.

Extensive deposits of good-grade phosphate rock were discovered in 1966 by a subsidiary exploration company of Broken Hill South Ltd at Duchess and other areas in the far northwest of Queensland. These deposits are of sedimentary origin and resemble those of western U.S.A. and north Africa. They are of great potential importance to a major producer of superphosphate

for agricultural purposes like Australia. Up to the present all our requirements of phosphate rock have had to be imported. Before these deposits can be worked, the disadvantage of the remoteness of the location and the distance from industrial centres and markets has to be considered.

The value of coal produced is more than that of any other mineral product and has been so for many years. The principal producer of black coal is New South Wales, with Queensland next. With increasing efficiency in the industry, coal production increases substantially each year. In New South Wales in 1966-1967 over one-quarter of the 26 million tons produced was exported, mainly to Japan. About 100 miles of new railway was built from Moura coalfield to Gladstone on the coast of Queensland, to transport the large quantity of coal consumed by the alumina plant.

The recent developments in the production of gas and oil are reported in the press at such great length that they are almost common knowledge.

Other large ore deposits are known but their ultimate economic importance depends on a number of factors. A large silver-lead-zinc ore body on the MacArthur River in the Northern Territory has been prospected and drilled by the Carpentaria Exploration Company, a subsidiary of Mount Isa Mines Ltd. The company's geological exploration teams have worked in the area since 1955. The fact that the area is remote and practically undeveloped presents one particular set of problems. Another problem is that the ore minerals are extremely fine-grained and intimately mixed with other minerals, and although much experimental work has been carried out there are metallurgical difficulties, yet to be overcome, in the way of carrying out an efficient separation of the ore minerals by flotation methods.

There still remain a number of mineral deposits shown on the maps accompanying this article. Yampi Sound and Koolyanobbing are well established ventures controlled by B.H.P. For many years B.H.P. has shipped iron ore from Yampi Sound to the Newcastle and Port Kembla steelworks. Since 1960 iron ore from Koolyanobbing has been mined by B.H.P. for its integrated iron and steel industry near Kwinana. Part of the agreement has involved the

Western Australian and Commonwealth Governments in the building of a standard-gauge railway line between Kalgoorlie and Broken Hill.

Low-grade iron ore deposits occur at Constance Range in the far northwest of Queensland, but the remoteness of the location and the fact that the deposits would require underground mining have led to the cessation of prospecting and development.

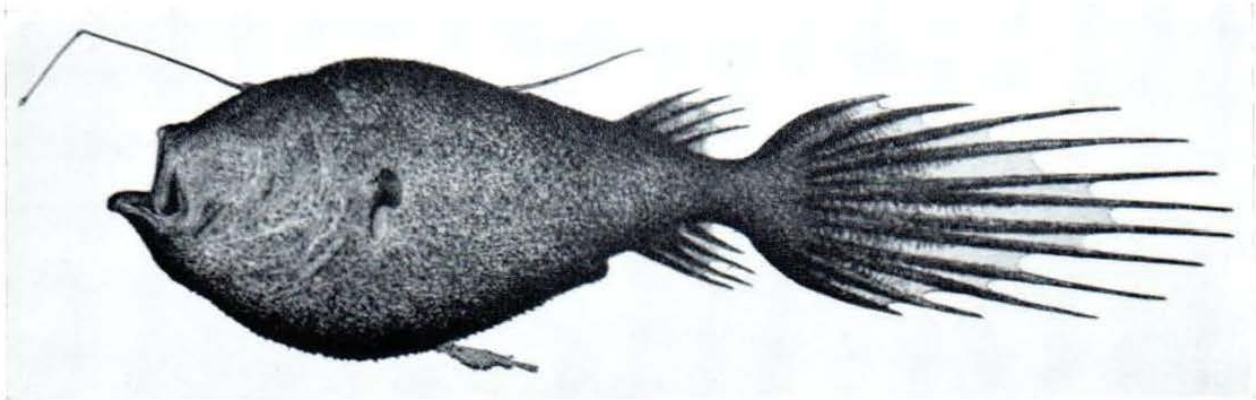
The iron ore deposits of Frances Creek in the Northern Territory are high grade but small by Western Australian standards. The entire production goes to Japan.

In Queensland the locations of two occurrences of good quality ornamental stones are shown. Agate is found at Agate Creek and chrysoprase at Marlborough. Both these minerals are worked commercially but are not of first-ranking economic significance.

In view of the spectacular mineral developments over the last 20 years the oft-repeated statement that no more outcropping ore bodies remain to be found in Australia has little validity. However, the principal discoveries now are mostly made by professional geologists working to a programme of scientifically planned search, as in the case of most of the major iron ore deposits in the Pilbara region, the Groote Eyland manganese oxide, the Weipa bauxite, and all of our gas and oil. It seems as though the pioneering period, when the bushman-type prospectors made their great discoveries in the face of considerable hardships, is past.

Gone forever are the days when Paddy Hannan pushed on in the searing heat beyond Coolgardie, in a waterless land, to find Kalgoorlie, when "Philosopher" Smith hacked his way in the cold and wet through the almost impenetrable "horizontal" scrub to discover the tin of Mount Bischoff, and when quiet, unassuming John Campbell Miles camped on the Leichhardt River with a team of horses he was taking to the Territory and found galena, the silver-bearing sulphide of lead, outcropping on a bare rocky ironstone ridge that came to be named Mount Isa.

*[The maps in this article are by Elvie Brown.]*



An angler fish, *Ceratias holboelli*, showing the lure on top of the head and a parasitic male attached to the underside. [After Bertelsen, 1951.]

## FISHES OF THE OCEANIC MIDWATERS

By JOHN R. PAXTON  
Curator of Fishes, Australian Museum

THE common names of midwater fishes—scaly dragon fish, fang tooth, long-tailed snipe eel, pearly lanternfish, whipnose angler fish—are indicative of the bizarre forms of life in the deep sea. The fishes themselves have a number of striking anatomical features or morphological specializations that suggest the midwater environment is vastly different from the more hospitable coral reefs or forest streams.

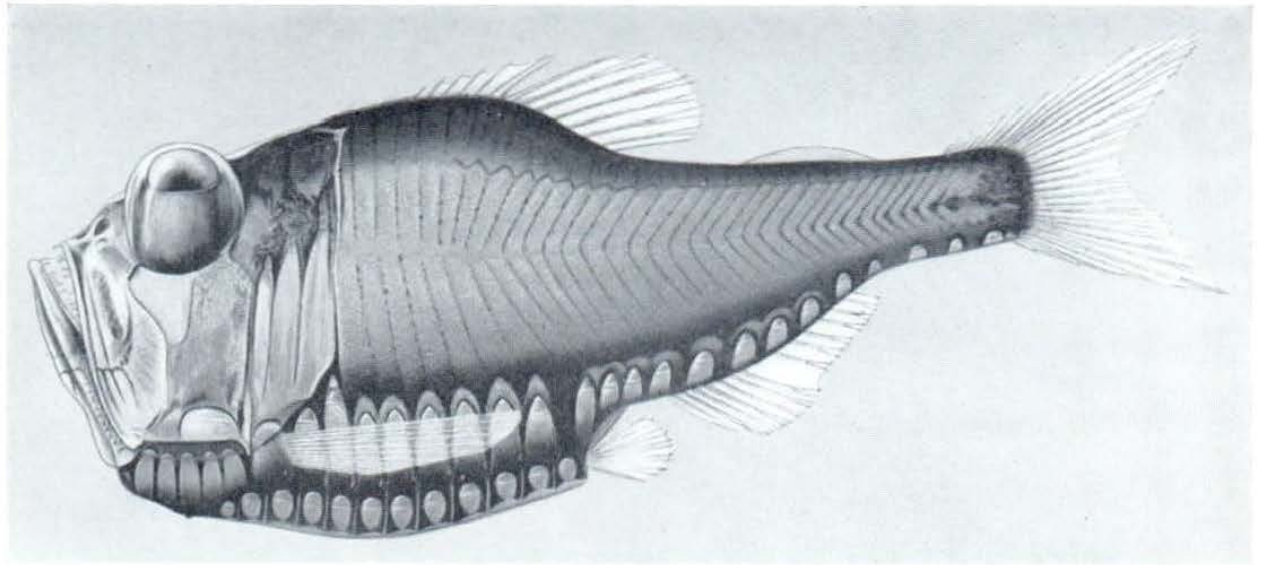
### The midwater environment

The midwaters are those areas below the well-lit surface waters of the world ocean. In the open ocean, down to 100 or 150 metres (330–500 feet), enough sunlight penetrates to allow photosynthesis to take place; microscopic phytoplankton live and produce food in this region to support all life in the waters below. The waters are very dimly lit below 150 metres, fading to complete darkness at about 1,000 metres, since sunlight is rapidly absorbed and scattered by sea-water. The midwater region extends to just above the ocean floor; it is therefore several miles in vertical extent in the deepest parts of the ocean. Midwater fishes are only those fishes below 150 metres which are free swimming and not associated with the

bottom. Deep-sea fishes are all fishes below 150 metres, including those forms associated with the bottom, such as flat fishes, rays, and the like.

Within the midwaters, various environmental parameters or characteristics change with increasing depth. Most noticeable is the decrease in light. Since the red, yellow, and violet portions of the light spectrum are those most rapidly absorbed by sea-water, the light between 150 and 1,000 metres is predominantly blue-green. Pressure increases with depth, and temperature decreases. Pressure increases at the rate of about 15 pounds per square inch every 10 metres. Below 1,000 metres, the temperature is usually 4° C or below; at great depths the temperatures approach freezing. The amount of dissolved oxygen in the water rapidly decreases with depth to about 1,000 metres; below this depth oxygen increases slightly. Slight changes in salinity are not correlated with depth.

The waters of the world ocean can be classified into various water masses. Each water mass is identifiable according to its particular temperature and salinity characteristics. These two characteristics are often plotted together as a temperature-salinity



A hatchet fish, *Argyropelecus affinis*, showing ventral photophores and tubular eyes. [After Brauer, 1906.]

curve for any given vertical column of water. The temperature-salinity envelope for each water mass includes all the curves found therein. Low temperature and oxygen, minimal light, and high pressure have all affected the fishes of the midwaters, through the forces of natural selection.

#### **Morphological specializations of midwater fishes**

Only a few of the general features and structural modifications of midwater fishes can be described in this short article. A large number of midwater fishes possess luminescent organs on various parts of the head and body. The light organs, or photophores, display a variety of shapes and structures, and many include a lens, reflecting layer, and pigment screen; the similarity to the basic structure of a vertebrate eye is striking. Light is produced either by luminescent bacteria which live in the photophore or by luminescent tissue in the photophore. Light is formed through a series of chemical reactions involving phosphorus and the enzyme luciferase. Those photophores with light-producing bacteria usually have a small opening to the outside. The relationship of fish and bacteria is mutually beneficial to both; the bacteria receive protection and probably nutrition from the fish, while the fish gains the advantage of light in the dark environment. Fishes with their own luminescent material usually have photophores without a pore to

the outside. The shape of individual photophores varies considerably, but the light produced is usually blue-green, much the same colour as the remaining sunlight below 150 metres. The eyes of midwater fishes are probably most sensitive to this colour.

Photophores are an obvious adaptation to life in a lightless or poorly lit environment. Many of the other specializations of midwater fishes are directly or indirectly correlated with the lack of light. The amount of food organisms, both phytoplankton and the larger planktonic organisms such as shrimp and other crustaceans, is much greater in the well-lit surface layers. The amount of food is proportionally less in deeper water, and a number of modifications involving feeding are apparent in midwater fishes. Some fishes have a light organ on the end of a long filament or barbel, which originates under the mouth or on the top of the head; the light organ hangs just in front of the mouth and acts as a lure for food organisms. In most such fishes, the mouth is extremely large and the dentition well developed. In the deepest living species, the musculature, skeletal system, scales, swimbladder, and kidneys may be very poorly developed. This is apparently a mechanism to conserve energy in an environment where food is very scarce. In these forms the stomach is often extremely distensible, an obvious adaptation for taking a rare, large meal. Some midwater fishes have been captured which have another fish, larger than them-

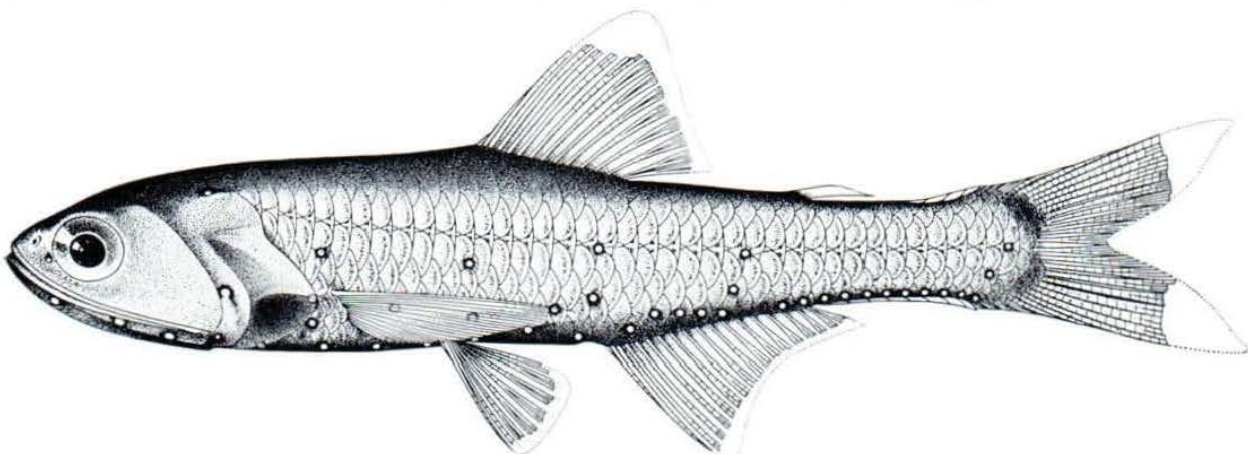
selves, in the stomach. The eyes of midwater fishes show great variation. Many species living below 1,000 metres have small or degenerate eyes. These same forms may have a highly developed lateral line system, which detects pressure waves. Fishes of the upper midwaters often have well developed eyes, particularly those species with photophores. Others have developed tubular, or "telescopic", eyes, which point either forward or upward. This specialization probably widens the field of vision and permits some binocular vision. The upturned eyes are probably an adaptation to predation from below the prey, utilizing the silhouette of the prey against the down-coming surface light. The body colours of midwater fishes, particularly the deepest species, are often black, dark brown, or deep red. In the midwaters where the only light is a dim blue-green, reds and browns will appear black. The dark colouration is doubtless a means of protective colouration, concealing an individual from either predator or prey.

The effect of low temperature on midwater fishes is difficult to assess; although no morphological specialization can be correlated directly with low temperature,

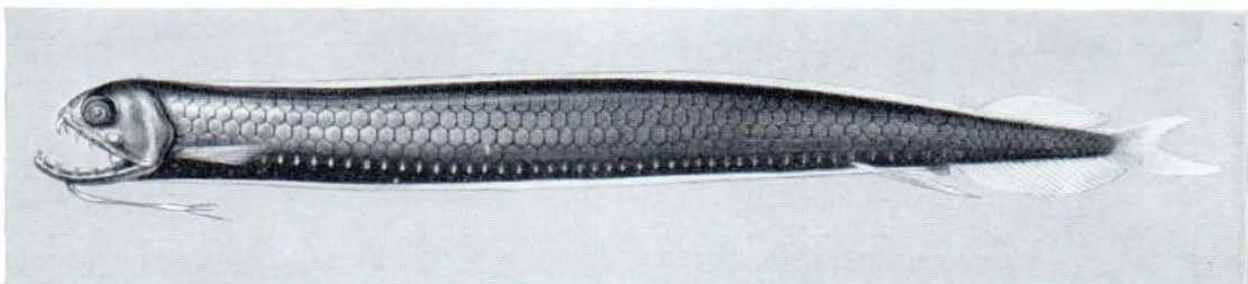
various biochemical reactions within the fish are probably changed, at least in rate, by low temperature. High pressure will only affect the air-filled or gas-filled spaces within the fishes, and this is normally found only within the swimbladder. In a number of midwater forms the swimbladder is either completely absent or is secondarily filled with fat and the air space is obliterated; thus the effect of extreme pressure in these species is negated. In the zones of lowest oxygen concentration, the gill structures, which play the important role in fish respiration, are often highly developed.

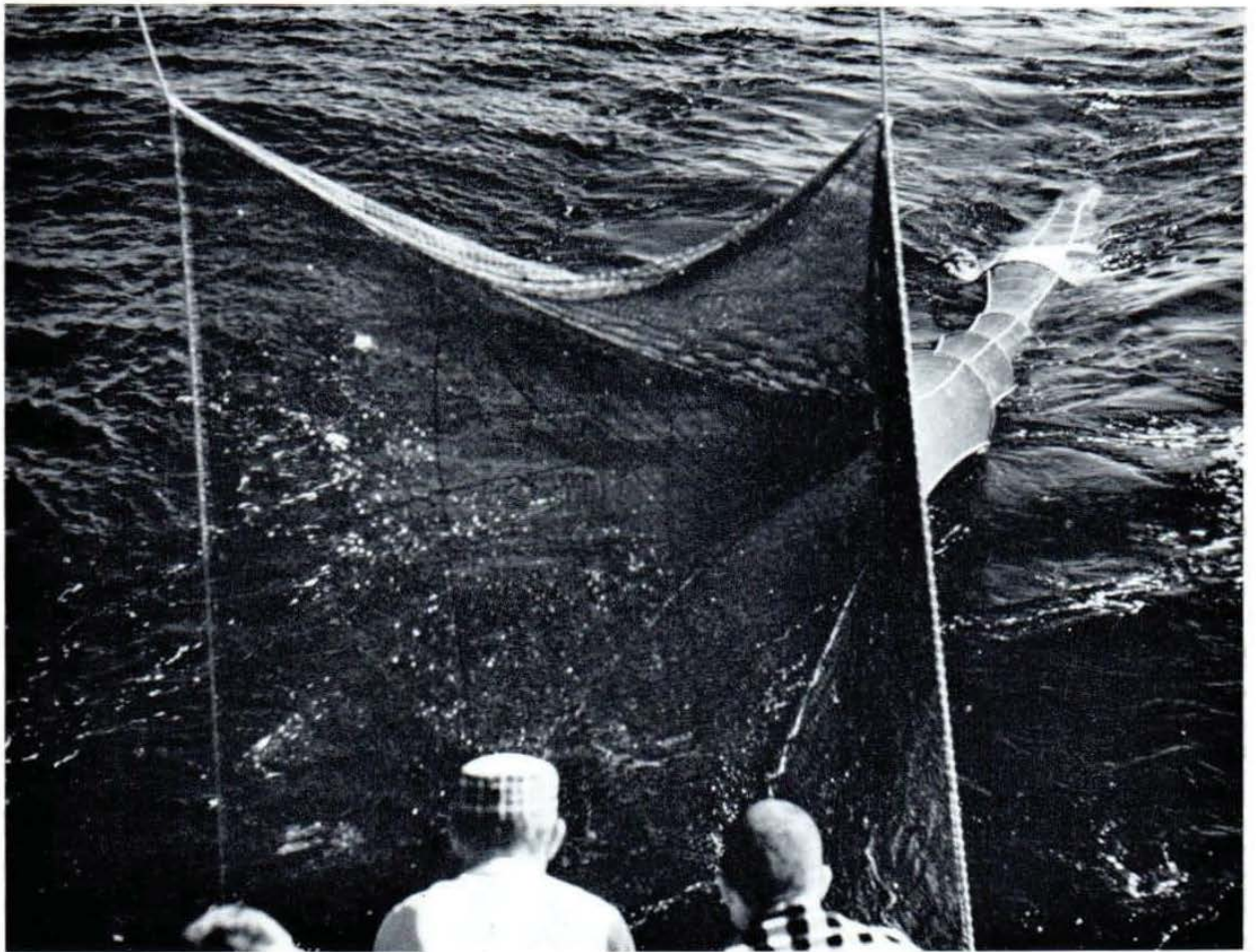
### Midwater trawling

Due to the great living depths of midwater fishes, the capture of these interesting creatures is a difficult task. Some of the first midwater fishes seen were from regions where strong upwelling brought them to the surface, as in the Straits of Messina. Occasionally midwater fishes are washed up on beaches; a few such specimens have been found on Lord Howe Island. But the main instrument of collection is with deep-sea nets. The first such nets were small, conical plankton nets with round mouths and fine netting. In 1949, marine



Above: A lanternfish, *Lampanyctus omostigma*, showing photophore pattern. [After Gilbert, 1908].  
Below: A scaly dragon fish, *Stomias affinis*. Note the ventral photophores, eye photophore, and chin barbel. [After Brauer, 1906.]





An Isaacs-Kidd Midwater Trawl entering the water. [Photo: J. C. Yaldwyn.]

biologists at Scripps Institution of Oceanography in California developed a very effective midwater fish collector, the Isaacs-Kidd Midwater Trawl. This trawl alleviates most of the disadvantages of small plankton nets in fish collection. The large size, some 40 feet long with about a 100-square-foot mouth, and the restriction of the fine mesh to the last few feet of the trawl, allow for fast trawling. The incorporation of a diving vane at the front makes the trawl dive as it is towed; at a speed of 4 to 6 knots, only three times as much wire as fishing depth is required. Although the high-speed trawl has revolutionized the capture of midwater fishes, not all problems have been solved. The size and complexity of the trawl require a large ship with a winch capable of holding thousands of feet of heavy trawling cable. The most serious disadvantage of the Isaacs-Kidd trawl is the lack of an opening-closing device. Fish are caught in the open mouth when the net is

lowered and retrieved. The determination of the upper and lower limits of the vertical distribution for a given species therefore requires a large series of trawls at different depths. Development of an opening-closing device is under study; one experimental model utilizes electrical trawling cable and a series of electrical signals to open and close the trawl at depth.

Little midwater trawling with large nets has been accomplished in the waters around Australia, and the midwater fishes from the Australian region are poorly known.

#### **Ecology of midwater fishes**

While the identification of species and the descriptions of morphological structure of midwater fishes are important areas of study, research on the ecology and life-histories of these fishes is equally fascinating. As a number of midwater species are used as food by commercially valuable species,

knowledge of their biology is important. Aspects of feeding, reproduction, schooling behaviour, and patterns of migration and distribution are all profoundly influenced by various parameters of the midwater environment.

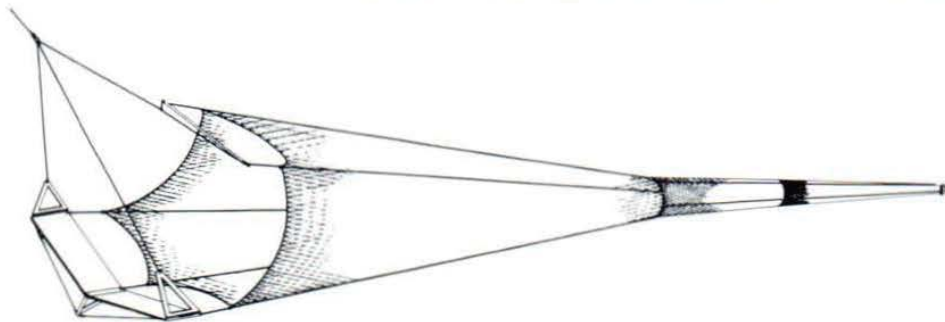
One characteristic feature of much of the life in the upper midwaters is the phenomenon of vertical migration. During the day, many fishes and invertebrates live a few hundred metres below the surface; at night they migrate to the upper 100 metres, and some even reach the surface, where they can be dip-netted under a light. During the Second World War, ship sonar, operated for the detection of submarines, found a sound-reflecting layer in the ocean that was far below the surface, yet not associated with the bottom. This Deep Scattering Layer, as it is now called, rose to near the surface during the early evening hours and descended to greater depths at dawn, much as some forms of midwater life were known to do. Research has now confirmed that the Deep Scattering Layer is composed of midwater animals—fishes, crustaceans, and siphonophores—that daily migrate between the surface waters and about 500 metres. The latest evidence comes from recent bathyscaphe observations made at the level of the Deep Scattering Layer. The gas-filled swimbladders of some midwater fishes, the floats of siphonophores, and the hard outer skeletons of shrimps are excellent sound reflectors that bounce back the sound produced by the sonar gear. While the composition of the scattering layer is now fairly well-known, other questions remain to be answered. Recent studies have shown that certain populations of lanternfishes migrate from about 750 metres to 50 metres and return every day. The energy expended is considerable; fishes averaging 5 centimetres (2 inches) in length are swimming almost one

and a half kilometers (almost 1 mile) every 24 hours. In addition, some of the migrating forms have functional, gas-filled swimbladders. To keep a constant pressure in the swimbladder during the migration, an enormous amount of gas in relation to the size of the fish must be absorbed or secreted. How this is accomplished by the small fishes is poorly understood.

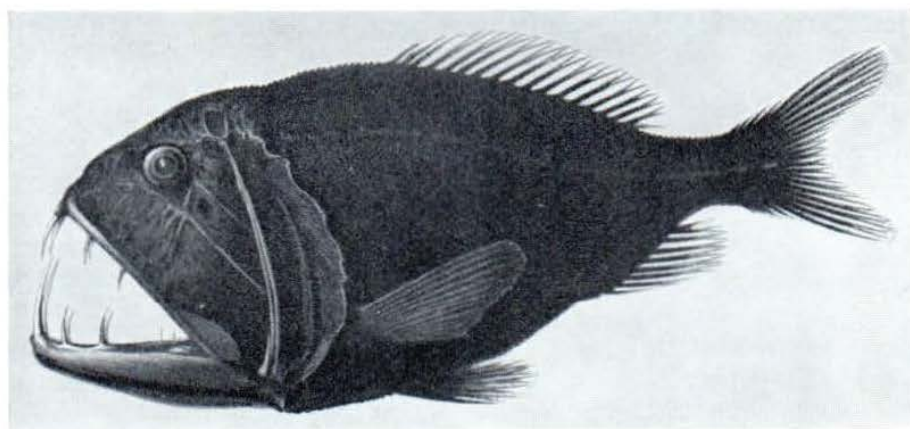
A number of hypotheses have been advanced to explain the migration. The most plausible explanation is that the migration is a feeding migration to the food-rich surface waters; however, the feeding habits of midwater fishes are little studied. The correlation of migration patterns with light intensity is striking, and light may act as a triggering mechanism for the movement. However, this would restrict migration to the upper 1,000 metres, and limited data indicate that deeper species migrate at night to levels above 1,000 metres. Hypotheses other than a feeding migration have been proposed. Reproductive potential may be increased by a concentration in the upper waters, or the vertical migration may significantly influence the patterns of horizontal distribution. A countershading effect of ventrally placed photophores against downcoming light has been suggested; vertical migration into waters of the same light intensity during sunset and sunrise would influence the light balance of such a scheme. Many questions concerning vertical migration remain unanswered, questions that also involve other aspects of the life of midwater fishes.

Many midwater fishes possess photophores, the functions of which are not fully understood. The function of some can be inferred from their structure and position. For instance, the light organ on the barbel of some fishes presumably acts as a lure for food organisms, for it hangs right in front of the mouth and often is adorned with small

Diagram of an Isaacs-Kidd Midwater Trawl. [After King and Iversen, 1962.]



A fang tooth, *Anoplogaster cornuta*. Note the well developed mouth and teeth. [After Brauer, 1906.]



tassels or fringes. But the majority of photophores occur on the body of the fishes, often in patterns, and their function is obscure. In some fishes, such as the lanternfishes, almost every species has a different pattern of body photophores. For this group the photophores appear to be important in species recognition, perhaps for the purposes of schooling or reproduction. Most midwater fishes have the majority of photophores concentrated on the lateral and, particularly, the ventral portion of the body. A recent hypothesis suggests the ventral photophores disrupt the body outline of the fish when viewed by a predator hunting from below; the photophores countershade the fish from the downcoming light. All of the hypotheses concerning the function of photophores remain untested.

In the vast midwater environment, there are special problems in the reproduction of midwater fishes. The larval life of many species is spent in the surface waters, where food is more plentiful. Of particular importance is the finding of a mate during the breeding season. For certain species, like lanternfishes, populations in a given area may number in the millions. Other species are much less numerous, particularly inhabitants of the deep midwaters. For these fishes, the problem of finding a mate during the reproductive season is acute. Certain species of angler fishes have solved this problem in a spectacular way. Large female angler fishes often have one or two small males attached as parasites to them. The mouth of the male becomes fused to the body skin of the female and the blood vessels of the two become closely associated

in this region. The male retains a small size, the eyes degenerate, and no angling device develops. Nourishment for the male is entirely from the female, and only the gonads of the male become fully developed. The males apparently become attached any time a female is encountered after larval transformation, and the two sexes are assured of being together during the breeding season. Other forms of midwater fishes are hermaphroditic; presumably, if a mate is not encountered in the breeding season, self-fertilization will take place. However, for many midwater species, the reproductive biology is unknown. A number of problems in midwater ecology are discussed in detail in *Aspects of Deep Sea Biology*, by N. B. Marshall, published in 1954 by Hutchinson, London.

Many of the unanswered questions outlined above are due to the inability to study midwater fishes alive. Most fishes brought up by a deep trawl are either dead or near death, probably due to the changes in temperature and pressure, as well as the damage done in the net. Even migrating species that have been surface netted at night have quickly succumbed in shipboard aquaria. It is to be hoped that the difficulties in maintaining midwater fishes alive can soon be overcome, for experimentation on living fishes will help to solve many problems. Data on tolerances to different environmental parameters, digestive rates, reproductive behaviour, and photophore display are needed. Direct observations from bathyscaphes can supply only some of the answers. Controlled experiments are necessary for the rest.





A potter smooths the rim with a wet *no-hean* leaf before the body of the pot is formed.

## *Pottery Making in Oralan Village, Portuguese Timor*

By I. C. GLOVER

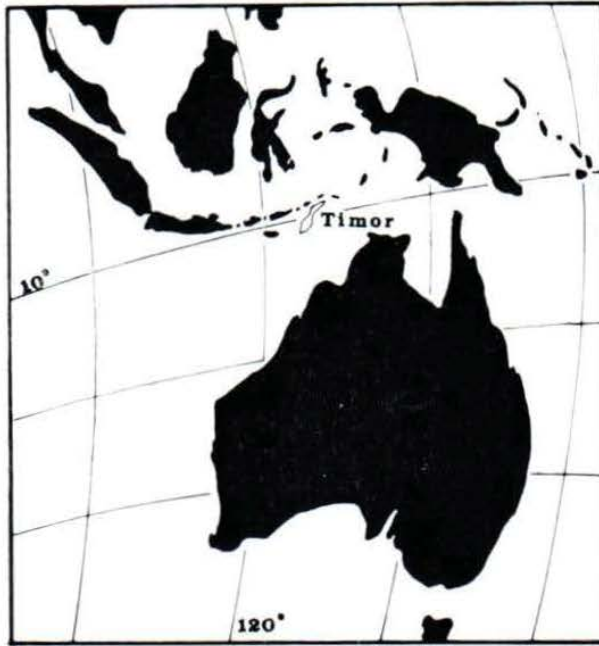
Research Scholar in Archaeology, Research School of Pacific Studies, Australian National University, Canberra

**I**N the course of archaeological fieldwork last year in Portuguese Timor I was able to record some details of the manufacture and distribution of pottery in the Vemasse district near the eastern end of the island.

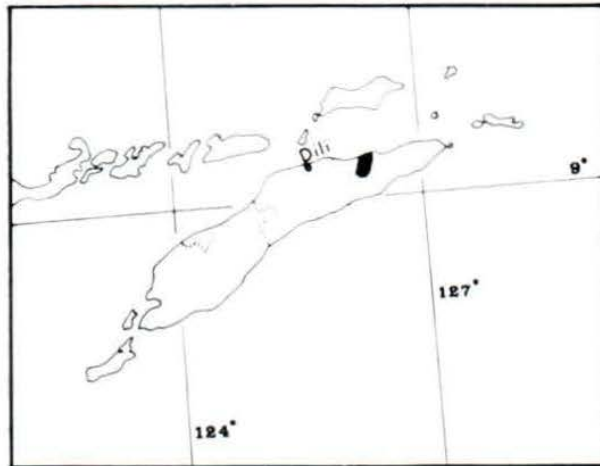
Pottery is one of the commonest artefacts found in archaeological sites in Timor and there is evidence for considerable continuity in vessel forms and manufacturing techniques from the first introduction of pottery some 4,000 to 5,000 years ago to the present day. It seemed reasonable, therefore, that a detailed study of the pottery industry in present-day Timor would prove useful in interpreting the excavated finds. And, although earthenware cooking and water

pots are still in common use in Timor, it is probable that they will be replaced in time by imported glass, enamel, aluminium, and plastic vessels. Indeed, this process is well under way now and there may not be many years left before this traditional craft disappears.

The time available meant that only the beginning of such a study could be made. The information recorded here was gathered during 4 days' observation in the village of Oralan at Vemasse, a small administrative post on the main north coast road 100 km (about 67 miles) east of Dili, the principal town of Portuguese Timor.



Above: The location of Timor. Below: Timor, with the Vemasse administrative district (east of Dili) shown in black.



### The social background

Vemasse is the headquarters of a *posto*, or administrative district, some 450 sq km in area, stretching from the coast to the foot of the main dividing range 25 km inland. It is not a rich district, even by the standards of Timor, and has a population of only 5,500, distributed among seven *sucos*, each under a chief or *Liurai*. The *sucos* are themselves divided into *provações*, of which there are usually between two and six in each *suco*. These are political and administrative units, not nuclear villages, which scarcely occur in Timor. The residential unit is the *cnua*, or house cluster, usually two to five houses owned by a man, or a pair of brothers,

and married sons. In the past they were built on isolated, steep ridges fortified with walls and fences and up to half an hour's walk from the next *cnua*. Scattered settlement is still the rule in Timor but there has been a tendency since the island was pacified 50 years ago for houses to be built round the administrative posts. The *provação* of Oralan is part of such a settlement.

Of the seven *sucos* in the *posto* only one, *Suco Vemasse*, makes pottery. And here, in the three *provações* nearest the sea, Oralan, Raha, and Lor, out of the four in the *suco*, most of the pottery for the 1,000 or so families in the district is made. Beto-lale, the fourth *provação*, further inland and speaking a different language from the other three, does not produce pottery.

Four languages are spoken within the district of Vemasse: Galoli, spoken in *Suco Vemasse* on the coast, and Cairui, Uai-Ma'a, and Midiqui. These three are predominantly inland languages and are spoken on the Baucau Plateau and around the central mountain ranges. Galoli is one of the eastern Indonesian group of languages and is closely related to Tetum, the principal language of Timor. The other three languages are possibly related to each other and are non-Indonesian in structure and vocabulary, as is commonly the case among the languages of the inland mountain regions of Timor.

The distribution of pottery in Timor is predominantly coastal and it appears to correspond to some extent with the areas of Indonesian languages. However, there are many exceptions: people speaking the two non-Indonesian languages in the eastern end of the island, Macassae and Fatu-lucu, make pottery on the coast and inland.

Throughout Timor, as far as I know, only women make pottery, and in the three *provações* of Vemasse only some 20 to 30 women practise the craft out of a total of 350 adult women. For these it is something of a full-time job and 200 to 300 pots are produced each week for the Sunday market. The potters generally work independently, they dig their own clay, make and fire their own pots, carry them to market and sell their own wares. Thus, for several hours a day, 3 to 4 days in the week, they are occupied with some aspect of pottery manufacture and trade.

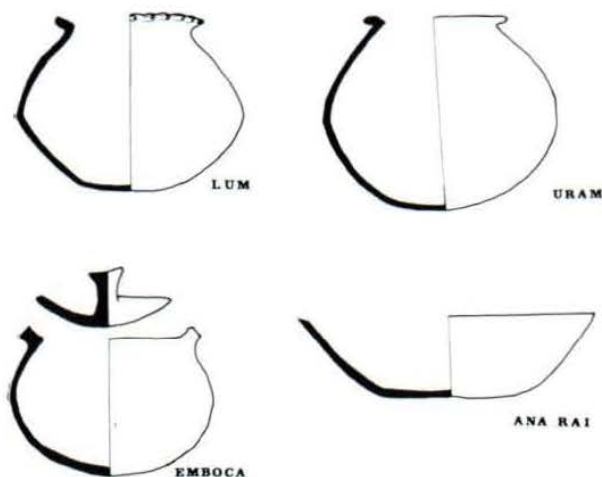
All the potters of Oralan, Raha, and Lor were born in, and married men from, the *provações* in which they now reside. This is unusual, for the majority of women marry out of the *provação*, and half of them out of the *suco* of their birth. Women of pottery-making families who do marry out give up the craft, and, though not unknown, it is rare for women to take it up after marriage into a pottery village.

Thus, pottery-making traditions have a continuity which comes from both locality and family inheritance. But to understand how this is maintained requires detailed anthropological study. For pottery is only one item in a complicated pattern of trade between different cultural and environmental regions which includes cattle and horses, rice, salt, fish, areca nut, tobacco, cloth, metal tools, and women in marriage. This exchange system today is only partly integrated into one using money and operating through the weekly markets held at the administrative posts.

#### Five kinds of pot

I was told that the following five different sorts of pot were made in Vemasse, each for a different purpose:

The *Lum*: a small pot about 20 cm (about 8 inches) in diameter, for fetching and storing water, roughly biconical in shape with a flat bottom, a narrow neck, and



Four of the five types of pottery made in Suco Vemasse. Few of the fifth type, *Bicam Rai*, or flat plate, are made, and it is probably an imitation of European and Chinese forms.

everted rim decorated with shallow thumb impressions on the outer edge. The exterior surface is burnished to reduce porosity.

The *Uram*: a cooking pot with a less pronounced shoulder than the *lum*. The neck and rim are similar, but the rim is less often decorated. The surface is not burnished. The size range is greater than the *lum* and is usually between 20 cm and 30 cm in diameter.

The *Emboca*: a cooking pot in the shape of a flattened sphere, unburnished, with a simple rim, two loop handles horizontally attached near the rim, and a lid rather like an inverted mushroom. These are only made, as far as I could discover, in Lor and Raha. The size range is similar to the *uram*.

The *Bicam rai*: a flat plate in various sizes between a saucer and a large dinner plate. I saw only a few examples of these, all made in Lor.

The *Ana rai*: a wide-mouthed basin with a flat bottom and steep sides ending in a simple rim. They are usually about 30 cm across and 10 cm deep. These are made by all potters, are burnished, and appear to be used solely for holding water and slip (semifluid clay) during the pottery-making process. They may have other uses, but I did not see them in houses other than those of potters.

Although I saw some overlapping of use between the *lum*, *uram*, and *emboca* (all three being used occasionally for boiling rice and corn), these are functional categories which seem to correspond well to what might be recognized as different formal types by an archaeologist.

*Lum* and *uram* form the majority of pots made in Vemasse, and at two markets the numbers of the different types offered for sale were roughly: *lum* 45, *uram* 30, *emboca* 7, *bicam rai* 3, *ana rai* 1.

#### Pottery manufacture

The following description is based on the observation of two women, Tomasia and Clara Freitas, in Oralan. The latter is an old woman who appeared to be the most skilful potter in the village, to judge from the symmetry and finish of her work.

I saw all stages in the manufacture of the two most common vessels, the *lum* and the *uram*. I think, but cannot be absolutely sure, that the sequence and timing of the processes were not altered by my presence, although some of the sessions had to be pre-arranged.

*Raw materials:* Clay is dug from three or four irregular pits, 2 to 3 metres across, dug in a line between the Vemasse River and the township. It is a sedimentary clay and is found some 50 cm below a layer of soil, sand, and gravel. The same few pits are used repeatedly from convenience but the clay is widespread and I found no indication that one or more women have exclusive rights to any particular clay pit. Clay is dug, sufficient for immediate use, with a steel-ended digging stick, and is collected in a palm-leaf basket.

*Preparation:* At the potter's house the clay is placed in a hollow log and broken up with a long hardwood pole. Stones and roots are removed at this stage.

Further refining is done in a flat, round, winnowing tray, where the coarse particles are separated with a tossing and rotary motion and scooped out by hand. The refined clay is stored in a deeper basket which holds enough for about ten medium-sized pots, the most that are made at one time.

A sand filler for the clay is gathered from the bed of the Vemasse River and the coarser grit is removed in the same way in the winnowing basket.

Clay and sand are measured out in coconut shells and mixed together in another basket. I was told that clay and sand were used in equal quantities, and one potter did in fact use two coconut shells of each to mix enough for two *lum*. But on another occasion the other woman used two measures of clay and three of sand and, after feeling its consistency, said that the mixture was right.

Clay and sand are mixed dry and poured on to an old pandanus sleeping mat, where the water is added slowly as the mixture is kneaded. The lump of wet clay is folded into a sausage shape, lifted, and flattened on one end. This process is repeated for 5 minutes or so; then the clay is divided into two or more pugs and each is shaped into truncated, inverted cones, about 15 cm

high by 10 cm across. Each pug is enough for one pot, and no more clay is added after the forming stage has started.

*Vessel forming:* The first part of the vessel to be shaped is the neck and rim—an unusual procedure for which I can find no precedent except in Timor itself.

The clay pug is held in the left hand and a hollow is beaten into the top with a wet coconut shell. The clay is wet thoroughly from a bowl of water by the potter's right hand, and then an everted rim is formed between the thumb and fingers of the right hand as the pug is rotated in a clockwise direction with the left hand. This is done carefully, as the symmetry of the finished vessel depends largely on the accuracy of the circular rim formed at this stage. A wet leaf is used to smooth the rim, which is then decorated on the outer edge with small indentations made with the thumb or index finger of the right hand (see photo, page 77).

With the rim made, the first stage in forming the pot is finished, and the clay is then placed in the hot sun to dry for between 30 minutes and 1 hour before the body can be started.

The body shape is first modelled by hand. Clay is pushed out from inside the neck with the right thumb as the pug is turned a few degrees at a time. The body is formed from the top down, and as the work progresses a column of clay is left in the centre of the pot which is gradually worked down and outwards to form the lower part of the body walls. The basic shape is now complete, although the body is rather baggy and the walls are thick and irregular. The pot is again put in the sun to dry for 10 to 30 minutes before the walls are thinned and consolidated with a paddle and anvil.

*Finishing with paddle and anvil:* The paddle is usually a light piece of wood made from the *nitas* tree (*Sterculia foetida* L.), about 25 cm long by 6 cm wide, thinned to form a handle at one end. The blade may have shallow grooves across its width, and some paddles are more heavily incised on one side than on the other. Paddles vary considerably in length and width but I could see no consistency in the use of different paddles for different stages in shaping and finishing the body. The anvil is a smooth river pebble between 1 and 2



Finishing the body of a pot with paddle and anvil. Here a paddle made of a buffalo rib bone is being used instead of the more common wooden paddle. The anvil is held in the other hand inside the pot to take the impact of the paddle.

pounds in weight, and again, although the potter has one or two spare anvil stones handy, there appears to be no regularity in the use of stones of different weights. Beating with the paddle is done in two stages, each lasting from 10 to 15 minutes, separated by 30 minutes or so while the pot is drying in the sun. The vessel is supported in a basket or *neru*, made from the *acadiro* palm (*Borassus flabellifer* L.), in the shape of a broad inverted cone which rests on the potter's lap. Unlike the baskets which are used to hold and winnow the clay and temper, the *neru* appears to be made especially for this purpose.

The walls are expanded by gentle taps on the outside of the body as the pot is rotated slowly on its side in the basket. The anvil is held in the left hand inside the pot to absorb the impact of the paddle. Both paddle and anvil are dipped in a bowl of water every 5 seconds in the early stages of paddling, less frequently towards the end. When the walls are of an even thickness the exterior surfaces are smoothed with a light stroking motion of the wet paddle and the neck is rounded off, using its edge.

The characteristic biconical shape of the *lum* is produced by gently tapping the walls while the pot is held by the neck. The anvil is not used to absorb the blows, and the walls are flattened into the required shape. The base is flattened simply by pressing the pot onto any handy piece of wood.

Shaping is now finished and the pot is given a light coat of slip of the same clay and put into the sun to dry.

Drying times seem to vary considerably, even in the same atmospheric conditions. One potter waited 3 to 4 days before firing, whereas the other fired her pots, on two occasions, less than 24 hours after the final shaping.

The two types of vessel which I saw manufactured, the *lum* and the *uram*, are finished differently. The *lum* is given a second coat of the same slip when it is leather-hard, and is polished with the seeds of two trees—first with a *kaleki*, a large flat leguminous seed, and then with the seed of the *nitas* tree. These are rubbed hard, with parallel strokes, across the exterior surface, the rim, and the top of the interior. This is to make the surface less porous. The *uram* is not given a second coat of slip, nor is it burnished.

*Firing:* The pots are fired within an hour of burnishing, and in two stages. They are first heated round a fire to remove excessive moisture in the clay which might turn to steam and split the walls. Only when the pots are thoroughly warmed is the proper firing started.

The fuel used on two occasions was cakes of dry buffalo dung, but I was told that dry sticks and palm leaves were also used. Temperatures were not measured but both fuels give short firings with temperatures of about 900° C. Dung is probably the better fuel because it retains its form while burning, allows a good circulation of air to provide an oxidizing atmosphere, and is less likely to collapse on the pots, leaving some dirty and unevenly baked.

After pre-heating for 15 to 20 minutes, pots are stacked, necks tilted down and facing inwards, on the glowing embers. Some pots may be touching and if more than ten are to be fired, they may be stacked in two layers. More fuel is placed evenly round and over the pots, forming a "beehive" mound 1 metre across by 70 cm high.



Sunday market in Vemassee. The smaller pots will sell for 1 escudo (3 cents) and the larger for 2 escudos, or the equivalent in produce.

When the last dung cakes are in position, the lower ones are well alight, and in 2 to 3 minutes the entire stack is burning well. No more fuel is added unless some falls off in the early stages of firing.

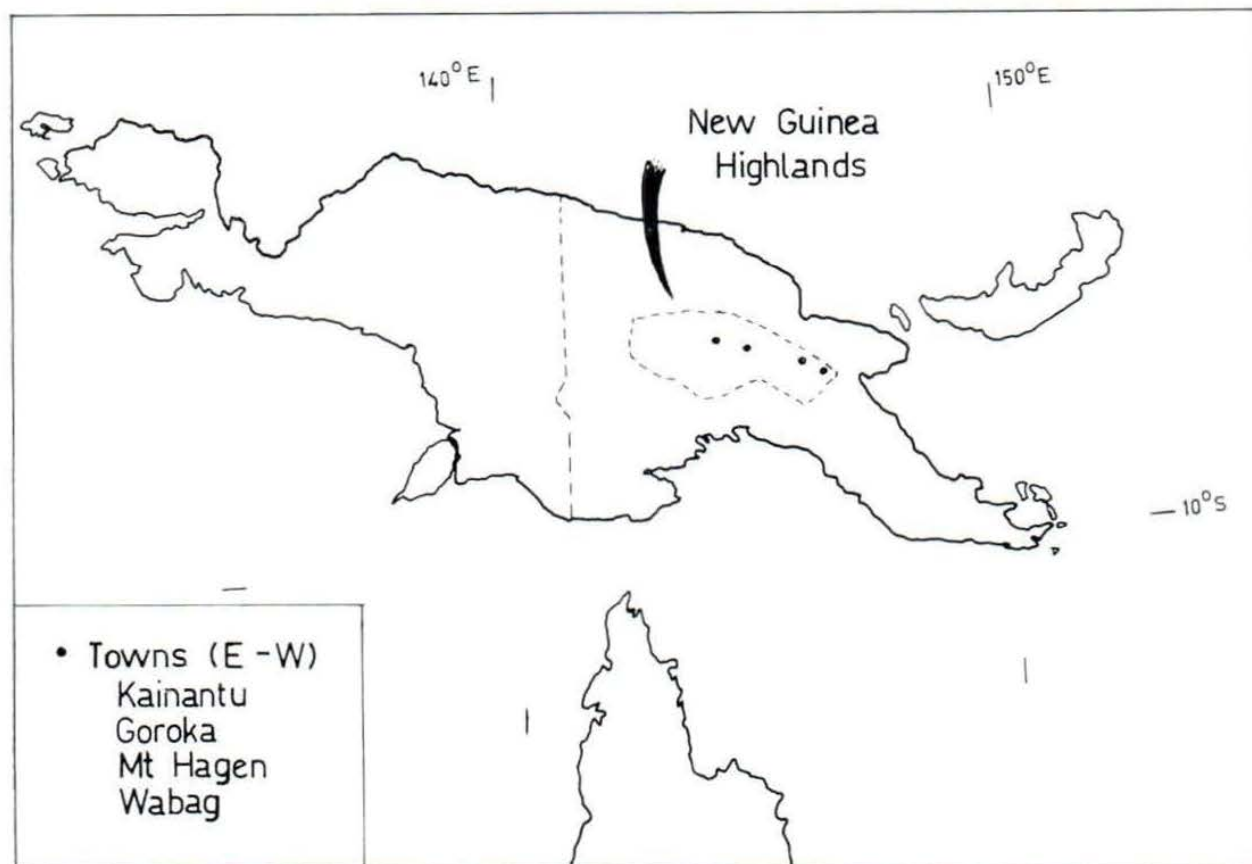
Between 10 to 15 minutes after the last fuel is added, firing is judged completed, and the dung, still flaming, is scattered and the pots are lifted out with a palm branch. They are placed on their sides for a few minutes and, when just cool enough to touch, they are washed in clean cold water. If this is not done while the pots are still quite hot it is said that they will break when first used. Most probably the aim is to reveal any flaws before they are sold.

After firing there is no further treatment to reduce porosity of the clay. And it is

noticeable that when they are first used the *uram* do leak, and need a few uses before carbon and fatty food deposits make them more or less waterproof. In the case of the *lum*, or water storage pot, a certain amount of evaporation from the outside walls can be an advantage, as it cools the remaining water.

Pottery fired on a Friday or Saturday is generally sold at the Sunday market near the administration post, where twenty or so women will sell between 200 and 300 pots each week. They are either sold for cash or exchanged for lime, fish, fruit, or tobacco, and find their way into most of the households in the *suco*.

[Photos, maps, and diagram in this article are by the author.]



New Guinea, showing the Highlands area of Australian New Guinea and its towns, from east to west.  
[Map by the author.]

# ***STUDIES OF PREHISTORY IN THE NEW GUINEA HIGHLANDS***

By J. PETER WHITE

Assistant Curator of Anthropology, Australian Museum

FOR an archaeologist there are two main reasons why working in New Guinea today is exciting. There is the whole problem of discovering the outlines of an unknown country's past, of seeing how man responded to the challenge of its environment and learned to exploit its natural resources. In New Guinea this will be especially important to the New Guineans, who lack any written history of their own. To know what they have been and done in the past, to know that they, too, have a history as long as that of the Europeans, will help them to create the national and cultural identity they are now beginning to look for.

The other reason is the chance of making new discoveries in the methodologically basic field of ethno-archaeology. The importance of this discipline has been increasingly recognized over the last few years as archaeologists realize that they must study present-day material culture in order to interpret their discoveries of past societies. In New Guinea, because stone tools and pottery were made there so recently by comparison with most of the rest of the world, a wide range of data of this sort can be collected. The important thing is to collect it before all New Guineans are using steel knives, enamel dishes, and so on, and have

forgotten the traditions of their forefathers.

### **Investigation methods**

The prehistory of the New Guinea Highlands has been investigated over the last four decades by both synchronic and diachronic disciplines. Synchronic disciplines such as linguistics, blood groups, art-form studies, geography, and ethnology draw their evidence only from the present time and make inferences about the past from the pattern which they find today. By contrast, diachronic disciplines, especially archaeology, palynology, and geology, can obtain dated evidence about past events from the records, such as tools, pollen grains, and rocks, that the events left behind them.

While both types of disciplines are, of course, necessary, the picture of the prehistory that emerges from the archaeological record is likely in some respects to be more accurate than that given by other disciplines. This arises because the questions that have been asked so far relate to the duration, nature, and extent of the occupation of the Highlands. Diachronic studies like prehistory can give accurately dated answers to these questions. In the case of synchronic studies answers are derived from distributional studies which may suggest how present forms came to exist, but these answers cannot be dated. For example, it has been argued that the much larger area of grasslands in the Eastern Highlands compared to the Western reflects a proportionately greater use of the former area by the agriculturalists whose activities caused these grasslands to occur. Since this area today is not heavily populated and on the assumption that the rate of conversion from forest to grassland is uniform, it has been suggested that agriculturalists entered the Highlands from the east and moved west. This would allow them more time in the Eastern Highlands, and thus the difference in the amount of grassland would be explained.

This argument, and others like it, can be challenged from two directions. In the first place, conflicting evidence may be sought. Thus, in the argument over grasslands a number of questions relating to the whole environment may be raised. We suspect, for instance, that in the Eastern Highlands continued human use of the land for gardens,

combined with frequent burning-off, has brought about changes in the nutritive content of the soil. This may have upset an already delicate balance to the point where forest will not regenerate and only grass and scrub will grow. The Western Highlands soils and climate may be considerably more favourable to forest growth and thus, in spite of comparable human activity, the forest continues to regenerate there. It is problems like these, many of which are very difficult to answer, that render synchronic evidence awkward to use as a guide to past history and the conclusions which arise from it often open to challenge.

The other test of the validity of this evidence comes from studies which can collect evidence directly about the past. The study of pollen grains of plants preserved from time to time in swamps will show us, for example, how the vegetation of the area has changed in the past. Since each layer of pollen has been deposited at a certain time it reflects, to some extent, the amount and type of pollen which was being produced in that area at that time. A number of different pollen diagrams which consistently show the same vegetation patterns from a particular period provide a good basis for generalizing about prehistoric environments.

### **Archaeological remains**

Archaeological remains are, however, the primary kind of diachronic evidence for the study of prehistory. Continued occupation of a site, whether a cave or a village, over a period of time leads to the building-up of refuse of various kinds. The scientific excavation of this can show the technology of the occupants and the way it changed over time, and also provides the basis for the study of their economy and in some cases some aspects of their social structure. The date at which changes occurred can be measured by counting the amount of radioactive carbon 14 preserved in charcoal or bones. As with other disciplines, it is necessary to obtain a large sample of information in order to ensure that the final picture is accurate—the evidence from only a few sites is normally insufficient.

In the New Guinea Highlands excavations have been made in both Eastern and Western Highlands, between Kainantu and Wabag.





Excavations at Kafiavana rock-shelter, Asaro Valley, Eastern Highlands. The lowest level of the deposit, 1.5 metres below the lowest point shown here, is dated to about 8,500 B.C. and yielded flaked stone tools, polished axes, and food bones. A little above this a few marine shells were found, while higher up pig bones were included among the food remains. The scale shown is in 20-centimetre sections. [Photo by courtesy of the Australian National University, Canberra.]

Since work started in 1960 only a few sites have been excavated, and most of these have been caves and rock shelters where the deposit has been preserved from the weather. However, two open sites have also been dug. We know already that men have been in the Highlands for at least 11,000 years. We suspect that, at that time, the climate may have been rather cooler than it is today and that men therefore tended to live in the valleys within the Highlands system, such as those around Goroka and Mt Hagen. They were probably hunters and gatherers and made a variety of stone tools. While most of their tools were flaked out of stone, they also ground stone axes into shape: the presence of this technique at such an early date is one of the unexpected discoveries in the Highlands. Previously, axes of this kind had been dated to no more than 5,000 years old. To find them in deposits dated to 11,000 years ago marked them among the oldest ground axes in the world. Was the technique of grinding perhaps invented independently somewhere in the Australasian area? At present we do not know. Those

early Highlanders also traded with the coast for valuable sea-shells, which they probably used for decoration, just as Highlanders do today.

Slight differences between the Eastern and Western Highlands seem to have been present from a very early stage. Heavy pebble tools, which may have been used for chopping, are not found east of the Chuave area, while it may be the case that ground axes were made rather earlier in the east than in the west.

The first remains of pigs occur about 5,000 or 6,000 years ago. These animals are not native to New Guinea and we must assume that they were introduced by man: but whether the pigs found in the Highlands sites were being kept as domestic animals by Highlanders we do not know. It is interesting that dogs do not appear in our sites either at this time or until very much later. Whether they were actually absent, and Highlanders lived without dogs until very recently, or whether this is simply a statistical error arising from the small numbers of sites excavated so far, we have no way of telling. Only further excavations will reveal the answer.

#### **First evidence of agriculture**

Some time after this we have the first evidence of agriculture. Recently, near Mt Hagen, a series of old ditches were discovered in what is now an uninhabited peat swamp. In the ditches were found wooden digging sticks, a paddle-shaped wooden spade and many stone axes. These tools and the ditches are very similar to those used in recent times in highly complex agricultural systems. It has therefore been inferred that the excavated artefacts record a similar sort of agriculture. This has been dated to some 2,500 years ago. We may expect to find earlier agriculture than this, for it is unlikely that the first excavations of this sort have uncovered the oldest site: we may also expect to find rather simpler forms of agriculture somewhat earlier.

Although nearly all Highlanders today live mostly on sweet potato this does not seem to have been the case for longer than about 300 years. All our evidence suggests that this crop was introduced to Melanesia and Micronesia by the Spaniards and that it was unknown before then. What, then, were

An Eastern Highlands man using a small stone knife to cut barbs on a wooden arrowhead at Legaiyu village, Asaro Valley. [Photo by courtesy of the Australian National University, Canberra.]



earlier Highlanders growing? The most likely crop is taro, which can be cultivated by similar methods to sweet potato and which is well-known throughout southeast Asia. But we will not know this for certain until further pollen and plant studies are made and these are combined with further archaeological excavations.

It will be noticed that in the discussion about agriculture the occurrence of similar ditch systems nowadays was used as the basis for inferring that the old ditches were in fact agricultural. This sort of argument by analogy is the most common method of interpreting archaeological remains. It is by this means that an axe, spade, or knife is so called: if today we had no axes, we would not know what a prehistoric axe was used for, although sometimes we might be able to deduce this from the traces of wear on it.

It is because archaeology uses analogy so widely that some research in the New Guinea Highlands assumes special importance. The Highlands are the largest area of the world where people still remember what it was like to live in the stone age. Even today a very few people still have never used steel tools, but the majority can at least remember what it was like before these tools were available. They can, if asked, recreate their traditional technology. The importance of this is that we can study not only what different types of tools were made and how they were used, but also the number that were used for different tasks, the types of wear that result from different sorts of use, and so on. We know

very little about these sorts of things for in the past almost no quantitative studies have been made by archaeologists or ethnographers. Some of these problems could be answered by experimental work in the laboratory, but this suffers from the difficulty that just because things *can* be done in a certain way it does not mean that they *were* done in that way. If we can observe people at work who were brought up in a society where stone tools were the only ones available then there is a greater chance that they will do things in the way their ancestors did. And that, after all, is what prehistory is about.

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#### MUSEUM FILMS

Two short colour-sound films, "Carnarvon" and "Rock Engravings", have recently been produced by the Australian Museum. "Carnarvon" shows Aboriginal cave paintings and rock engravings in the Carnarvon Ranges of Queensland. "Rock Engravings" deals with Aboriginal rock engravings in western New South Wales. The films are based on field research carried out by Mr F. D. McCarthy, Principal of the Australian Institute of Aboriginal Studies, Canberra, when he was Curator of Anthropology at the Australian Museum. They are for general adult audiences and secondary school pupils and are available for purchase.

# *Bushfires and Their Effect on Fauna and Flora*

By H. J. de S. DISNEY  
Curator of Birds, Australian Museum

THE Englishman William Dampier recorded seeing bushfires in 1699, and Governor Phillip observed in his travels that nearly all the bush appeared to have suffered from fire. Many of the early travellers also referred to bushfires which had apparently been started by the Aborigines. It is now known that the Aborigines set fire to the bush to produce new grass with the rains, and to allow them free movement through the forest when hunting. In certain areas they perhaps practised a primitive form of rotational burning on approximately a 5-year cycle.

Although the Aborigines have always practised burning-off the bush, which is a common practice among hunting people, particularly in Africa, it is certain that there have always been frequent wild fires, as the vegetation has adapted itself to fire. For some species fire may be necessary before the seeds will readily open and germinate. Other species, like many eucalypts, which appear burnt and dead, regenerate by sending out epicormic shoots or, if low mallee type species, from lignotubers. The method of regenerating may vary with the species; some low-growing *Banksia* regenerate from the bottom, but others, like *Banksia ericifolia*, are completely killed except for their seeds. Although Mulga (*Acacia aneura*) is destroyed by fire and regenerates from seed, in Africa most of the *Acacia* are fire-resistant, particularly in the tropics, and even when attacked with diezoline flamethrowers only die on the side on which the actual hot flame is concentrated. Not only are trees and shrubs resistant to fire in Australia, but also sedges such as *Gahnia*.

There is evidence that the Aborigines tried to choose a time to set fire to the bush—a time when conditions were suitable for a low-intensity or cool fire, with flames only 2 to 3 feet high, that only removed the ground herbage and fallen trees or branches, which are designated by foresters as fuel for future bushfires. Even if the fire did become a hot

fire there was so much bush available that some would still remain as a reservoir to restock the burnt areas. With the arrival of Europeans, the forests were cut down for timber and much fuel was left, so that when a fire started it became a tremendous conflagration and travelled very fast.

As settlement and the population increased, so did these hot fires, often as crown fires, which burnt through the tops of the trees, throwing spot fires for several miles ahead and rapidly jumping barriers like roads and rivers. The most frequent cause of these fires, and it remains so, was burning-off for new pasture and the fires getting out of control. Many of these fires were not finally controlled until they reached the sea.

During the past few years much research has been carried out on the control and behaviour of fires. Bushfire brigades now have bulldozers, four wheel-drive vehicles, and radio contact to help them fight fires. Fire access roads have been made in many places and have allowed firefighters to reach outbreak areas quickly. Many nature-lovers and conservationists may object to these roads as they also give easy access to those shooters who will shoot anything anywhere, but their value has been proved and other methods will have to be used to stop these people. Conservation is unlikely to become really effective until all guns have to be licensed. In one area of the south coast of New South Wales during the very bad season 1964-65, 57,000 acres were burnt, but in the same area with no access roads in 1951-52, 656,000 acres were lost.

Foresters have for years tried to prevent fire in the forests under their control, but have rarely succeeded, and when a fire did come the fuel available was so great that a very hot fire resulted and more total damage was caused than if smaller cooler fires had occurred more frequently, keeping the fuel down. Foresters are now carrying out low-intensity burns in the cool and moister times of the year to prevent fuel build-up. Large

Right: Two months after the Chatsbury-Bungonia fire *Banksia ericifolia* was completely dead, but grass and herbs were starting to grow underneath. Below: A year after the fire the ground underneath the same dead *Banksia* was covered with grass.



acres are annually subjected to prescribed or controlled burning by both foresters and other authorities responsible for keeping the fire hazards down. Tables have been constructed for calculating the amount of fuel present and for determining safe conditions for a cool burn.

The full effect of prescribed burning is not yet known; it may in time actually reduce the fertility of the soil more than if there were only occasional burns. Continuous or frequent burning may result in a uniform herbage coverage, such as bracken, which may please the eye of the forester, but not that of the botanist. In coastal heath country the woody species like *Banksia* and *Leptospermum* begin to disappear and open areas with grasses and sedges become dominant. When the whole environ-

ment is considered, the full effects of fire are not known, nor are the needs of the environment to keep it approximately stable. In the early days this did not matter as there were plenty of unburnt areas from which to restock, but now there is very little bushland left, and most of this is now retained as reserves which are isolated from each other by large areas of cultivated land unsuitable for most of the mammals and birds to live in. This means great care must be exercised in managing these reserves and much research is required into the habits of both the flora and fauna.

Information can fairly easily be obtained on the plants and how they recover, but little is known about the habits of the mammals, birds, insects, and other animals in the bush before and even less after fire.



Above: Four months after the Chatsbury-Bungonia fire eucalypts were showing well-developed epicormic shoots. Below: One year after the same fire, but in a different area, eucalypts were looking green again and the ground was covered with herbs.



After the Chatsbury-Bungonia fire in New South Wales in March, 1965, a Spiny Ant-eater (*Trachyglossus aculeatus*) was found next day walking along the roadside in one of the worst burnt areas. A Ring-tailed Possum (*Pseudocheirus peregrinus*) was found in similar circumstances. Regular banding of birds had been carried out in one part of the area before the fire, and this was visited 7 days after the fire. Birds which had been banded before the fire were retrapped in the burnt area, and Rock Warblers (*Origma solitaria*) were seen feeding on the ground in burnt areas. Two months later epicormic shoots were well established on the eucalypts, with insects feeding on the new growth. Birds banded before the fire were again captured. Six months later the Lyrebird (*Menura superba*) had returned to a gully below and banded birds were again caught. A year after the fire it was difficult to realize, unless the regenerating habit of the bush was known, that a fire had been through the area only 12 months before. The whole area again looked green except for those plants actually killed by the fire. The main effect of the fire appeared to be the destruction of nesting sites and nectar flowers, but a few birds remained in the area or continued to pass through on passage. Elsewhere it has also been found that Lyrebirds soon return to their usual territories after fire, and in Western Australia the Noisy Scrub-bird (*Atrichornis clamosus*) was again soon found in its usual locality after the area had been burnt. In some cases the appearance of fresh green grass after fire appears to attract kangaroos, but they may have been there before and merely become more visible.

It is thus considered that, provided there are still some unburnt reservoirs, fires do not seriously affect bird populations, except perhaps if they occur when the birds are nesting and feeding young. The larger mammals probably move ahead of a fire or get round it. The smaller animals perhaps escape underground, although there are reports from bushfire fighters that they have seen small animals at night dash back into the flames. Low-intensity fires, which do not occur too frequently, probably do good. It is back fires and crown fires, which spot ahead and burn back, that are probably the most dangerous to all fauna.

[Photos in this article are by the author.]

# BOOKS ON SUBANTARCTIC AND BARRIER REEF REVIEWED

**THE AUSTRALIAN GREAT BARRIER REEF IN COLOUR**, by Keith Gillett. A. H. and A. W. Reed Pty Ltd, Sydney, 1968; 112 pages, 50 colour plates, 16 black and white plates, 6 line drawings. Price, \$3.50.

Keith Gillett has had a lifelong love of the Great Barrier Reef, and, in addition, is a colour photographer of high calibre. In *The Australian Great Barrier Reef in Colour* this combination has given us a rich sample of reef beauty, with photographs, for example, of the green and blue shaded patterns of the reefs as seen from the air; the feathery delicacy of plant-like hydroids; glossy, rich-patterned shells; the bizarre colouring of reef fishes, and much else. The sixty-six colour plates are, with few exceptions, of high quality.

Although the colour photographs are clearly chosen for their beauty, and fill half the book, the text is surprisingly informative, and is accurate and up-to-date. I noticed with some interest that recent knowledge on the role that the single-celled plants (zooxanthellae) in coral polyps play in calcium deposition is included, as well as a fair description of possible reasons for the formation of various types of coral reef.

This book does not purport to be a full text for a visitor to the reef, and for a deeper insight *The Great Barrier Reef and Adjacent Isles*, by Keith Gillett and Frank McNeill, is still the best guide. As an introduction to the reefs, and at half the cost, *The Australian Great Barrier Reef in Colour* is nevertheless good value and the quality of production is high. It should delight as well as inform.

Keith Gillett says of this book: "All that can be attempted here is to reveal a little of the Reef's secrets and beauty. If this fraction stimulates in the reader a full awareness of a natural legacy that should be nationally cherished the author will have fulfilled his purpose". It is to be hoped that this fine little book as well as the sentiments expressed by the author will act as a timely reminder that we hold one of the world's great natural wonders in trust for future generations.—*F. H. Talbot.*

**SUB-ANTARCTIC SANCTUARY: SUMMERTIME ON MACQUARIE ISLAND**, by Mary Gillham. A. H. and A. W. Reed, Wellington, 1967. Pp. 1-223, 32 photographs, 46 line drawings. Price, \$5.95.

This is an account by a distinguished British botanist and ecologist of a visit to desolate and windswept Macquarie Island, some 1,400 miles south of Melbourne and one of the most remarkable wildlife sanctuaries in the world. The author was one of a party of four women scientists who visited the Australian National Antarctic Research Expedition Station at Macquarie in December,

1960, on the relief ship *Thala Dan*. These scientists stayed ashore during the annual change-over period of about a week, and were the first women scientists ever to visit Macquarie Island.

Dr Gillham describes how the narrow, 21-mile-long island, despoiled by sealers in the nineteenth century, was declared a sanctuary by the Tasmanian Government in 1933 and, since 1947, has become one of the most important centres for scientific research in subantarctic biology, especially in the fields of seal and sea-bird life-history and population dynamics. She brings to life in her very easy, readable and descriptive style, and illustrates in her own delightful and numerous sketches, the routine of subantarctic station life and aspects of island ecology and natural history such as skua aggressiveness and scavenging; the estimated 110,000 elephant seals, with beachmasters ranging up to 5 tons in weight and 20 feet in length (nearly half a million tons of sea-elephants!); plant communities of seal wallow areas, subglacial herbfields and tundra; the "feather bed" and other peat bog types; tussocks and native buttercups; the anti-scorbutic Macquarie Island "cabbage"; the two-year nesting cycle of the wandering albatross; the breeding of mollymawks and giant petrels; the introduced New Zealand ground rails or wekas and their egg-stealing habits; blue-eyed cormorant colonies and burrowing petrels; the richness of breeding penguins—crowded "slums" of kings and endemic royals, "garden suburbs" of gentoos and rockhoppers; the endemic grass, *Poa hamiltoni*, restricted to enriched penguin soils while the widespread, genetically isolated *P. foliosa* grows in other habitats; the slow but destructive spread of introduced rabbits (at a rate of 14 miles in 20 years) at the expense of tussock and herbfield, and the complexities of feral cat predation on rabbits and rats on one hand and ground-nesting birds on the other.

There is a final section containing a most useful check-list of the forty-six birds and five seals recorded from Macquarie (divided into breeders and casual visitors), a list of the thirty-eight vascular plants, forty-two mosses and four liverworts known from Macquarie, and last, but by no means least, a bibliography of ninety-four references to the natural history of the island. The latter will be of very real interest to the serious worker, but runs the risk of being overlooked as an appendix to a book intended for the general reader. The only errors and omissions seen in the whole book—and very minor they are, too—are all in this last check-list section. Why "Dominica gull" when "Dominican" is used everywhere else in the book? Why "*novae-zealandiae*" and "*novae-hollandiae*" still, when the Rules of Zoological Nomenclature have specified, for the last 7 years, that specific names should be written as one word? What printer's gremlin has managed to put "sp." (an abbreviation for "species" when the specific name is unknown) in italics as

if it was an actual specific name? Finally, why is the Kerguelen fur seal not listed as a casual visitor to the island when it has apparently been recorded on Macquarie (see Csordas, 1962, in the book's bibliography)?

This is altogether a most interesting and welcome book on the wildlife of Australia's subantarctic dependency, but it is rather a pity that the fine colour photograph on the dust jacket (king penguins, elephant seal, and giant kelp) does not appear in the book itself, where it would have added another dimension to the black and white photographic coverage.—*J. C. Yaldwyn.*

**NATURE WALKABOUT**, by Vincent Serventy, 1967; 137 pages, 22 pages of colour plates; A. H. and A. W. Reed, Sydney, Wellington, and Auckland. \$4.50.

Vincent Serventy is well-known throughout Australia for his writing and television appearances. A former Western Australian schoolteacher, he now lives in Sydney and devotes his life to natural history and conservation. This book tells the story of his move from Perth to Sydney and (in what I suspect might be the typical Serventy manner!) he chose not to follow the usual route. With his wife and two children, he set off in a

4-wheel-drive Nissan "Patrol", towing a large caravan, and headed north into those parts of Australia where most naturalists yearn to go, but never do go. The account which is given of his journey is delightfully readable. It is packed with information about the natural history of the country through which he passed and the personalities he met, and contains vivid descriptions of the places visited. Throughout, the message is "conservation before it is too late". Serventy's observations reveal the extent to which the Australian fauna and flora have been affected by man's spreading dominance over the face of the land, and he expresses the deep concern which many Australians now feel over the indifference we have shown towards our natural heritage.

This book is more than a plea for conservation, however. It is the story of a happy family group to whom natural history is almost the only thing that matters, and whose experiences and observations during their journey Vin Serventy now shares with his readers. The book is superbly illustrated with photographs by the author which add to the charm of the narrative.

This is a book which should be in the library of every nature-lover and, indeed, of every Australian.—*D. F. McMichael.*

## *Gallery of Melanesian Art Opened*



Part of the Australian Museum's Gallery of Melanesian Art, which was opened by His Excellency, the Governor of New South Wales, Sir Roden Cutler, on 10th July. A handbook on the exhibits, *Melanesian Art in the Australian Museum*, is obtainable at the Museum. [Photo: C. V. Turner.]

# THE COMPUTER AND THE TROPICAL RAINFOREST

By W. T. WILLIAMS, CSIRO Division of Computing Research, Canberra, A.C.T., and L. J. WEBB, Rainforest Ecology Section, CSIRO Division of Plant Industry, Brisbane, Queensland

THE tropical rainforest is perhaps the least understood of all the natural environments on earth. It is the most complex of plant communities, "forest piled on forest" as Humboldt said, and crammed with a great variety of life-forms, plant and animal. The first English book on tropical rainforest, by P. W. Richards, appeared only 16 years ago; before that we relied on German accounts nearly 70 years old. The richness and variety of the flora and fauna of these forests have never failed to excite the professional biologist, but in recent years the need for their study has taken on a new urgency. It is not only that, in a world whose virgin vegetation is fast disappearing, we need to conserve those habitats which, if destroyed, will take with them for ever those plants and animals which can survive nowhere else; nor is it only our need to study the many as yet undescribed plants of the forests, in case these should be sources of new and powerful drugs. The new urgency arises from the fact that the equatorial belt, where these forests reach their highest expression, is the home of most of the underprivileged, "developing" peoples of the world, for whom the gulf between food production and population is increasing all too rapidly. In this region, agricultural methods are generally primitive, and it has been estimated that the problem of "shifting cultivation" and its replacement by more permanent and productive forms of land use affects over 200 million people occupying 14 million square miles in the wet tropics.

But clearing the rainforest is by no means always successful. Such complex systems have a stability that is lacking in the simple ecosystems of agriculture, and all too often the result is a decrease in soil fertility, a fall in productivity, even a complete loss of soil by erosion. Our immediate problem is therefore one of scientific land use. We need to find a means of predicting the effect of clearing a given forest area; more generally, we need to find criteria which will



Complex wet tropical rainforest, north Queensland. Note the plank buttresses of the large tree, *Argyrodendron peralata*, the prominent aroid epiphytes on the trunks of adjacent trees, and the dense understorey, which includes palms and other special life-forms. [Photo: Queensland Forestry Department.]

enable us to decide, for any area of forest, whether it should be cleared for agriculture, replaced by conifer forest, logged for timber, or conserved in its natural state. To do this we must be able to define specific forest types, types to which we can give names, and which can be described in such a way that they can be easily recognized. The rainforests, in fact, must be *classified*; and classification is undoubtedly the single most important problem which today





Simple temperate rainforest, Tasmania. Note the structural differences from the forest in the photo on the opposite page. The tree layer is composed essentially of one species, *Nothofagus cunninghamii*, which may be branched low down and which, unlike most tropical species, has small simple toothed leaves. Ferns characteristically dominate the ground layer, and mossy epiphytes may be conspicuous. [Photo: University of Tasmania.]

confronts everybody who works in these forests.

In temperate regions classification of forests has been by floristic composition, that is by the tree species (and sometimes the ground flora) that they contain; but any attempt to apply the same system to tropical rainforests has always in the past been blocked by the sheer scale of the problem. In only 18 forest sites in northern Queensland we collected no less than 818 different plant species, and this is too many for the human brain to handle intuitively. It is at this point that we can invoke the aid of the computer. The Control Data 3600 computer at Canberra is furnished with a battery of programmes for numerical classification, and it took the computer only 13 minutes to suggest that

these 18 sites were best regarded as six groups, each of three sites. The divisions between the groups reflected, firstly, climate—whether the sites were in humid or monsoonal climates—and, secondarily, details of moisture regime, of soil mineral availability, and of altitude. There was no doubt that floristic classification of tropical rainforests was possible.

But this is not the whole problem. The complete data, for every vascular plant over 18 inches high, including the accessible lianes and epiphytes, required a year's field survey, plus more than a year's work by Mr J. G. Tracey in herbarium identification. The next question is, therefore, "Is it possible to reproduce this classification using only a proportion of these species and, if so, which?" This, too, is a relatively simple problem in numerical classification, and the answer was unequivocal: of these 818 species, 269 were canopy trees or capable of becoming so, and if these alone were used the classification was unchanged. Evidently the big trees exposed in the forest canopy most faithfully reflect the differences in external environment; species in subsidiary layers and the special life-forms—except perhaps lianes and epiphytes in the tree crowns—are mainly conditioned by the internal environment of the forest.

Yet 269 species are still too many, and further calculation showed that the entire system could be analysed using only 65 tree-species, in most cases the commonest ones. This suggests a startlingly simple way of collecting floristic data for purposes of classification: to go to an area and "spot-list" the larger and commoner trees, because they carry most if not all the information about general site conditions. Admittedly, foresters have been doing just this for years and we have all criticized them for doing so, taking the attitude that so superficial and empirical a means of sampling could not but be utterly inadequate. However, those whose training most predisposes them to feel superior to the forester are just those most apt to regard a computer's findings with reverence. It is important to demonstrate that methods based on years of practical experience often have a more fundamental basis than some care to realize.

We therefore selected a further 70 sites, ranging from Cape York to Bellangry State

Forest (near Port Macquarie, New South Wales); the canopy trees were spot-listed and yielded in all 513 species. Again the computer's classification was informative, and demonstrated the validity of the method. But two further difficulties now became apparent. First, it is obvious that the project involved the presence of people—in our case, Mr J. G. Tracey and Mr B. P. M. Hyland—who could name the forest species virtually on sight, and in many parts of the world no such person exists. The second difficulty was more subtle, but more serious. With so wide a geographical range—some 20 degrees of latitude—large changes in flora will inevitably occur, for many reasons, and as a result the main classificatory divisions tended to reflect only geographical regions. This was information we already possessed, and was not particularly helpful. We needed to use characters that

reflected the *type* of environment that was determining the forest, rather than where precisely it was.

Now, everybody is aware that the mountain grasslands of Mount Kosiusco look very like those of the mountains of Scotland, and that neither could be mistaken for a forest; in other words, similar climates in different parts of the world carve out similar "structural blocks" of vegetation, irrespective of floristic differences. These blocks are defined, not by species, but by morphological, "structural", or "physiognomic" characters of plants. Much work has been done in classifying the vegetation of the world along these lines, on a very broad scale; the next question was, therefore, "Can this system be used for the more complex and specialized problem of rainforest classification?". One of us (L. J. Webb) had, in fact, already attempted this on a small scale, and the



Low tropical monsoon forest, north Queensland. Note the deciduous emergents; deciduous species are also common in the canopy. The understory is dense, with many thorny species which have shrub-type branching. The ground layer is sparsely developed. [Photo: L. J. Webb.]



Tropical mixed palm forest, north Queensland. The tree palm is *Licuala muelleri*, and the broad-leaved species in the canopy are characteristically evergreen. The strangling fig, a typical tropical life-form, is seen on the tree on the right. Lawyer Vines (*Calamus* species) and pandans are also common. [Photo: L. J. Webb.]

resulting classification proved valuable; but there was a suspicion that its successful application might, like identification of species, rest on years of experience, and might not be practicable for workers new to the forests. It was even possible that floristic bias, or deductions from observed environmental factors, might be used unconsciously by experienced workers, so an objective test was essential. We therefore listed (with some computational assistance in the selection) what we believed to be the twenty-four most useful structural features of the eastern Australian rainforests, and incorporated these into a pro forma. At the same time as we prepared the spot-lists for the seventy sites, independent observers (from the Australian National University, the University of Queensland, and the Forestry Departments of Queensland and New South Wales) completed one of these pro formas for each site, most observations

being ranked on a three-point scale.

These data in their turn were submitted to the computer for classification. This time the classification tended, as we had hoped, to reflect combinations of major environmental factors irrespective of location. For example, cool and uniformly moist upland habitats, whether subtropical-submontane at Bellangry or marginal submontane in the tropics on the Atherton Tableland, bore forests characterized by small leaf-sizes, an even canopy, common tree-ferns, and slender wiry lianes, and the complete absence of plank buttresses, strangler figs, robust lianes, thorny shrubs, deciduous plants, zingibers, or aroids. The classification showed, too, that the same type of forest could be generated by different combinations of factors; for example, features normally characteristic of a tropical climate will extend to a higher altitude or latitude on high-fertility soils such as basaltic red loams. We have no

doubt that our questionnaire can be improved, but the project has at least shown that the rainforests can be classified by reference to features that do not require years of training to recognize.

But in ecology every success brings a new problem in its train. The computer analyses showed very clearly something we had long suspected: that structural characters vary more or less continuously, so that they define forest trends rather than sharply-defined forest types. Alone, therefore, they will not permit us to allocate a forest to one of a list of definite types whose properties and potentialities are known. It might be that a combination of structural and floristic characters (i.e., the presence or absence of a limited number of important trees) would be better than either alone; this, too, accords well with past forestry practice and we have the problem under investigation at the present time.

Moreover, the fact that rainforest vegetation is in some sense continuous may itself be put to good use; for, even if only floristic data are used, it is then possible to *ordinate* forests instead of classifying them—that is to say, to regard them as having been generated in response to a small number of underlying trends. This opens up some exciting possibilities; for if we can interpret these trends, and analyse a vegetation system before and after clearing, we may be able to define those features of the forest, or factors of the environment, which will determine the fate and value of the land after it has been cleared. We are currently investigating the practicability of this approach in a number of paired (intact and cleared) forest sites in the Moreton district in southeastern

Queensland, and the preliminary results are promising.

The way now seems clear to a deeper and more extensive understanding of the rain forests than has been possible before; but it is the computer that has opened up the road. Without a powerful computer and the necessary programme we could not have classified the original 18 sites with 818 species; nor the 70 sites with 513 species; nor the data from the structural questionnaires. We might, it is true, have undertaken the Moreton ordinations by hand, but the computation would have taken many months instead of a few minutes. Nevertheless, the opportunities for carrying out this type of work are desperately limited. Success in this field can only be attained given five requisites: there must be rainforests of wide variety and easy access for study; there must be ecologists with sufficient experience of rainforests to define the problems and to assess the ecological significance of the numerical results when these appear; there must be numerical workers with sufficient understanding of both ecology and numerical analysis to advise on the computer programme to be used or, if necessary, written; there must be a battery of programmes for the classification and ordination of large-scale data of a variety of types; and there must be a computer large and fast enough to carry out the necessary computation in an economically reasonable time. At this point in history we believe that the only place in the world where all five requirements coexist is eastern Australia. We must not waste this unique opportunity; the mature tropical rainforest is one of the world's most rapidly shrinking assets, and time is not on our side.

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