CHAPTER 2

THE MARKHAM VALLEY

The Markham trough forms the eastern extension of one of the major physiographic and tectonic lineaments of Papua New Guinea. The depression follows a fault zone running approximately 300 km along the lower Ramu and Markham valleys, and extends eastward as a submarine canyon to join the 6 000 m deep New Britain trench (von der Borch, 1972).

The Markham Valley (Fig. 2.1) is bounded to the north by the Finisterre and Saruwaged Ranges that rise steeply to an altitude of over 4 000 m. To the south are the Kratke Ranges and Herzog Mountains, northern extensions of the Owen Stanley Ranges that form the backbone of the country. About 3 km wide at the Ramu divide, 360 m above sea level, the Markham Valley reaches a maximum width of 22 km at the confluence of the Leron River. The Markham River and its tributaries drain a catchment of about 12 000 km^2 (Löffler, 1977). Leaving the northern mountains at an altitude of *c.* 450 m, the river follows a relatively steep plain course along the southern margin of the valley. The anastomosing channel discharges into the Huon Gulf at Lae, 140 km to the south-east.

GEOLOGY AND GEOMORPHOLOGY

The main features of the geology of the Markham Valley and its environs are shown in Fig. 2.2. This map and the following account are based largely on the work of Tingey and Grainger (1976), Robinson (1974), Robinson *et al.* (1974) and Jacobson (1971). Additional geomorphological data for the area may be found in Holloway *et al.* (1973) and Löffler (1977).

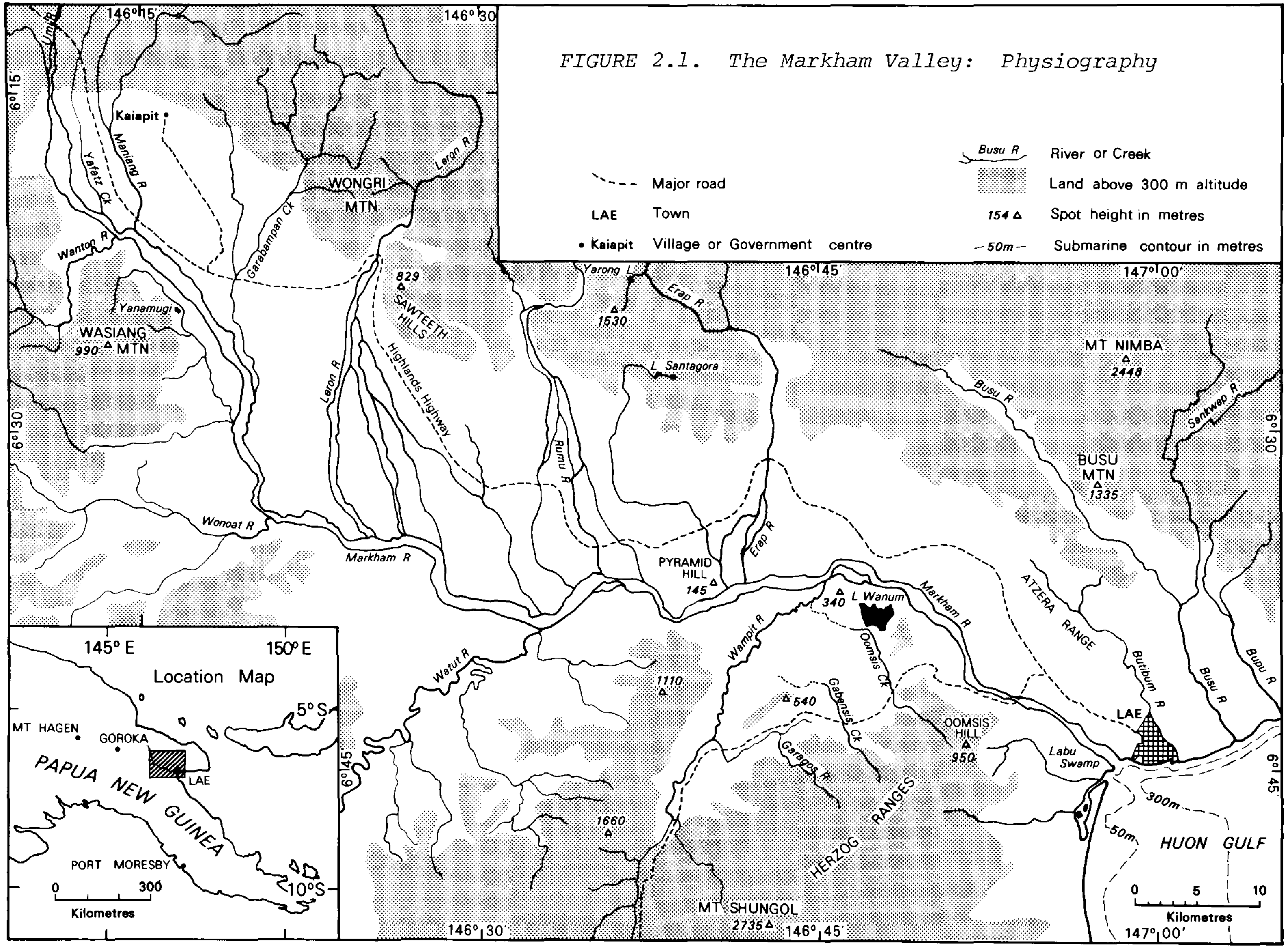


FIGURE 2.1. The Markham Valley: Physiography

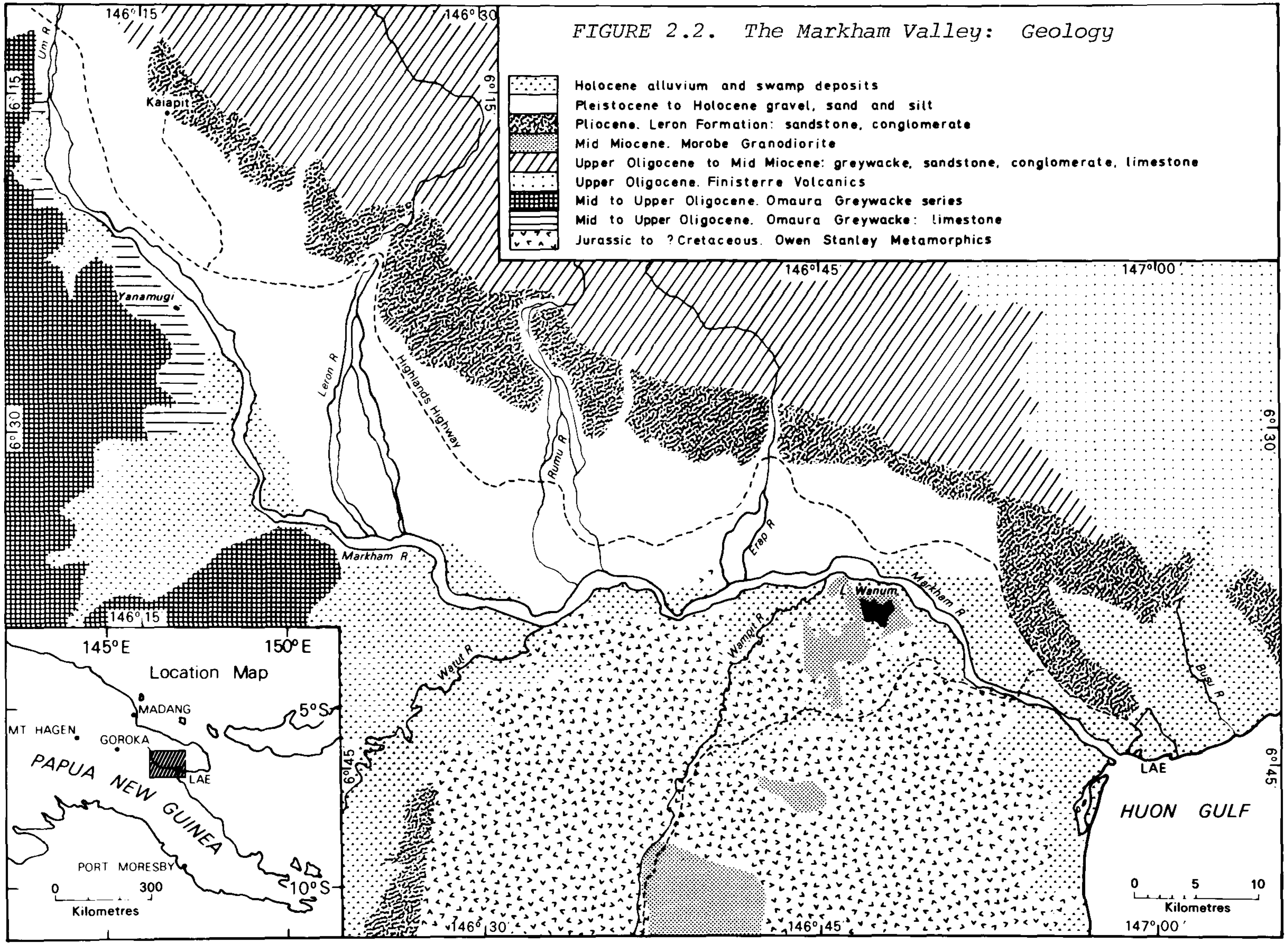


FIGURE 2.2. The Markham Valley: Geology

The Ramu-Markham fault zone is considered to have originated in middle Miocene times when the north-moving Australian Plate collided with an island arc developed on the oceanic crust of the Pacific Plate (Robinson *et al.*, 1974). The oceanic crust was thrust over the metamorphic rocks of the orogenic belt to the south; the Ramu-Markham fault zone approximating the position of the former plate boundary.

The geology of the ranges to the north and south of the Markham Valley reflects their different origin. The Oligocene to middle-Miocene sediments of the central massif of the Saruwaged Range are largely marine. Outcropping in the east of the range, the Oligocene Finisterre Volcanics were also deposited in a marine environment. The lower foothills are composed of sandstones and conglomerates of the Leron Formation, thought to be of Pliocene age. Analogous sediments are found south of the Markham in the lower Watut Valley, suggesting that a shallow sedimentary basin may have existed in the region at this time (Tingey and Grainger, 1976).

To the south-west of the Markham Valley, the bedrock consists largely of the Omaura Greywacke, an extensively folded and faulted complex of middle- to upper-Oligocene age. Limestones of this series outcrop in several places along the margin of the valley. To the east of the Watut River the Mesozoic Owen Stanley Metamorphics form the core of the Herzog Ranges. These rocks, of probable Jurassic to Cretaceous age, underwent low grade metamorphism in Eocene or Oligocene times. A later metamorphic event may have been related to the emplacement, during the middle-Miocene, of the Morobe Granodiorite batholith, isotopically dated at 12 to 14.5 million years by K-Ar and Rb-Sr techniques (Page, 1971). Granodiorite occurs along the margin of the Markham Valley in the vicinity of Lake Wanum although the greatest extent of the batholith is to the south of the study area in the Morobe Goldfields (Dow *et al.*, 1974).

The nature of the fault zone along the Markham Valley is not clearly known. The faulted southern margin of the valley may form the major boundary with the Pliocene Leron Formation underlying the valley sediments (Pettifer, 1974). Movements along the fault zone are thought to be predominantly of a left-lateral transcurrent nature, although vertical displacement of up to 1 km may also have occurred (Robinson *et al.*, 1974). Chappell (1973) sees the Markham trough as zone of, at least relative, subsidence in comparison to the rapid uplift of the surrounding mountains, particularly those to the north. The Saruwaged Ranges have undergone uplift of at least 4 000 m since the late-Miocene, making the area one of the most tectonically unstable in Papua New Guinea. Veeh and Chappell (1970) show the coast on the north-east of the Huon peninsula to have risen by up to 100 m in the past 35 000 years. Continued rapid uplift of the massif is indicated by recent faulting in the foothills of the Saruwaged Ranges. Such evidence is not found in the ranges on the southern flank of the valley. As a result of this tectonic instability, the Markham trough has become a locus of fluvial deposition. Deflection of the Markham River along the southern margin of the valley suggests that the bulk of the deposits derive from the rivers of the northern ranges. The very high sediment load of these rivers is a function of slope instability caused by the rapid uplift, although is in part due to the relative erodability of the rock types that form the Saruwaged Ranges.

Much of the alluvium in the Markham Valley is clearly fluviatile, consisting of well rounded gravel and boulders, and finer sediments. Fan deposition is active where rivers emerge from the mountain front at the northern margin of the valley. Holloway *et al.* (1973) recognise two categories. Individual fans are deposited by the larger rivers such as the Erap, Rumu, and Leron. These semi-circular fans are usually several kilometres in radius, the largest, 20 km wide, being formed by the Leron River. Many smaller fans, deposited by streams that do not reach the major rivers, coalesce laterally to form a sloping 'piedmont'. In some larger fans, particularly those of the Leron and Umi rivers, the channel is entrenched into terraced fan deposits by up to 20 m (Jacobson, 1971).

Alluvial deposition is associated with existing or prior river channels as well as with fan construction. Floodplain alluvium is predominant in the lower Markham Valley east of the Erap fan, and in the valleys of the Wampit and Watut rivers, the major southern tributaries of the Markham River. Changes in the shape and position of many active river channels since 1943 AD can be demonstrated (Holloway *et al.*, 1973).

The maximum thickness of the sediments of the Markham Valley is not known exactly. The floodplain alluvium is at least 40 m deep at the site of the Markham Bridge, whilst cores to a depth of 80 m in the piedmont alluvium have not encountered bedrock (Jacobson, 1971). A gravity survey (Pettifer, 1974) estimated the maximum depth of sediments of the southern Leron fan to be 500 to 1 000 m. A very large amount of alluvium has thus accumulated in Pleistocene and Holocene times, and the depositional and erosional processes involved continue to be active today.

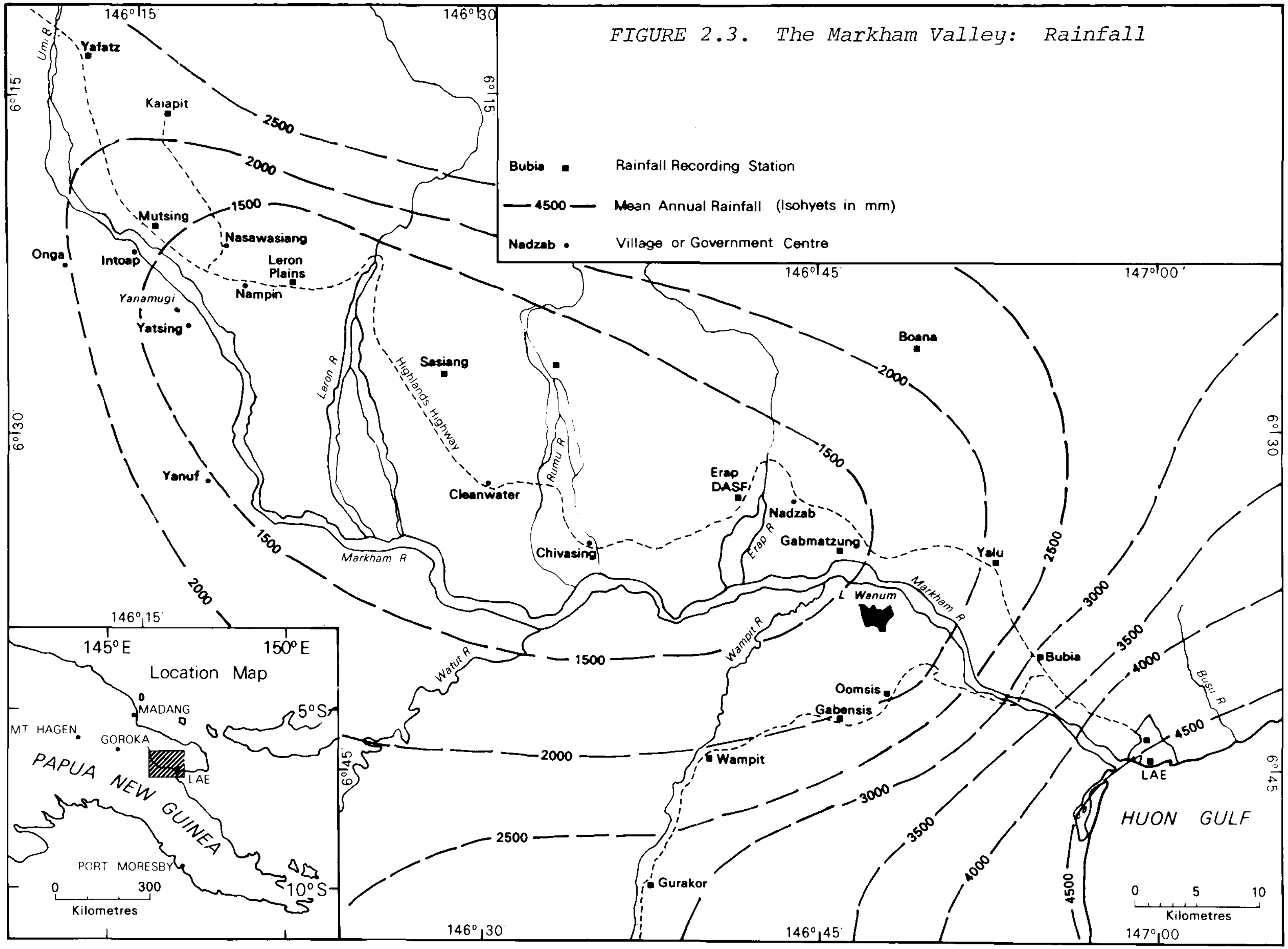
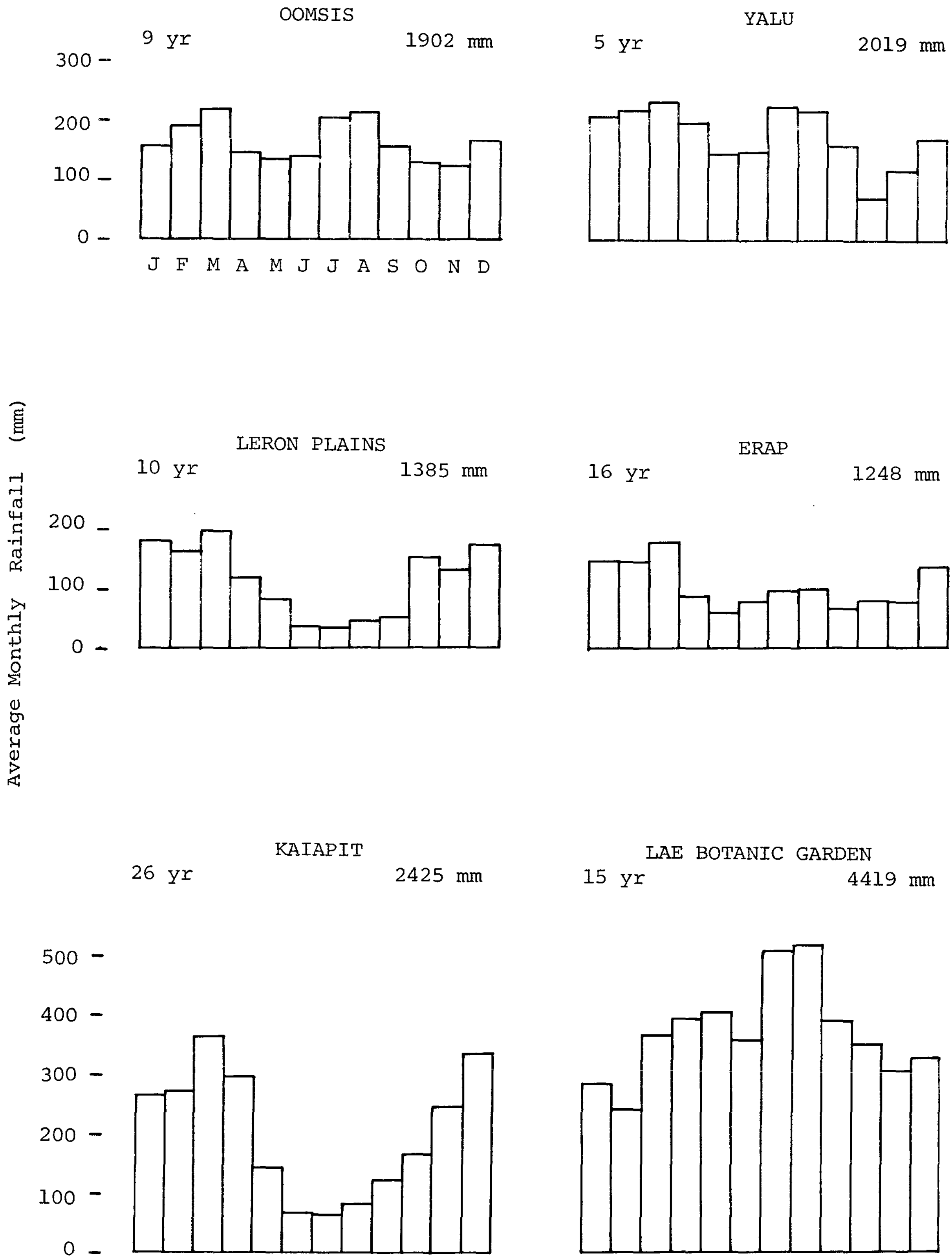


FIGURE 2.3. The Markham Valley: Rainfall

FIGURE 2.4. The rainfall regime of selected Markham Valley Stations



CLIMATE

The climate of the Markham area is discussed by Holloway *et al.* (1973). Rainfall data are available for much of the region although the records of a number of stations, especially those in the central Markham Valley, are of short duration. The southern part of the valley is poorly served by weather stations, and there are no data from the area to the south of the Markham River, west of the Wampit River.

Adequate temperature records are available only from Lae, Kaiapit, Bubia and Erap. However, the general temperature regime is very similar throughout the valley. The annual mean temperature is 26.2 °C at Lae, and about 1 °C higher at Erap. The hottest months are from November to February, although the mean diurnal temperature range (6.8 °C at Lae, 11.3 °C at Erap) is much greater than the annual range of mean monthly temperature. The annual range of mean monthly maxima (3.4 °C at Lae, 3.6 °C at Erap) is greater than that range of minima (2.6 °C at Lae, 2.0 °C at Erap).

Rainfall intensity and seasonality show great variation throughout the area. Figure 2.3 maps the approximate annual isohyets for the Markham Valley and environs. Monthly mean rainfall totals for selected stations are given in Fig. 2.4. Both figures are based on unpublished data collated by the Land Use Research Division of the CSIRO. The records of additional stations (Fig. 2.3) are from Holloway *et al.* (1973), and Johns (unpubl. *a*).

The incidence of rainfall in the area can be related primarily to the two patterns of atmospheric circulation that influence most of Papua New Guinea. From December to March, the 'north-west' or 'monsoon' season, low pressure vortical systems associated with the intertropical convergence zone (ITCZ) dominate the circulation. Between May and October the ITCZ is located north of the equator and has no direct influence on the area. At this time, the 'south-east trades' season, south-easterly winds moving towards the equator dominate the circulation. During April and November, when the ITCZ is moving across the region, either circulation system may predominate. Due to the great variations in topography, circulation patterns produced by anabatic and katabatic winds along the valley margins have a significant effect on local rainfall.

The south-easterlies are the only strong and persistent wind system affecting the area. They are also moist, and become increasingly unstable towards the equator. A temperature inversion, the 'trade-wind inversion', frequently occurs at low altitude. Under such conditions much of the winds' moisture is released as rain along the coastal ranges, whereas precipitation in the leeward area of the Markham Valley is unlikely. Although the coastal area is very wet throughout the year, maximum rainfall occurs during the south-easterly season. Rainfall during this season decreases very sharply inland, reflected by the reduction in annual precipitation at stations various distances from the coast (Fig. 2.3). Lae Botanic Garden receives an average of 4 419 mm yr^{-1}, whilst at Erap, 40 km to the west, the annual total is only 1 248 mm.

Due to the decreased influence of the south-easterly circulation, stations in the mid- and upper-Markham Valley receive nearly 40% of their rainfall during the height of the north-west season from January to March. Conversely, the central valley area is relatively dry from July to September, the degree of seasonality increasing with distance from the coast. At Erap, 21% of the total rainfall falls during these months. This proportion declines to around 10% or less at Sasiang and stations to the west. Kaiapit, and similar marginal valley areas, experience greater annual rainfall due to local circulation effects, although the seasonality of the rainfall is very similar to that of the nearby open valley stations. The lower valley area around Oomsis and Yalu is influenced equally by both circulation patterns, and rainfall distribution is less seasonal than in other areas.

A large section of the Markham Valley thus experiences a seasonally distributed annual rainfall of less than 1 500 mm. The only extensive region of the country drier than the mid-Markham is the Central Coast of Papua (Brookfield and Hart, 1966). This relative aridity is reflected by increased drought frequency and intensity, and by seasonal or annual water budget deficits. Estimates for Erap and Leron Plains stations (Holloway *et al.*, 1973) show the potential annual evapotranspiration to exceed rainfall by 460 mm and 334 mm respectively. McAlpine and Short (1974) indicate an excess of theoretical evaporation over rainfall of 555 mm yr^{-1} for Erap.

VEGETATION AND SOILS

Figure 2.5 shows a highly generalised map of the vegetation of the Markham region. Due to the paucity of ecological data (see Appendix II) the vegetation units mapped are largely physiognomic, similar to those proposed by Paijmans (1975). Floristic lists for specific locations within the area may be found in Lane-Poole (1925), Holloway *et al.* (1973) and Johns (unpubl. *a*).

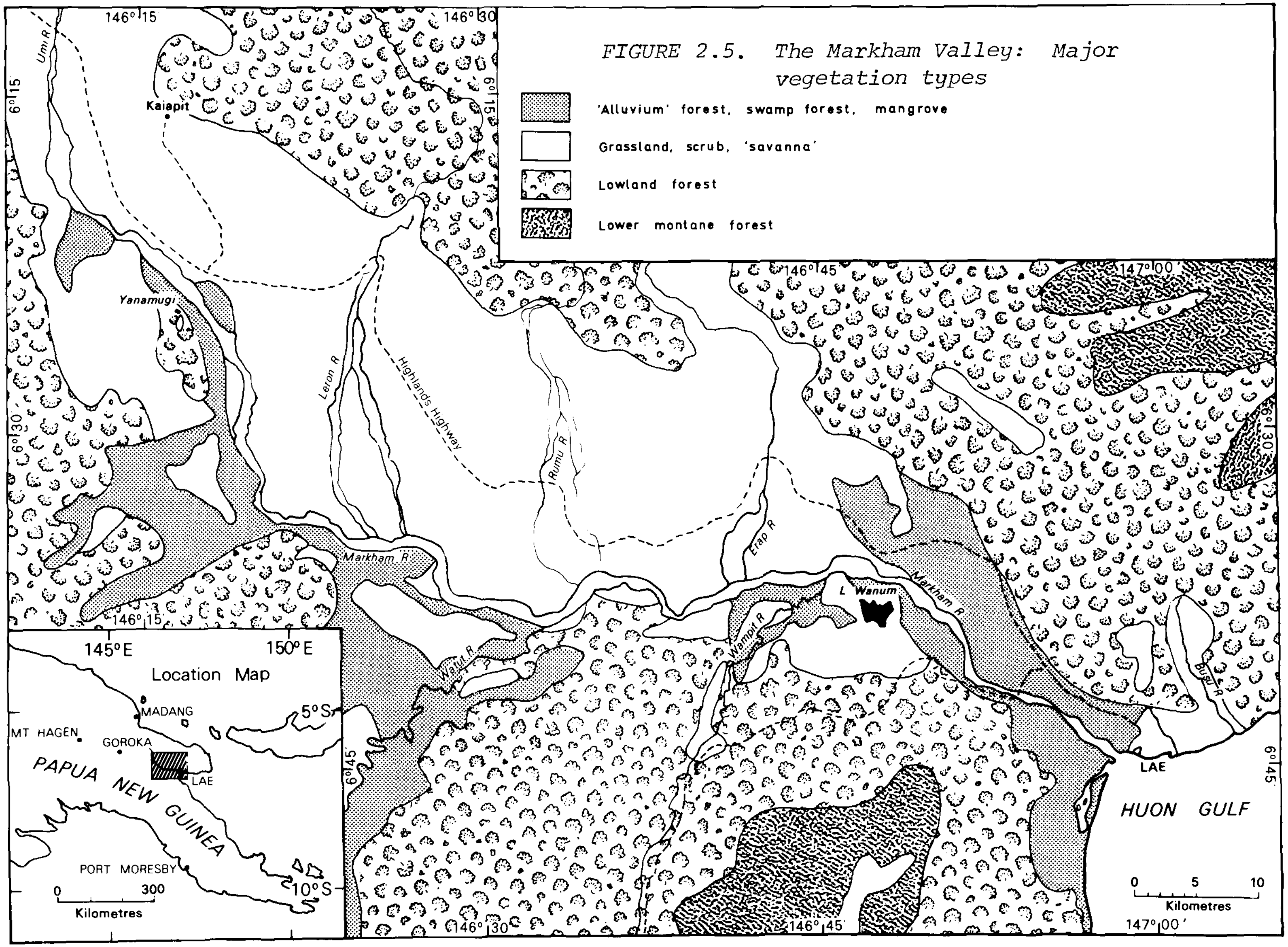


FIGURE 2.5. The Markham Valley: Major vegetation types

The vegetation units are described in a wider context by Paijmans (1975, 1976). Vegetation boundaries are mapped on Fig. 2.5 by interpolation from aerial photography, photomosaics, and LANDSAT imagery of the area. The following units are recognised:

Grassland comprises most of the non-forest vegetation of the area. Grass dominated vegetation occupies much of the drier central valley of the Markham, from the Erap River westwards to the margin of the Leron fan. It also covers an extensive area of the lower mountain slopes, up to about 500 m, particularly on the northern flanks of the valley. South of the Markham River, grassland is less widespread. It occurs along the floodplains of several rivers, but is most abundant over the granodiorite of the Lake Wanum area, and on the foothills in the vicinity of Wasiang Mountain. In the latter area, grasslands ascend to almost 1 000 m above sea level.

In mapping the floor of the Markham Valley, Holloway *et al.* (1973) recognise a number of non-forest vegetation alliances. A short grass association, dominated by *Themeda australis,* is found especially on active surfaces of the piedmont, and of the Leron, Umi and, to a lesser extent, Erap fans. The tall grass alliance, composed of *Imperata cylindrica* in association with *Ophiuros toncalingii* and *Saccharum spontaneum,* appears to dominate areas of deeper soil. It is particularly abundant around the margin of the Leron fan, and from this area eastward to the Erap River. Scattered trees, often *Albizia procera* or *Nauclea orientalis,* may occur either individually or in groups. In the upper valley west of the Leron Fan and along the piedmont and Garabampan fan, such trees become more abundant. Holloway *et al.* (1973) classify much of this area as 'savanna' or 'woodland'.

The grassland associations of the foothill slopes and valley floor appear essentially similar in floristic composition. In the vicinity of Lake Wanum, the grassland is almost totally dominated by *Themeda australis,* although *Arundinella setosa* also occurs. On similar slopes on the metamorphic rocks at nearby Redhill, *Imperata cylindrica* is the most abundant species. A wider diversity of grass species is seen in the wetter depressions in both areas. In such situations *Coelorhachis rottboellioides* and *Ischaemum barbatum* are particularly common.

'Alluvium' forest includes all substantially forested areas of the alluvial plain. Both Holloway *et al.* (1973) and Paijmans (1975) differentiate between swamp forest, and the forest of the flood-plain. However, apart from small areas of floristically distinct mangrove vegetation east of Labu, and along the coast, none of the area is permanently inundated. There is perhaps an environmental gradient related to frequency and depth of flooding. Pure stands of sago (*Metroxylon sagu*) occur particularly in the lower Markham Valley where inundation is frequent, and the palm is common in the understorey at other periodically flooded sites. The floristic composition of 'alluvium' forest appears essentially similar throughout the area. Some of the more common trees encountered are *Artocarpus communis, Buchanania heterophylla, Bischofia javanica, Octomeles sumatrana, Terminalia* spp. *Neonauclea* spp. and *Ficus* spp.

'Alluvium' forest extends over most of the lower Markham floodplain. West of the Erap River it is much less widespread, although forest patches occur on some lower-fan areas, and adjacent to the Markham River. In this part of the valley, the major 'alluvium' forest tracts are south of the river, along the floodplains of the Wonoat, Watut and Wampit rivers.

Lowland hill forest encompasses all areas of closed canopy forest on well drained sites, below about 1 400 m. This omnibus category undoubtedly includes a wide variety of structurally and floristically different forest types. Most are dominated by evergreen broad-leaved species. However, semi-deciduous forest occurs along the southern margin of the Markham Valley in some seasonally dry areas notably the limestone foothills of Wasiang Mountain.

Some of the more abundant tree taxa recorded by Johns (unpubl. *a*) from valley side forest plots in the Oomsis-Gabensis area are *Celtis kajewskii, Intsia bijuga, Diospyros, Pimeliodendron alternifolium* and *Maniltoa*.

Lower montane forest (*sensu* Paijmans, 1975) is mapped at altitudes greater than 1 400 m. In the study area the unit extends over small areas of the Herzog and Saruwaged Ranges.

Where sufficient data exist, the effect of edaphic factors on the vegetation appears important. The apparent contrast between grassland on granodioritic soils and that on soils derived from metamorphic substrates has been mentioned.

The only systematic pedological study is that reported by Holloway *et al.* (1973), on the alluvial soils of the Markham Valley floor. Most soils investigated were found to be lacking in some major plant nutrients and trace elements. Drainage and topography, by their control of runoff, leaching and erosion, were found to be the most important factors influencing soil development. In the drier areas of the valley soil formation processes were considered 'more characteristic of semi-arid' than humid tropical climates. The young and unstable nature of the valley floor soils is emphasised. In many profiles, one or more ancient pedogenic phases, indicated by buried 'A-horizons', were encountered.

HUMAN ACTIVITY

Although the cosmopolitan port of Lae is the country's second most populous town, the majority of the area's inhabitants live in traditional villages. Most villages are located along the foothills, or in tributary valleys, rather than in the open expanse of the Markham Valley. Population densities for the valley floor are thus low. The area between the Erap and Leron rivers has a density of only 3.4 persons km^{-2}. In the upper valley from the Leron to Umi rivers there are a larger number of villages and the number of persons rises to 18.5 km^{-2}.

The majority of the population practises subsistence agriculture in shifting gardens, although excess crops, particularly betel nut (*Areca catechu*) and coconuts, may be traded. Staple crops include the many varieties of banana (*Musa* spp.) and the coconut (*Cocos nucifera*). Sweet potato (*Ipomoea batatas*) is also important, but does not dominate the diet to the extent that it does in highland areas. Sago (*Metroxylon sagu*) is utilised in the lower Markham Valley and coastal areas, although nowhere does it appear the sole staple crop. Many other plants supplement the diet. Yams (*Dioscorea* spp.) and taro (*Colocasia esculenta*) are cultivated, and mangoes (*Mangifera indica*) may be found as shade trees in villages. A large number of plants are harvested from the wild; breadfruit (*Artocarpus altilis*) being one example. An extensive list of other food plants is given by Powell (1976). Domestic pigs are usually kept, and fishing and hunting are practised where appropriate resources are available.

Plantation agriculture is established particularly in the lower Markham Valley within 30 km of Lae. The major crops grown are coconuts and cocoa, and *Sorghum* is also widely cultivated. Many other plants have been introduced in attempts to promote village cultivation of cash crops (Holloway *et al.*, 1973) and a large cattle station is in operation at Leron Plains.

The pre-European history of the area is almost totally speculative. The two main peoples of the valley proper, the Adzera and Wampar (or Laewomba) are closely related culturally (Holzknecht, 1974). Both speak an Austronesian language, in contrast to the non-Austronesian affinities of the mountain inhabitants to the north and south (Hooley and McElhanon, 1970). No archaeological sites of any antiquity have been found within the area, although Specht and Holzknecht (1971) have recovered ceramic and stone artefacts from surficial deposits at abandoned village sites. A shallow rock shelter containing ancestoral skulls, at the southern end of Yanamugi lake, was encountered during fieldwork near Yatsing village.

Accounts of the oral and post-contact history of the lower Markham Valley (Willis, 1974, Sack, 1976) suggest widespread population movement in response to specific intertribal disputes. No sustained migration patterns are evident, however. European contact has had an increasing influence on the region since the late nineteenth century.

SELECTION OF SITES FOR PALAEOECOLOGICAL STUDY

Potential sites for palaeoecological study were evaluated on the basis of the following desiderata:

(i) probable existence of continuous sedimentary history of some antiquity,

(ii) preservation in the sediments of macroscopic and microscopic plant remains,

(iii) sufficiently low in altitude to reflect changes in lowland vegetation,

(iv) location in relation to vegetation associations, and

(v) reasonable access for equipment.

Few sites fulfilled all critera. No suitable sites exist on the floor of the Markham Valley. Although some swamp areas and alluvial plains to the south of the river contain organic material, this is unlikely to have been deposited continuously, or to be of great age, given the unstable nature of the alluvial environment. Neither are such sites with a fluctuating watertable likely to preserve much pollen. Perennially inundated sites only were therefore considered, restricting the search to permanent lakes or swamps.

Several lakes are found in the foothills of the Saruwaged Range. Yarong Lake and the two Santagora Lakes (Fig. 2.1) are located between about 600 m and 800 m altitude in the headwaters of the Erap River and Wawin Creek respectively. These lakes are in an interesting position at the upper limit of major cultivation in the foothills, although may have been formed relatively recently by landslips in this unstable area. The sites might also be too elevated to reflect vegetation events in the Markham Valley. Due to their relative inaccessibility, these lakes were not investigated, although they would undoubtedly bear further study.

Possible sites also occur at low altitude in the foothills along the southern margin of the valley. Two small lakes in the forest between the Wampit and Watut rivers were observed from a light aircraft. They could not be located subsequently on aerial photographs and may be ephemeral.

Two areas were chosen for initial palaeoecological investigation. The vicinity of Mount Ngaroneno, at the southern margin of the lower Markham Valley, contains the greatest expanse of swamps and lakes in the region. Lake Wanum is by far the largest, although other lakes and swamps are also found. Several small lakes or ponds occur in the second area, the limestone region of Wasiang mountain. The largest of these, Yanamugi, appeared suitable for study.

Both areas are critically located in relation to the environmental factors outlined in this chapter. They occur on rock types uncharacteristic of most of the area, granodiorite and limestone. The prevailing rainfall regimes differ, the Lake Wanum area probably receiving 1 500 to 2 000 mm, distributed throughout the year. Yanamugi lies within the area of strongly seasonal precipitation, with an annual average of less than 1 500 mm. Grassland vegetation is abundant around both sites, although the immediate vicinity of Yanamugi is forested. These areas thus appear well sited to detect any past change in major environmental conditions or vegetation occurring in the region.