OBSERVATIONS ON THE VEGETATION OF NORTHEASTERN MATO GROSSO

I. THE WOODY VEGETATION TYPES OF THE XAVANTINA–CACHIMBO EXPEDITION AREA

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The Xavantina–Cachimbo Expedition worked during 1967–9 in a 20 km square around a base camp (12° 49′ N, 51° 46′ W), *ca.* 260 km north of Xavantina (NE Mato Grosso) and near Xavantina itself.

The vegetation is of special interest because the base camp is situated near the junction of the savanna region of Central Brazil and the Amazonian forest. It is a pattern of savanna (cerrado), savanna woodland (cerradão), forest and treeless grassland (campo) with often remarkably abrupt boundaries between the different communities. Until 1967 the area had been very little affected by man.

The climate is characterized by high temperature throughout the year, an annual rainfall of about 1200 to 1400 mm, and a more or less rainless dry season from June to September inclusive. During the dry season the cerrado, campo and some forms of cerradão vegetation are subject to fire, but are not burned every year. The forest, except the Deciduous Seasonal forest, is not normally burned.

The rocks consist of sandstones overlying shale and mudstones. The sandstone weathers to form widespread dystrophic soils of low nutrient content, whilst the finer textured rocks, exposed in some deeper valleys, produce somewhat richer mesotrophic soils.

The woody vegetation types of dystrophic soils are classified into three types of Evergreen Seasonal forest ('Swampy Gallery' forest, 'Valley' forest and 'Dry' forest), cerradão and cerrado. The Swampy Gallery forest is found along streams where the water table is close to the surface even in the dry season and is often bordered on one or both sides by strips of campo. In composition it resembles an impoverished Amazonian rain forest. The top-storey is dominated by *Qualea ingens* and *Q. wittrockii*, growing sometimes to 40 m, and the undergrowth includes numerous dicotyledons, Scitamineae, grasses and other monocotyledons.

At a slightly higher level in stream valleys there is another type of tall forest, Valley forest, in which characteristic trees (all growing to about 40 m) are *Apuleia molaris*, *Copaifera langsdorfii*, *Hymenaea stilbocarpa* and *Ormosia* sp. (Tento).

Much the most extensive type of Evergreen Seasonal forest is the Dry forest which represents the southern fringe of the Amazonian forest and covers a vast area stretching away northwards from the base camp area. This is a mixed community in which the trees seldom grow to more than 20 m. The most abundant species of the upper storey in the area studied are *Chaetocarpus echinocarpus*, *Licania blackii*, *L. kunthiana*, *Sacoglottis guianensis* and *Xylopia amazonica*.

The transition from Dry forest to cerrado is sometimes abrupt, but elsewhere there is an ecotone in which *Hirtella glandulosa* cerradão forms a recognizable nodum, occupying a zone up to 4 km wide. Characteristic species in this are *Emmotum nitens*, *Sclerolobium paniculatum* and *Vochysia haenkeana*, as well as *H. glandulosa*. The boundary between cerrado and Dry forest appears to be dynamic and there are some indications that the forest has recently invaded the cerrado. The present boundary does not seem to be primarily dependent on climate or burning but shows some relation to soil conditions, though apart from a higher clay content in the latter the cerrado and forest soils are much alike.

Cerrado has a lower degree of crown cover than cerradão; it is a type of open savanna with grassy undergrowth and is extremely variable in floristic composition and no clearly defined associations could be recognized. The boundary between cerrado and campo in valleys is sharp and appears to be determined by the height of the water table in the wet season.

The mesotrophic soils are occupied by Deciduous Seasonal forest, the only woody community in the area in which the top storey becomes leafless in the dry season. The floristic composition of this community is very different from that of the other forest types and characteristic top-storey species include *Cedrela fissilis*, *Piptadenia macrocarpa*, *Platypodium elegans* and *Sterculia striata*, with *Acacia polyphylla* and *Bauhinia cupulata* as a second storey. Bamboos and the palm *Acrocomia* sp. are features of the undergrowth. Floristically this community is similar to forest types found on calcareous rocks in Goiás and Minas Gerais. It is fringed by a characteristic cerradão, termed *Magonia pubescens*/*Callisthene fasciculata* cerradão.

Introduction

In the early 1960s the Brazilian Government, to promote the development of Mato Grosso State, decided to construct a road from Xavantina (14° 45′ S, 52° 20′ W) northwards along the Serra do Roncador to the region of the Fazenda Suiá Missú. This event was quickly recognized as outstandingly important for science. The new road would open up a large region previously untouched by civilized man and several important and little studied types of vegetation would become readily accessible for the first time. It was to exploit these opportunities that the Royal Society and the Royal Geographical Society in 1967, at the invitation of the Government of Brazil, initiated the Xavantina–Cachimbo Expedition, which remained in the field from April 1967 to July 1969. During this time over 50 British, Brazilian and other scientists took part in

detailed studies, mainly in the fields of biology, soil science, geomorphology and medicine, the results of which are appearing in various British, Brazilian and American journals.

The following account attempts to describe the vegetation in the neighbourhood of the Expedition's base camp (12° 49′ S, 51° 46′ W, approximately 260 km north of Xavantina, see

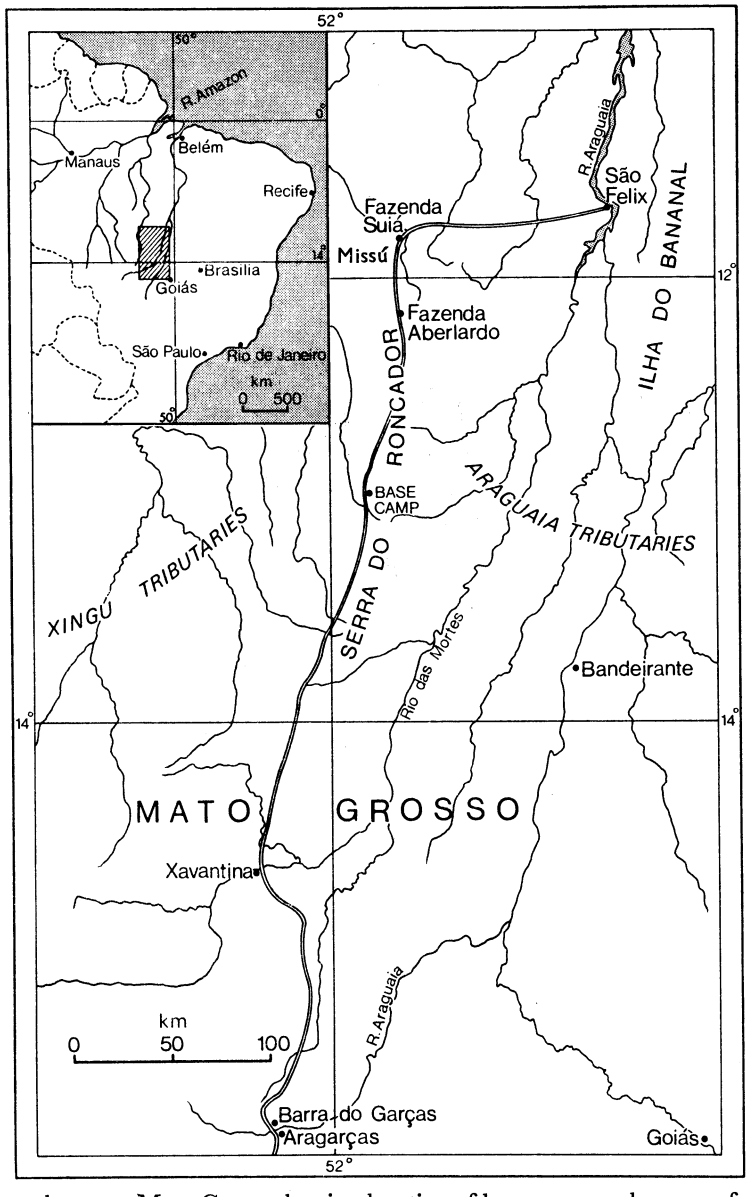


FIGURE 1. Map of northeastern Mato Grosso showing location of base camp and course of road from Aragarças to Fazenda Suiá Missú and São Felix. From Askew, Moffatt, Montgomery & Searl (1970*a*, Fig. 1, p. 212). (Reproduced with permission of the Royal Geographical Society.)

figure 1) and around Xavantina itself. The base camp was sited at the junction of two great plant formations: the Cerrado (or campo cerrado), a type of savanna, which stretches for hundreds of kilometres to the south and east, and the 'Dry' forest (mata sêca) which forms the southernmost part of the great forest which extends north to the Amazon. In addition to these major formations other vegetational types occur in situations with special hydrological, edaphic

or other environmental features. An area (20 km × 20 km) centred on the base camp, included almost the whole gamut of vegetational types occurring in the region and was therefore chosen for intensive work. Detailed studies were also carried out near Xavantina and less detailed observations were made along the 560 km stretch of road between the base camp and Aragarças (15° 55′ S, 52° 12′ W) to the south and between base camp and São Felix (11° 40′ S, 50° 40′ W) to the northeast.

The aim of the present paper is to give a general description of the structure and floristic composition of the tree-dominated vegetation types (forest, cerradão and cerrado) of the region, especially in the contact zone between the cerrado and the Dry forest. This is intended to provide the necessary introduction and background for the biological and geomorphological work in course of publication by other members of the Expedition. Much of the information in the paper was obtained from long belt transects in the 20 km square at the base camp and near Xavantina: it is intended to publish further details of some of these later. The vegetation of the treeless campos (grasslands) will also be dealt with in later papers.

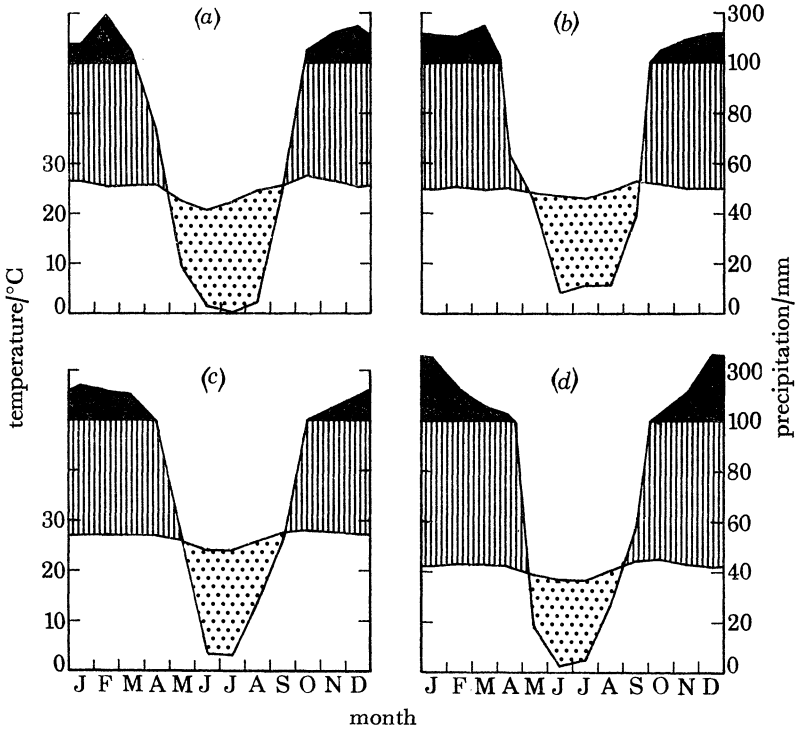


FIGURE 2. Temperature (mean monthly) and precipitation at base camp in 1968 compared with climatic diagrams for three other localities in central Brazil. Scale for precipitation reduced 10:1 above 100 mm. (*a*), Base camp (elevation *ca.* 400 m); (*b*) Araguaiana (elevation 490 m(?)); (*c*), Cuiabá (elevation 165 m); (*d*) Formosa (elevation 912 m).) (*b*, *c* and *d* re-drawn from Walter & Lieth (1967).) N.B. The locality referred to by Walter & Lieth as 'Araguaya' appears to be the same as that shown as 'Araguaiana' on most maps: its elevation is probably somewhat less than that given by them.

(*a*) *Climate*

Observations on temperature, rainfall, atmospheric humidity, wind and sunshine were recorded at the base camp from 1 October 1967 to 29 May 1969, a period comprising two wet seasons, one complete dry season and part of another. Apart from this information, no data are available on the climate of the northern Mato Grosso except for the stations Araguaiana

(15° 41′ S, 51° 41′ W) and Cuiabá (15° 32′ S, 56° 05′ W) (figure 2) which are both more than 500 km from the base camp. Records are also available for Formosa (Goiás) which is at about the same distance, but as its altitude is 912 m its climate may be significantly different from that of our area. Fragmentary as this information is, it makes the general features of the climate sufficiently clear.

The northeastern Mato Grosso, being south of the equator, has a seasonal tropical climate dominated by the north and south shift of the intertropical convergence: during the southern winter (May to October inclusive) there is a dry season of many consecutive rainless weeks, while during the remainder of the year there is a wet season characterized by heavy rainfall, high atmospheric humidity, less bright sunshine and more cloud. According to Eidt (1968) the climate of this part of central Brazil belongs to Köppens 'Savanna Subtype' (Aw) of the 'Tropical Rain Climate' (A) and grades into the 'Monsoon Subtype' (Am) towards its northern boundary.

The annual rainfall at the base camp was 1372 mm in 1968 and the monthly totals in millimetres (figure 2) were as follows:

January	February	March	April	May	June
176	295	148	74	18	3
July	August	September	October	November	December
0	4	48	150	211	245

How typical these figures are is uncertain: judging from the data from Brasília, which probably has a similar climate, there is considerable year to year variation and at base camp there was a striking difference between the dry season of 1967 when (at least at Xavantina) there was no rain in July or August and that of 1968 when there were some quite heavy falls during these months. The estimated average annual rainfall is between 1200 and 1400 mm, the limits given by Aubréville (1961) for the 'Sous-climat Haut-paraguiaien' of the 'Climat Brésilien central'. There are about five consecutive 'arid months' in the sense of Lauer (1952).

In 1968 the mean annual temperature at base camp was 24.9 °C, the mean maximum was 32.7 °C and the mean minimum 17.0 °C. The difference between the mean for the hottest month (October) and that for the coldest month (June) was about 6.9 °C. The mean daily range of temperature was 19.2 °C in the dry season (May to October) and 12.1 °C in the wet season (November to April): the climate is thus a typical 'Tageszeitklima' (Troll 1947) in which the daily variation of temperature is much greater than the seasonal variation.

The biological effects of drought during the dry season are reinforced by a dry atmosphere, especially during the hotter hours of the day. Few observations of relative humidity are available. Some observations made by Mr S. G. Daultrey during September 1968 (late dry season) at various sites near the base camp show relative humidities ranging from 56 to 70 % between 09 h 53 and 11 h 25. A few days later (26 September) at the same sites the relative humidity round 09 h 53 varied from 37.5 to 61 % and round 16 h 06 from 11.0 to 31 %. On the 'pantanal' (see p. 458) near Xavantina one of us (P. W. R.) made daily observations from 1 to 28 September 1967 and about noon the relative humidity frequently fell below 30 %.

Strong winds are not a common feature of the climate of our area, though as in most tropical countries strong gusts often precede thunderstorms. At 10 m on a tower at base camp Mr Daultrey found that the average wind speed measured at 07 h 00–07 h 30 and at 17 h 30–18 h 00 during the period October to December 1968 varied from 0.49 to 0.85 m s^{-1} and the maximum gust observed was about 10 m s^{-1}. Seventy-four per cent of the readings were less than 1 m s^{-1}.

The strikingly different physiognomy of the three principal types of vegetation in the north-eastern Mato Grosso, added to the effects of a gently hilly topography, results in a range of diverse micro-climates and this, as Camargo (1963) points out, is characteristic of the cerrado region generally. No systematic study of micro-climates was attempted, but the set of observations made at Xavantina from 1 to 28 September 1967, gives some idea of the differences in temperature and relative humidity at 0.5 m above ground level in the gallery forest and at 0.25 m in the pantanal *ca.* 250 m away. The maximum temperatures were up to 6 °C higher in the pantanal than in the forest, but the minima were a few degrees higher in the forest than in the pantanal. Relative humidity in the forest was commonly above 60 % and fell below 50 % only on one day, but in the pantanal it fell below 50 % on about half the days and on one occasion to 25 %.

In the dry season, heavy early morning dew may mitigate the effects of dryness to some extent. It was noticed both at Xavantina and at the base camp that dew was particularly heavy in a belt about 10 m wide in the open vegetation (campo or pantanal) bordering the gallery forest, apparently because during the night warm, relatively humid air passed out into the surrounding open vegetation and became cooled. The distribution of certain plants such as *Lycopodium eichleri* seemed to be limited to this belt, possibly because of the additional water supply from dew.

(*b*) *Topography and relief*

The Expedition's area lies wholly within the state of Mato Grosso, close to its eastern boundary with Goiás and some hundreds of kilometres south of its boundary with Pará. The base camp was situated about 1 km east of kilometre 262 (from Xavantina) on the Brasília–Cachimbo road which in 1967–8 terminated at the Fazenda Suiá Missú 177 km farther north, and with a few minor changes of direction runs straight following approximately the line of the divide between the Xingú on the west and the Rio das Mortes and Rio Araguaia on the east. The first of these rivers runs north to join the Amazon, whilst the Araguaia flows into the Tocantins, its waters eventually reaching the Atlantic near Belém. Both road and watershed divide the Expedition's 20 km square unequally, about three-quarters of its area draining into the Rio Baracajú and thence into the Rio das Mortes, and the remainder into the Rio Suía Missú which joins the Xingú near Diauarum.

The whole region around base camp is a plateau and is a planation surface of Jurassic, or more probably Tertiary, age (King 1967). It is an area of low relief with no features as bold as the hills close to Xavantina or the strikingly precipitous escarpment at Vale de Sonhos 70 km farther to the south. Within the 20 km square the range of relief is 174 m (Brown 1970). To the east the plateau falls away to the broad alluvial valleys of the lower Rio das Mortes and Araguaia. The slightly elevated 'spine' between the Xingú and the Araguaia drainages is known as the Serra do Roncador, and has an average elevation of about 400 m. These small differences of elevation, though important in their effects on drainage, are probably not large enough to have a significant effect on climate in this latitude.

Much more striking than the features of relief are the differences between the contrasting land forms and pattern of plant communities of the Xingú and Araguaia drainages (figure 3). The divide is asymmetrical: the gradient of the Araguaia in this area is about three times that of the Xingú and in the base camp square the headwater streams of the former are about twice as steep as the sluggish Xingú streams (Brown 1970). Linked with these differences in geomorphology is a striking contrast in plant cover: the vegetation of the more dissected Araguaia land-

scape is a constantly repeated threefold pattern of cerrado, campo and gallery forest, while that of the Xingú drainage to the north and west of base camp is continuous forest broken only by streams and swamps.

(c) *Geology and soils*

The underlying rocks in the vicinity of base camp consist of a gently dipping sequence of quartzose sandstones, shales and mudstones of Devonian–Carboniferous age (Barbosa, Ramos Gomes & Helmbold 1966). The sandstones overlie the finer grained rocks and are therefore much more extensive on the surface. The shale and mudstone outcrops occur commonly in the lower parts of the valleys to the east. Lying between the coarse and fine grained rocks is a pebble band which may be up to 30 cm in thickness.

The geology and topography of the Xavantina area is more diversified than that around the base camp. To the southeast and east of Xavantina unconsolidated but firm argillaceous sands of pluvial origin which are a part of the Pleistocene deposits of the Rio das Mortes–Rio Araguaia Basin give rise to a somewhat monotonous, low-lying and gently sloping landscape. To the south and southwest of Xavantina, rocks of the Pre-Minas series of Pre-Cambrian age protrude through the cover of Pleistocene deposits and the succession of alternating hard quartzites and schistose mudstones and slates form a cuesta type of land form consisting of a repetitive sequence of steep-sided ridges (escarpments and dip slopes) trending northeast to southwest.

TABLE 1. COMPOSITION OF SURFACE HORIZONS (*ca.* 0–10 CM) OF TYPICAL DYSTROPHIC AND MESOTROPHIC SOILS (MEANS OF 20 DYSOTROPHIC AND 5 MESOTROPHIC SITES)

(From Askew *et al.* 1971.)

soil type	organic carbon %	silt %	pH in H_2O	Ca	Mg	K	extractable phosphorus 10^{-6}
				me/100 g soil			
dystrophic	1.2	1.1	4.6	0.05	0.043	0.064	17
mesotrophic	4.3	24.0	5.6	4.7	3.26	0.58	140

Analtyical methods. Organic carbon by a modified Walkley & Black method (Metson 1961); nitrogen by micro-Kjeldahl; exchangeable calcium by extraction with ammonia at pH 7.0 and determination by absorption spectrophotometry; extractable phosphorus by the NaOH extraction method of Saunder (1956).

Limestone does not occur in the base camp region or at Xavantina.

Throughout the Expedition the botanists and soil scientists worked closely together so that their results could be directly correlated. Some of the results of the soil studies have already been published (Askew, Moffatt, Montgomery & Searl 1970*a*, *b*, 1971) and the soil data need only be briefly summarized here.

The soils of the base camp area, which were the most intensively studied, can be grouped into two main 'landscape associations', freely drained automorphic soils on the broad interfluves and on certain valley sides, and poorly drained hydromorphic soils on valley floors and sometimes also on valley sides.

The automorphic soils can be separated into a group of highly weathered and leached dystrophic soils (oxisolic soils) of low nutrient content and availability and a group of less weathered mesotrophic soils (tropepts and ustalfs) of high nutrient content. The soil type can readily be related to the parent rock and topography: the dystrophic soils are developed on the widespread sandstones while mesotropic soils occur on the rather restricted shale and mudstone outcrops.

Table 1 shows some of the more important differences in the surface A_2 horizons (approximately 0–10 cm in depth) of dystrophic and mesotrophic soils.

Dystrophic soils are by far the most widespread in the region. Their vegetation is either cerrado, cerradão, or Dry forest; as will be discussed later, Askew *et al.* (1970*b*) believe that in our area soil texture is probably the main factor controlling which of these vegetation types is developed. In the dystrophic soil landscape the hydromorphic soils are of low base status, although the exchangeable calcium of the A horizons (average 0.16 me/100 g) is somewhat higher than in the A horizons of the automorphic soils (average 0.04 me/100 g); such hydromorphic soils carry Swampy Gallery forest, Valley forest or campo according to differences in ground water level and its seasonal variations.

The more nutrient-rich mesotrophic soils carry Deciduous Seasonal forest, a very distinct forest type with few, if any, species in common with the forests of the dystrophic soils. Hydromorphic soils in the mesotrophic landscape are also usually characterized by forest of this type.

(*d*) *Fire and other anthropogenic factors*

One of the chief reasons for studying the Serra do Roncador region was that it had been very little affected by human activities, but even before 1967 it was not entirely uninhabited (or at least unvisited) by man. Until the road from Xavantina to the Fazenda Suiá Missú was constructed (1963–6) there were probably no settled inhabitants except here and there along the Rio das Mortes and Araguaia, but the whole area is a hunting ground for small numbers of Xavante indians who every dry season leave their villages and roam through it in pursuit of game, sleeping in temporary bivouacs. It is likely that the indians were more numerous in earlier times, but there is no evidence suggesting that there were ever settled populations away from the larger rivers. The infertility of the soils must always have discouraged agriculture except on the limited tracts of mesotrophic soils (p. 455).

As soon as the road was made, settlers from Goiás and elsewhere began to move into the area and develop small fazendas (farms), burning the cerrado to provide grazing for cattle, and felling small areas in the gallery forests to grow food crops. At Fazendas Suiá Missú, Aberlado and elsewhere much larger cattle-raising enterprises were started. Even during the two years 1967–8 the number of fazendas and the human impact generally increased markedly. Since 1969 development has proceeded apace and the forest has been felled for at least 1 km on either side of the road from 23 km north of the base camp to the Fazenda Suiá Missú.

In 1967–9 the actual clearing and destruction of natural vegetation was limited in extent, but human influence by grazing and burning was very widespread. Except at the Fazenda Suiá Missú where the African *Panicum maximum* and other grasses had been planted on a large scale, the cattle feed was entirely native grasses, supplemented in the dry season by the foliage of woody plants. As the density of stocking was nowhere very high the effects of grazing as such were probably small, except locally near the larger fazendas, but we have no exact information on this.

Fire is certainly of much more importance than grazing, and it affects every part of the area which is not covered by forest. The cerrado, campo and some types of cerradão are frequently burnt, usually in June or July (early in the dry season). The fazendeiros burn the cerrado in order to increase the amount of grass relative to the woody plants, and in the campos when the dried remains of last season's vegetation are burnt, the grasses and other plants soon produce fresh young growth. As in other savanna areas this regrowth appears to be stimulated by

burning and happens well in advance of any substantial falls of rain. In 1968 a large campo in the 20 km square which was burnt early in June was covered with a lush growth of grasses which were coming into flower early in August, though no rain had fallen in the meanwhile. The indians also start fires on their hunting expeditions, but we found no evidence of lightning-induced or other natural fires; our Brazilian assistants, who on a number of occasions pointed out trees hit by lightning from which fire had not spread, were firmly of the opinion that such natural fires did not occur. But even in the remotest places we were able to visit there was evidence of past fires and the fire-tolerant characteristics of the cerrado and campo flora as a whole suggest that recurrent fires have been a normal factor of the environment for a very long time. This conclusion accords with the views of botanists with much longer experience of Brazilian vegetation than ourselves. Professor J. Murça Pires, for example, assured us that even in the most remote and uninhabited areas of Brazil he had never seen cerrado vegetation which did not show signs of having been burnt.

We have no precise information about the frequency of burning but it was evident that, as might be expected, fires are more frequent and more severe near Xavantina and the larger fazendas than elsewhere: it seems probable that in areas far from large settlements such as much of our 20 km square (as it was in 1967–9) fires do not occur every year and perhaps not more often than once in every four or five years. Such infrequent fires are fiercer and probably cause more damage than those taking place at annual intervals, since there is time for a greater quantity of dry grass and other combustible material to accumulate; thus it was common in the base camp area to see charring of the bark of cerrado trees to 4 m, or even higher above the ground, whereas around Xavantina charring was generally confined to the lowermost metre or two of the trunk. The varying frequencies of fires, together with differences in their severity caused by topographical variation, are probably important factors in influencing differences in structure and composition of the cerrado in our area.

The fires often encroach on the margins of the Dry forests and Swampy Galleries, but unless they are encouraged to do so they do not normally penetrate far, although they may sweep right through very narrow galleries. On the other hand, fires are probably quite common in the Deciduous forests and do no more damage there than in the cerrado.

2. Vegetation types and their distribution

The vegetation of the Xavantina–Serra do Roncador area belongs for the most part† to three main physiognomic types: forest, savanna and treeless grassland. These are known in Brazil as *mata*, *cerrado* and *campo* (or *campo limpo*) respectively. Like the Old World savannas, the Brazilian cerrados include a range of vegetation types ranging from open grasslands with scattered trees to savanna woodlands with a fairly continuous tree canopy and a scanty ground cover of grasses; the latter are called *cerradão* (the augmentative of *cerrado*, plural *cerradões*). Each of these physiognomic types includes several floristically distinct associations.

The distribution of forest, cerrado and campo in the Expedition's area follows a well-defined pattern (figure 3; figure 10, plate 39). In the northwestern part of the 20 km square there is almost unbroken forest, mostly of the type here termed Dry forest. This begins a few kilometres north of the base camp and stretches for many hundreds of kilometres north and west, eventually

† Exceptions are submerged aquatic vegetation in rivers and lakes, reed swamps, and the vegetation of temporarily emergent rocks and sandbanks in rivers.

merging with the great 'hylaea' of the Amazon. In the immediate neighbourhood of the base camp, from there to Xavantina, and for a great distance south and east, the landscape is a threefold pattern of cerrado, campo and gallery forest, characteristic of a vast part of central Brazil. The gallery forests form narrow strips following the rivers and their tributaries: they are seldom more than 100 to 200 m wide and are seen from the air as a characteristic dendritic pattern. Usually, but not invariably, the gallery forests are bordered on one or both sides by strips of open campo which are frequently no more than 40 to 50 m wide. On all the higher ground the plant cover is cerrado or cerradão, except locally on rocky scarps and lateritic outcrops where there are often small areas of very dry treeless grassland (the 'dry' or 'hill' grasslands of our classification).

A striking feature of the landscape in our area (and indeed of the cerrado area generally), whether seen from the air or on the ground, is the remarkably abrupt transitions between the different plant communities: the boundaries between gallery forest and campo, and between campo and cerrado are almost always very sharp. On the other hand, the transition between Dry forest and cerrado is generally more gradual and an intermediate band of cerradão, which is sometimes up to several km wide, often occurs between the two communities.

TABLE 2. CLASSIFICATION OF THE VEGETATION TYPES OF THE XAVANTINA–CACHIMBO EXPEDITION'S AREA

(Based on Richards (1968) with modifications by J. A. Ratter (1969). Aquatic vegetation omitted.)

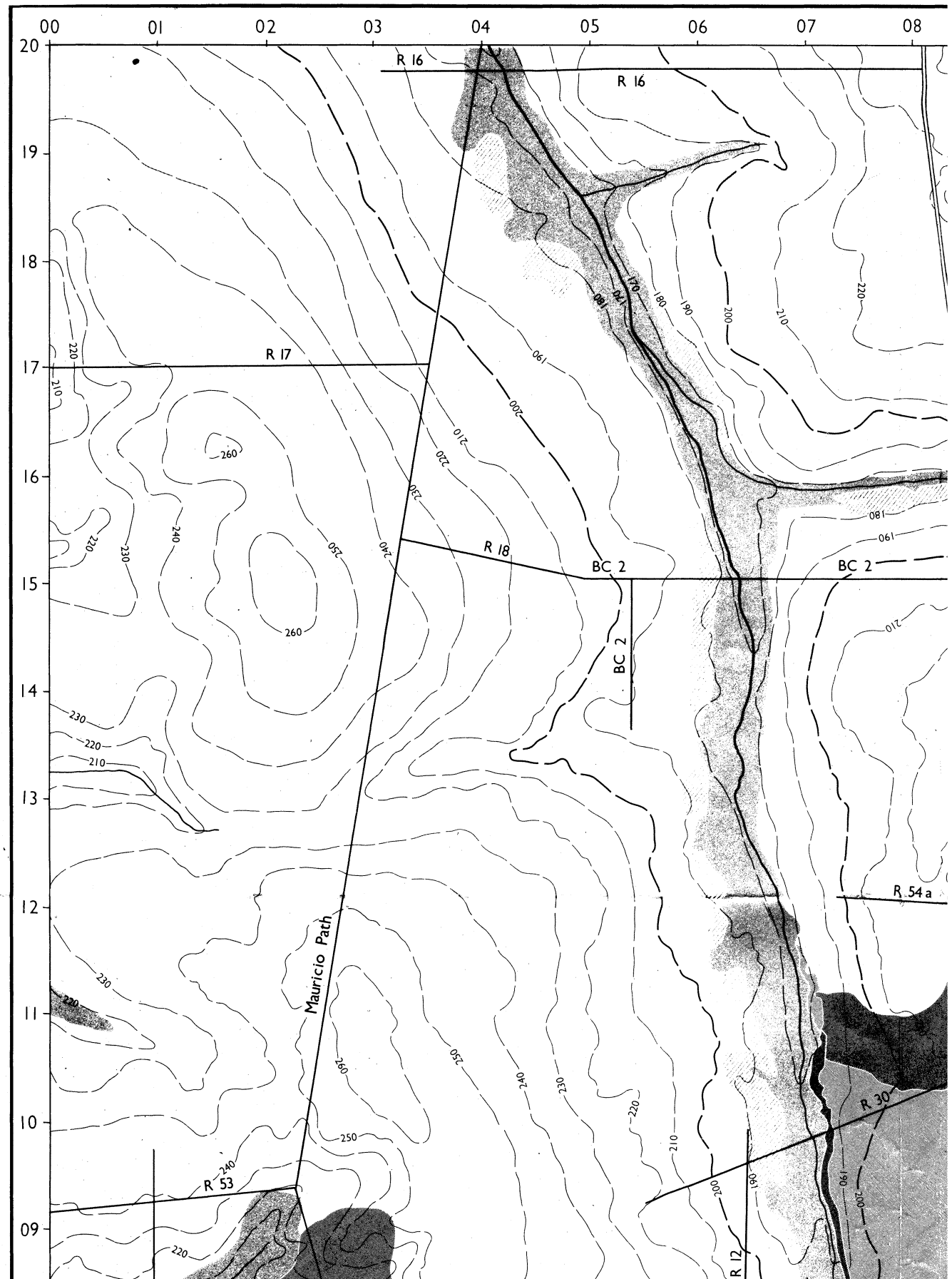
1. FOREST
   - Evergreen Seasonal forest (dystrophic soils)
     - 1.1 Swampy Gallery forest
     - 1.2 Valley forest
     - 1.3 Dry forest
     - 1.4 Carrasco (low forest on white sand)
   - Deciduous Seasonal forest (mesotrophic soils)
     - 1.5 Deciduous forest
2. SAVANNA
   - 2.1 Cerradão
     - 2.1*a* *Hirtella glandulosa* cerradão
     - 2.1*b* *Magonia pubescens*/*Callisthene fasciculata* cerradão
     - 2.1*c* Undifferentiated cerradão
   - 2.2 Cerrado
3. GRASSLAND
   - 3.1 Dry or hill grassland
   - 3.2 Moist valley grassland

The only important type of landscape which is poorly represented in the 20 km square, but occupies large areas in neighbouring parts of northeastern Mato Grosso is what is locally called 'pantanal' (not to be confused with the somewhat different vegetation types called pantanal in the basin of the Paraná in southern Mato Grosso). This is a type of 'termite savanna' in which mounds up to 2–3 m high and not more than 6–7 m in diameter, each carrying a group of cerrado trees and one or more termitaria, are scattered remarkably evenly over flat treeless grassland which is flooded in the wet season but dry from May or June until December or January. Studies were made of a small 'pantanal' a few kilometres southeast of Xavantina and very much larger areas were seen lower down the valley of the Rio das Mortes and in the Araguaia valley near the Ilha do Bananal.

VEGETATION MAP C

(Ratter et al.)

XAVANTINA-CA



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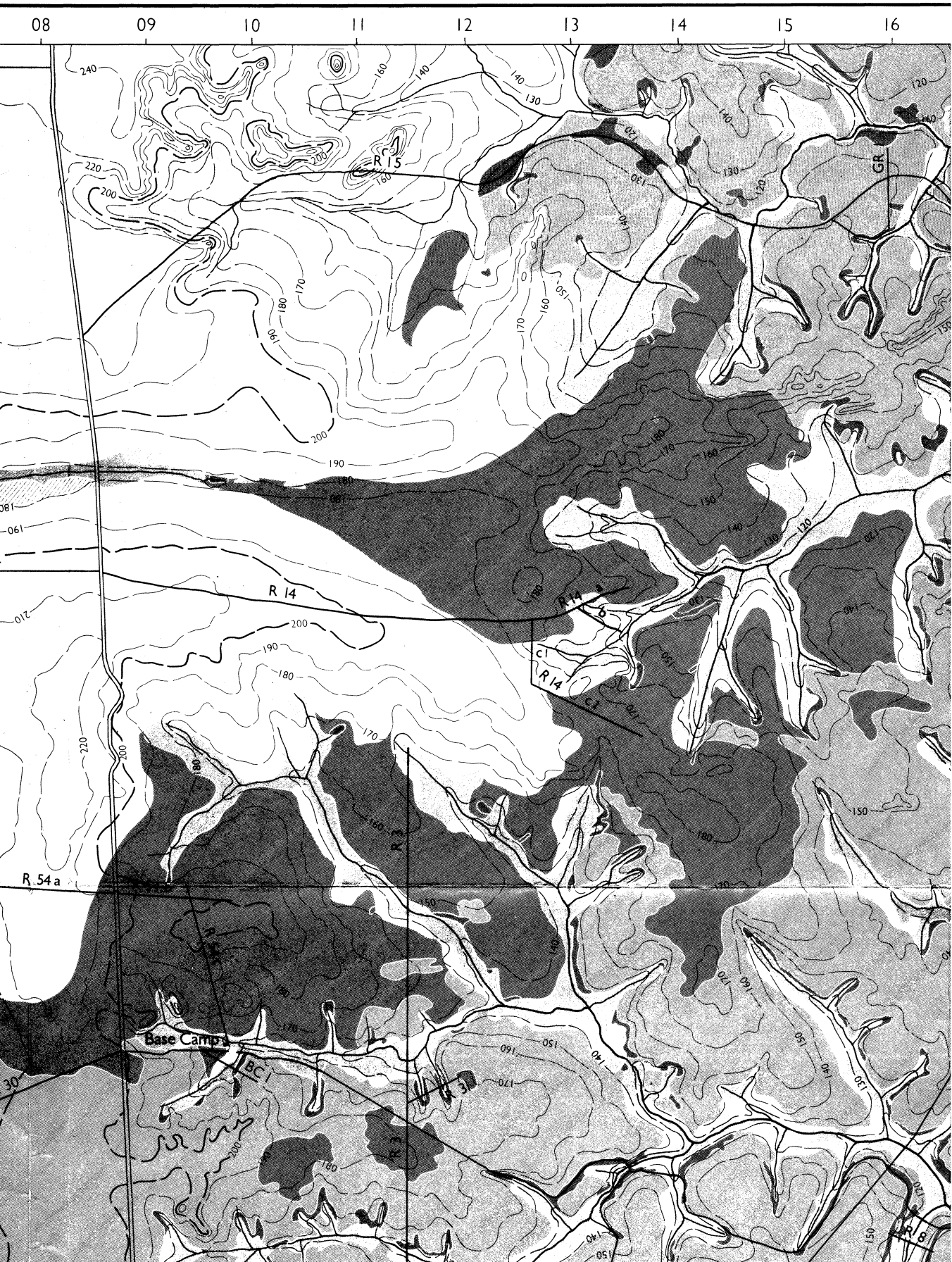
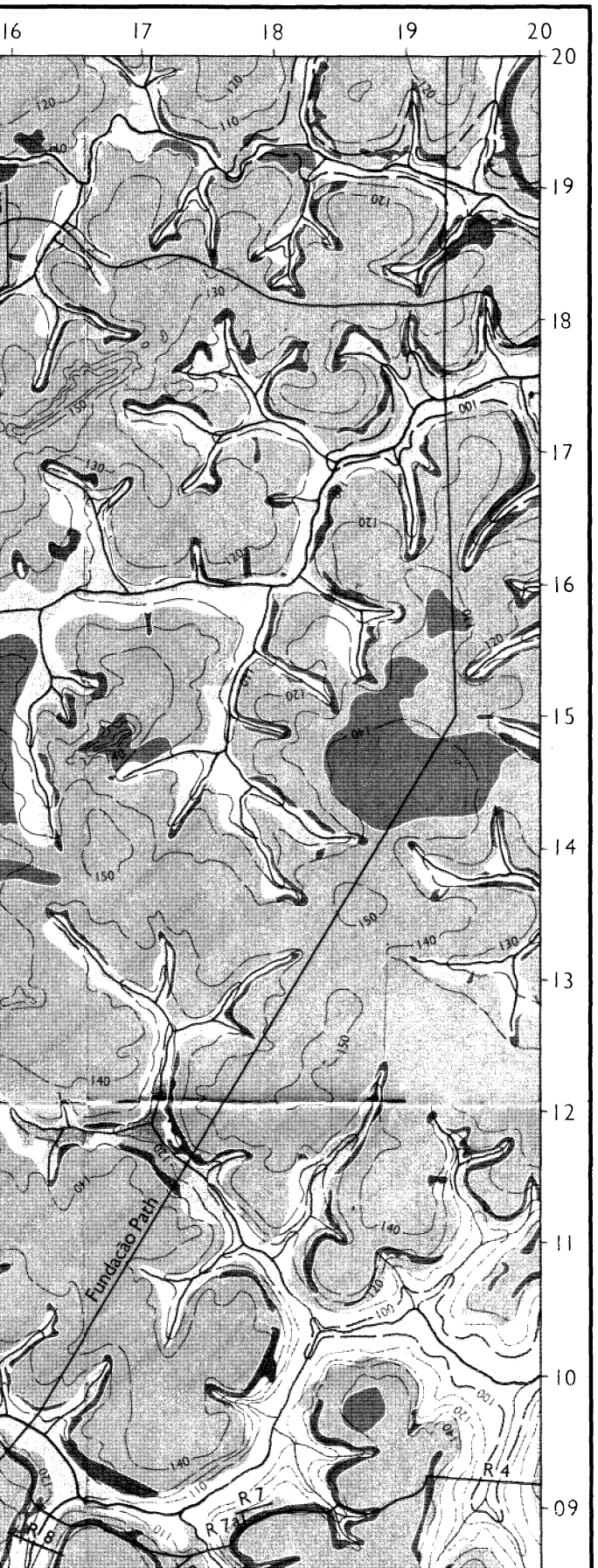
NA-CACHIMBO EXPEDITION TO CENTRAL BRAZIL





FOREST

Evergreen Seasonal Forest

SWAMPY GALLERY FOREST

VALLEY FOREST

DRY FOREST

CARRASCO

Deciduous Seasonal Forest

SAVANNA

CERRADÃO

CERRADO

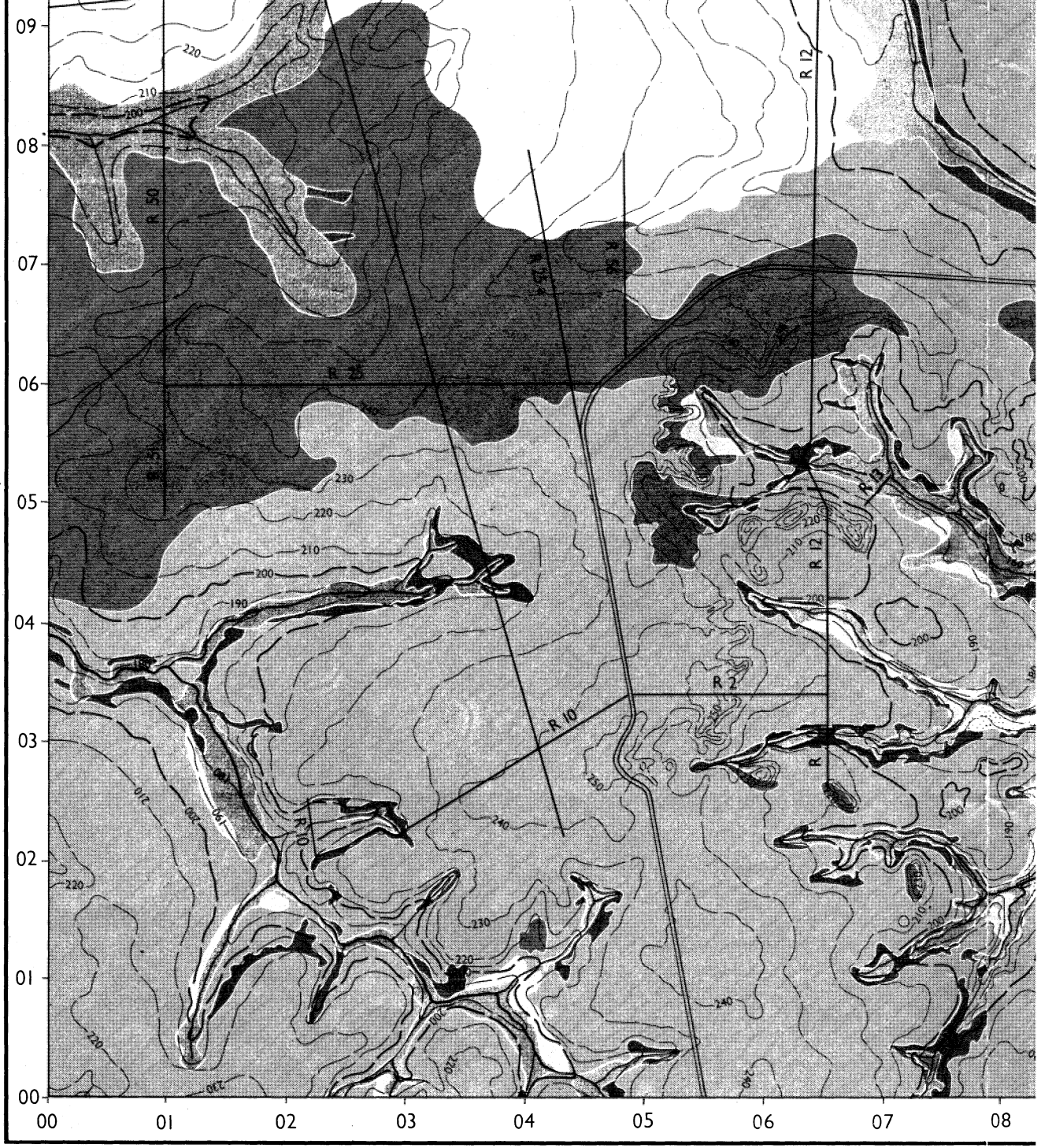
GRASSLAND (CAMPO)

Transect lines R 56

SCALE 1:50 000

Kilometres

1 0 1 2



G.P.Askew, D.J.Moffatt, R.F.Montgomery & P.L.Searl.

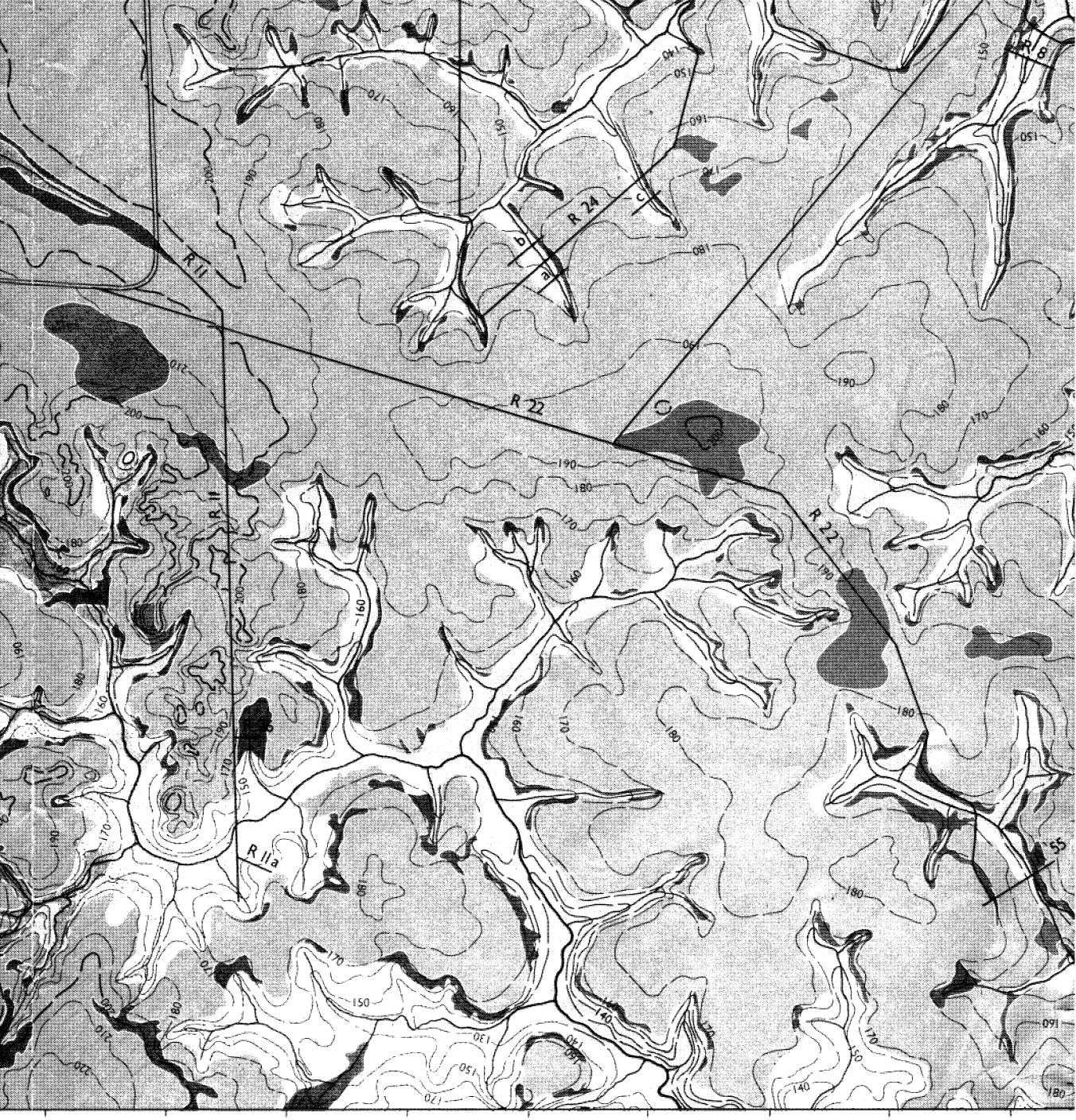
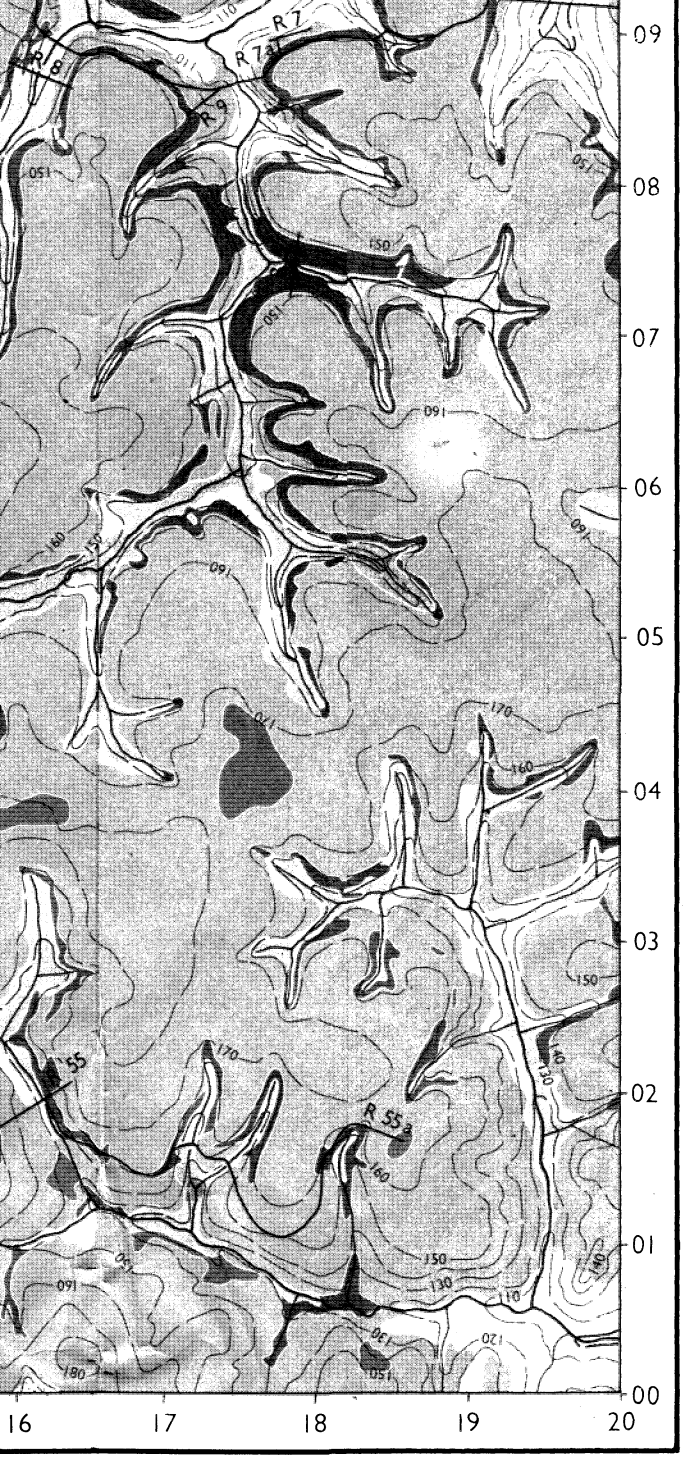


FIGURE 3

Repr



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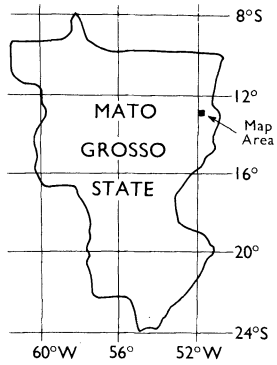
SCALE 1 : 50 000

Kilometres

1 0 1 2

Approximate position of Base Camp 12° 49'S 51° 46'W

Formline vertical interval 10 metres



Location of map in Brazil

COMPILATION NOTE

The base details for this map were produced photogrammetrically in 1968 by Fairey Surveys Ltd. from 1 : 45 000 scale photography. At that time no ground control was available and an arbitrary datum of 90 metres was given to the lowest formline. The road, soil transects and access paths have been added subsequently. The vegetation boundaries, as interpreted on the 1 : 45 000 scale air photographs by the authors, were transferred photogrammetrically to the base map by the Department of Surveying, University of Newcastle upon Tyne.

The classification of vegetation types set out in table 2 is adapted from the provisional scheme of Richards (1968) with modifications by Ratter (1969), which was adopted by the Xavantina–Cachimbo Expedition and has been used in some papers already published (Askew *et al.* 1970*a*, *b*, 1971; Ratter 1971). The terms 'Evergreen Seasonal forest' and 'Deciduous Seasonal forest' follow the usage of Beard (1955); the former was designated as 'Semi-evergreen Seasonal forest' in our earlier classifications, but since the proportion of truly deciduous trees is clearly less than a third of the total we now think it is more correctly placed as Evergreen Seasonal forest on Beard's criteria.

It is difficult to compare precisely the categories we recognize with others described in the literature, but it is worth mentioning that our Valley and Dry forests belong to the 'Amazon semi-deciduous' category of Veloso (1966), while our Deciduous Seasonal forest probably corresponds to his 'Tropical Deciduous forest of the central Western uplands'. Our categories fit into Eiten's (1968) elaborate scheme for describing world vegetation as follows: the Dry forest represents a form of his 'Evergreen broadleaf forest with emergents', while the Valley and the Swampy Gallery forests both belong to his 'Evergreen Broadleaf forest' (or possibly 'Semi-deciduous Broadleaf forest', since he requires 90 % of the stand to be evergreen to fall within the former category whilst Beard stipulates only two-thirds). Our Deciduous Seasonal forest represents a form of Eiten's 'Deciduous Broadleaf forest' or possibly, 'Deciduous Broadleaf open forest with closed scrub'. All our cerradão forms would probably fall into his 'Semi-deciduous Broadleaf forest', while the structurally variable cerrado falls into several of his classes.

Figure 3 is a map of the distribution of the main vegetation types in the intensively studied 20 km square: it was constructed by Askew *et al.* (1970*a*) who correlated air photographs with ground observations.

(*a*) *Swampy Gallery forest* (1.1)

This occurs as narrow strips along streams in the dystrophic soil landscape wherever the drainage is so impeded that the water-table, even in the dry season, never falls far† below the surface of the ground and sometimes forms permanent pools. Swampy galleries are best developed near the headwaters of streams (cabeceiras), where the water has not cut a deep channel: here the gallery forest, which farther downstream is usually quite narrow, may expand to a width of 100 m or more. Like most plant communities of the area, the Swampy Gallery forest usually has sharp boundaries: where it abuts on open campo its margin is a solid wall of vegetation, a mass of Scitamineae, climbers and smaller woody plants filling the spaces between the trunks and branches of larger trees. In contrast to this, the interior of the gallery forest is mostly comparatively open and easy to penetrate.

The substratum is a hydromorphic soil rich in organic matter. Below the litter of twigs and dead leaves there is a blackish humose mineral horizon that is sometimes covered by a well-developed peaty layer; the latter is 10 cm thick on the transect at Xavantina. Askew *et al.* (1970*a*) found that the base status of the soil is low, although the exchangeable calcium of the A horizons is on the average about four times higher than in the drier dystrophic soils of the Dry forest.

The structure of the tree layers is shown in figures 4*a* and 5*a*. Although the trees are not clearly stratified, it is convenient to speak of them as forming three strata, the uppermost con-

† The maximum depth of the mean ground water level in Swampy Gallery forest sites at the height of the dry season in 1968 was 112 cm (Askew *et al.* 1971).

sisting of trees 25–40 m high with boles up to 2 m in diameter and massive crowns. This layer is formed chiefly by two *Qualea* species, the blue-flowered *Q. ingens*† and the white-flowered *Q. wittrockii*, which together constitute 58 % of the trees over 120 cm in girth at breast height and 90 % of those over 190 cm on the plots which we examined; both species are represented in the lower layers by numerous seedlings and saplings. Other trees characteristic of this layer are *Luheopsis* sp. (R 6898) and several species of *Sloanea*, whilst *Virola albidiflora* and various other species sometimes reach it also. *Symphonia globulifera*, a widespread species of seasonally flooded (várzea) forests in Amazonia and the Guianas, also belongs to the uppermost layer of the galleries near base camp; it was not noted near Xavantina. In the middle storey *Pseudolmedia laevigata*, *Guarea trichilioides*, *Pouteria* sp. (Ra 599) and other species are common, and below these are numerous smaller trees of about 4–10 m, e.g. *Protium* (three species), *Bauhinia dubia*, *Miconia tomentosa* and other Melastomataceae.

Most of the trees seem to be completely evergreen, but others lose part of their foliage in the dry season without ever becoming completely bare. The total leaf area is thus somewhat reduced in July and August compared with the rest of the year.

Buttresses are in general not well developed in Swampy Gallery forest trees, but occur in a few species, e.g. *Pouteria* sp. (Ra 599), *Qualea wittrockii* and *Symphonia globulifera*. The roots of the trees are very superficial, and form a dense tangled mat close to the ground surface in which the thick cylindrical surface roots of the two Qualeas are conspicuous. As in most tropical swamp forests the root systems of some species form specialized 'pneumatophores'. Small loop- or knee-like pneumatophores are produced by *Qualea ingens* (but not by *Q. wittrockii*), *Symphonia globulifera*, *Luheopsis* sp., *Virola albidiflora*, and probably other trees. In small pools of standing water the last named also produces upright 'peg-roots' of the *Avicennia* type. In places great numbers of loop-like roots are massed together to form hummocks 30–50 cm high on which dead leaves and humus collect: these form the main habitat for most of the terrestrial ferns in this community. Stilt roots were observed only in *Symphonia globulifera*.

Tall palms play an important part in swampy galleries and *Euterpe* sp. (Ra 2044) is characteristic. *Mauritia flexuosa* is frequent on the margins of galleries bordered by campos, and in some galleries very tall individuals (unaccompanied by smaller ones) occur many metres within the forest: this suggests that the gallery has recently invaded the adjoining campo, since the only situations in which we have seen young plants is on open campos by streams or where there are possibly underground watercourses.

The undergrowth beneath the trees consists of young trees, shrubs, and both tall and low-growing herbaceous plants: its density is very variable, depending apparently on the completeness of the tree canopy and the height of the water table. The tall shrubby *Piper arboreum* is very common and two semi-woody myrmecophilous Melastomataceae, *Tococa formicaria* and *Myrmidone macrosperma* are frequent in wetter areas. Smaller melastomataceous herbs, *Cephaelis tomentosa*, *Faramea salicifolia*, *Heliconia hirsuta*, Marantaceae, *Rapatea* sp., *Costus* sp., Cyperaceae and ferns (including the hygrophilous *Trichomanes pinnatum*) locally form a dense ground cover. A scrambling 'razor grass', *Scleria* sp. (Ra 2118), is common and dense stands of the bamboo-like *Olyra latifolia* cover many square metres in the less shaded areas. In some of the larger galleries stands of the banana-like *Phenakospermum guyanensis* (formerly placed in *Ravenala*)

† A full list of species mentioned (with authorities and collecting numbers) is given in the appendix. Collecting numbers are given in the text only when species are still unidentified. A complete list of vernacular plant names of the area will be published elsewhere (Ratter). A few such names are used in this paper.

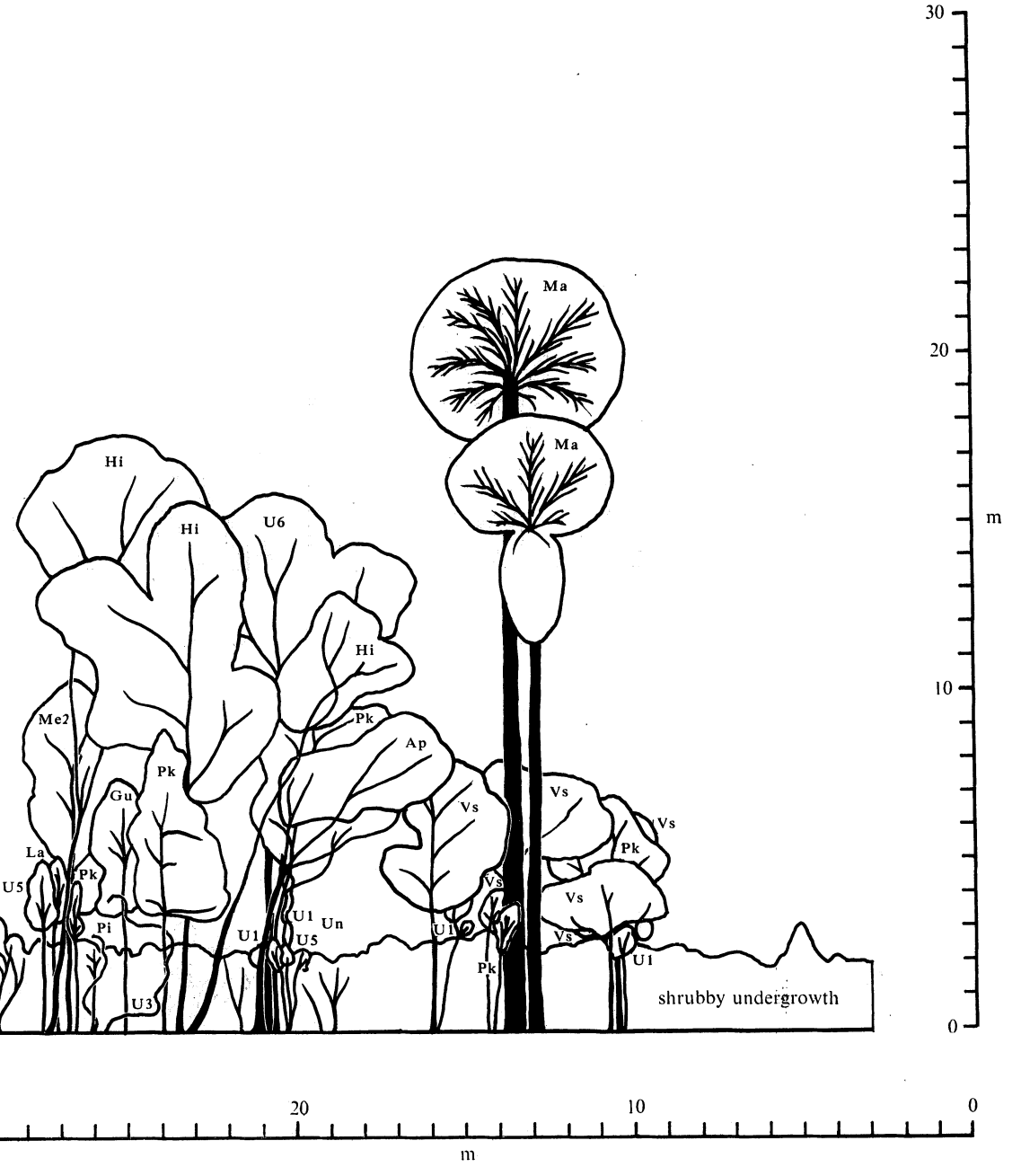
(*a*)


Qw
Qi
Qi
Pk
Pk
Ce
Ce
Ce
Ce
Hi
Sl
Pi
Pi
U1
Pi
Pi
Pi
Sl
Sl
Ps
Hi
Sl
U7
Pi
Me
Pi
Me
Pi
Pi
Po
Qi
Qi
Ma
Vi
Sl
Po
Sl
Sl
U3

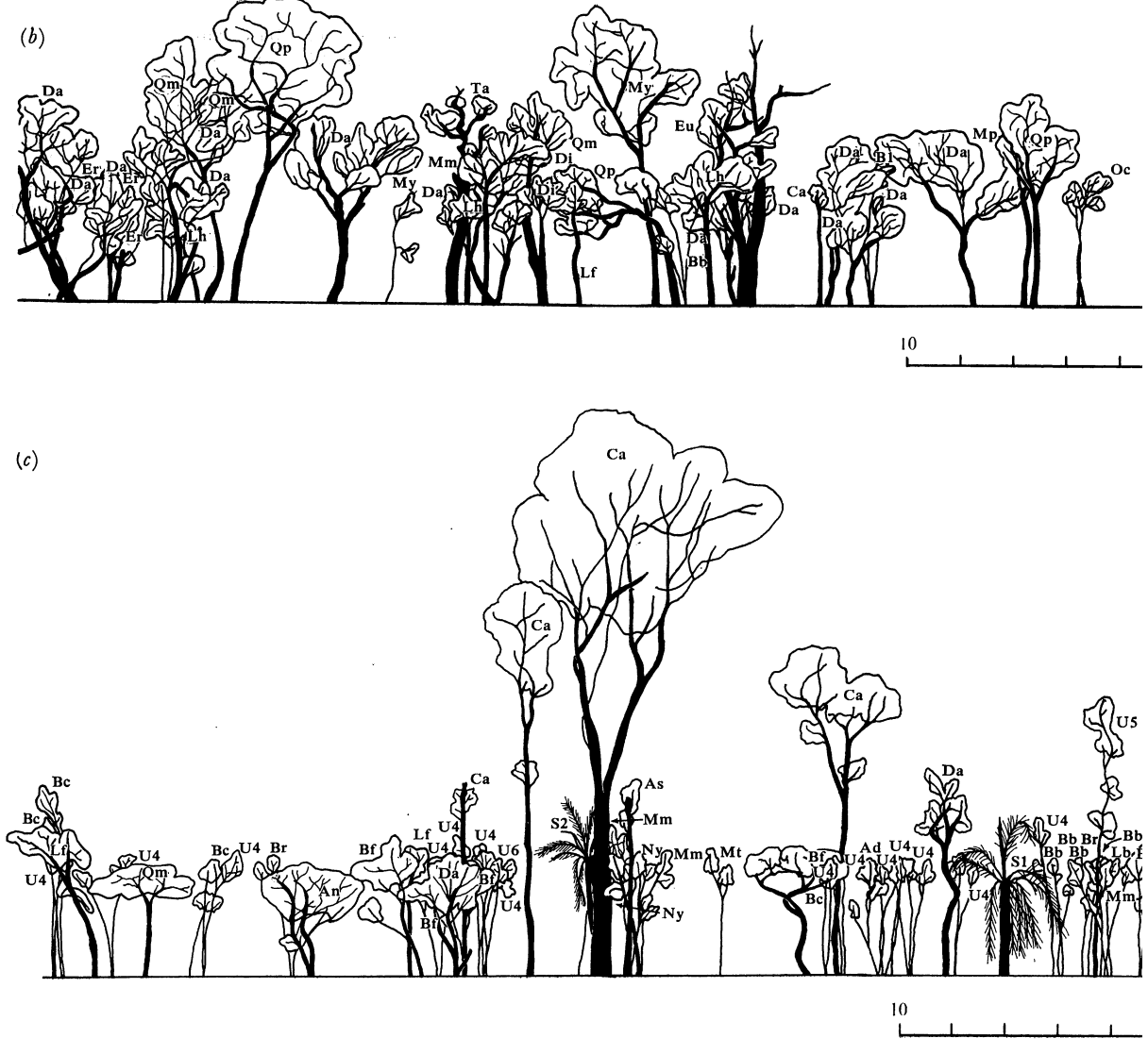
(*b*)

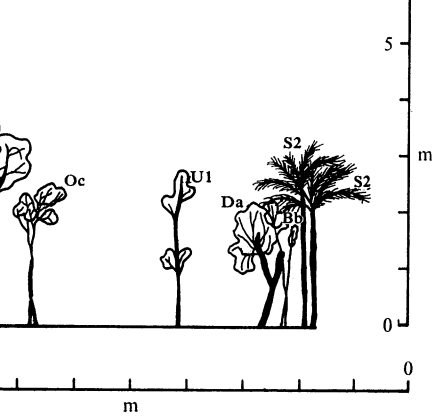

Qp
Qm
Ta
My

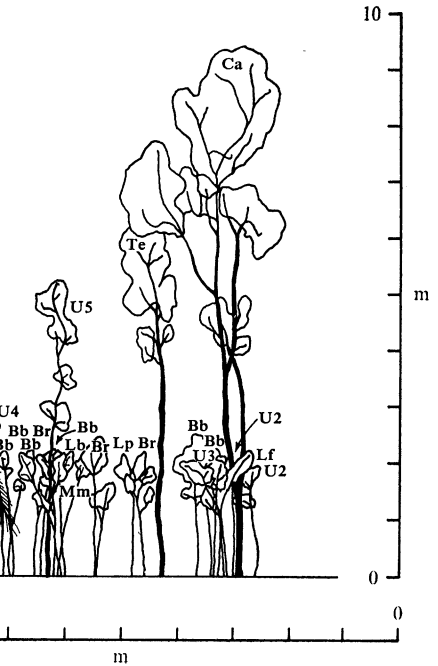
FIGURE 4. Profile diagrams of vegetation at Xava
ning longitudinally) through strip of Swampy
mounds) (90 m × 8 m); (*b*) cerrado on low-ly
with affinities to *Magonia-Callisthene* cerradão
8 m).



n at Xavantina. All plants 2 m high and over shown. (*a*) section (run-
f Swampy Gallery forest to margin of pantanal (grassland with termite
on low-lying site close to margin of pantanal (25 m × 8 m); (*c*) cerrado
cerradão at slightly higher level (400 m further from pantanal) (25 m ×


(b)
Da
Qm
Qp
Ta
My
Eu
Mm
Dj
Qp
Lf
Bb
Ca
Mp
Oc
Er
Lh
10
(c)
Ca
Bc
Lf
U4
Qm
Br
An
Bf
U6
Da
As
S2
Mm
Ny
Mt
Ad
S1
Bb
U5
10





ning longitudinally) through strip of Swampy
mounds) (90 m × 8 m); (*b*) cerrado on low-ly
with affinities to *Magonia-Callisthene* cerradão
8 m).

(*a*)	Ap	*Apeiba tibourbou*
	Ce	*Cecropia pachystachya*
	Fi	*Ficus* sp.
	Gu	*Guarea trichilioides*
	He	*Heliconia hirsuta*
	Hi	*Hieronyma alchorneoides*
	La	*Lauraceae* (indet.)
	Lu	*Luheopsis* sp. (Jangada, R 6898)
	Ma	*Mauritia flexuosa*
	Me	Melastomaceae (Ra 583)
	Me2	*Miconia tomentosa*
	Pi	*Piper arboreum*
	Po	*Pouteria* sp.? (Jará, Ra 599)
	Pk	*Protium krukoffii*
(*b*), (*c*)	Ad	*Andira cuyabensis*
	An	*Annona coriacea*
	As	*Aspidosperma nobile*
	Bb	*Bauhinia bongardi*
	Bc	*Bauhinia curvula* (?)
	Br	*Brosimum gaudichaudii*
	Bf	*Byrsonima crassifolia*
	Ca	*Callisthene fasciculata*
	Da	*Davilla elliptica*
	Di	*Dimorphandra mollis*
	Er	*Erythroxylum suberosum*
	Eu	*Euplassa inaequalis*
	Ht	*Heisteria densifrons*
	Lb	Labiatae (indet.)
	Lf	*Lafoensia pacari*
	Lh	*Licania humilis*
	Lp	*Luhea paniculata*
	Mt	*Matayba guianensis*

f Swampy Gallery forest to margin of pantanal (grassland with termite on low-lying site close to margin of pantanal (25 m × 8 m); (*c*) cerrado cerradão at slightly higher level (400 m further from pantanal) (25 m ×

key to species

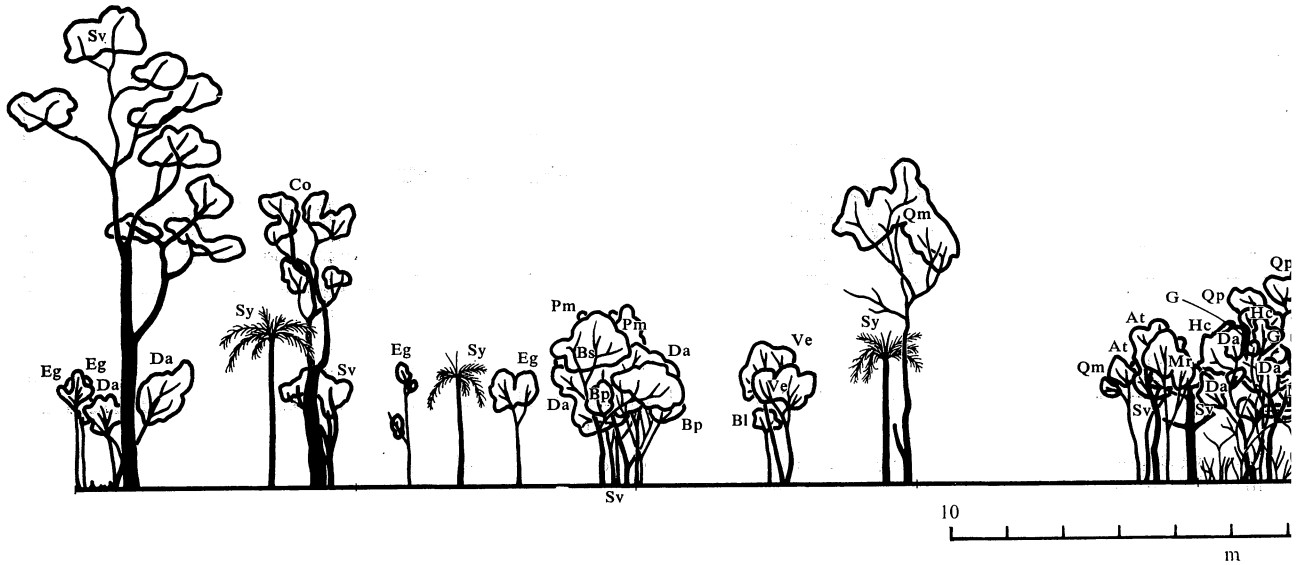
Ps	*Pseudolmedia laevigata*
Qi	*Qualea ingens*
Qw	*Q. wittrockii*
Sl	*Sloanea sinemariensis* (and *S. eichleri*?)
Un	*Uncaria guianensis*
Vi	*Virola albidiflora*
Vs	*Vismia magnoliaefolia*
U1	Unknown (Mororo)
U2	Unknown
U3	Unknown (liane)
U4	Unknown (Guache)
U5	Unknown
U6	Unknown (Pau chorão)
U7	Unknown

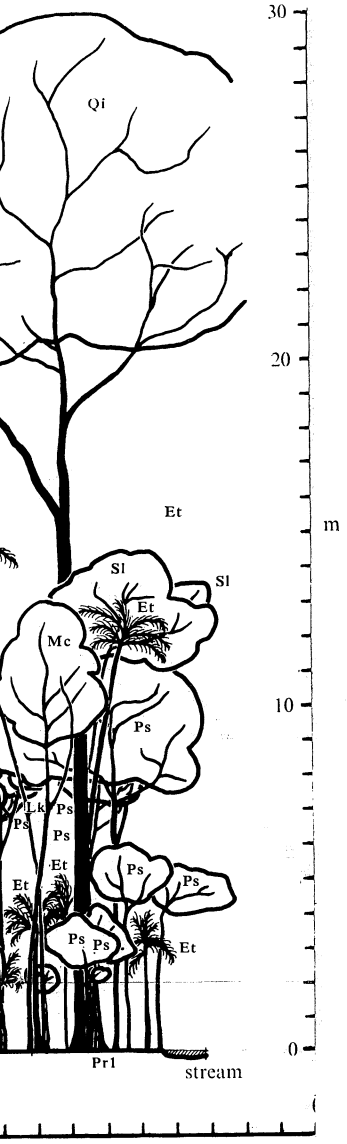
Mm	*Mimosa obovata*
Mp	Malpighiaceae (indet.)
My	*Myrcia* sp
Ny	Nyctaginaceae (indet.)
Oc	Ochnaceae (?) (indet.)
Qm	*Qualea multiflora*
Qp	*Q. parviflora*
S1	*Syagrus* sp. (1)
S2	*Syagrus* sp. (2)
Ta	*Tabebuia caraiba*
Te	*Terminalia* sp.
U1	Unknown (1)
U2	Unknown (2)
U3	Unknown (3)
U4	Unknown (4)
U5	Unknown (5)
U6	Unknown (6)

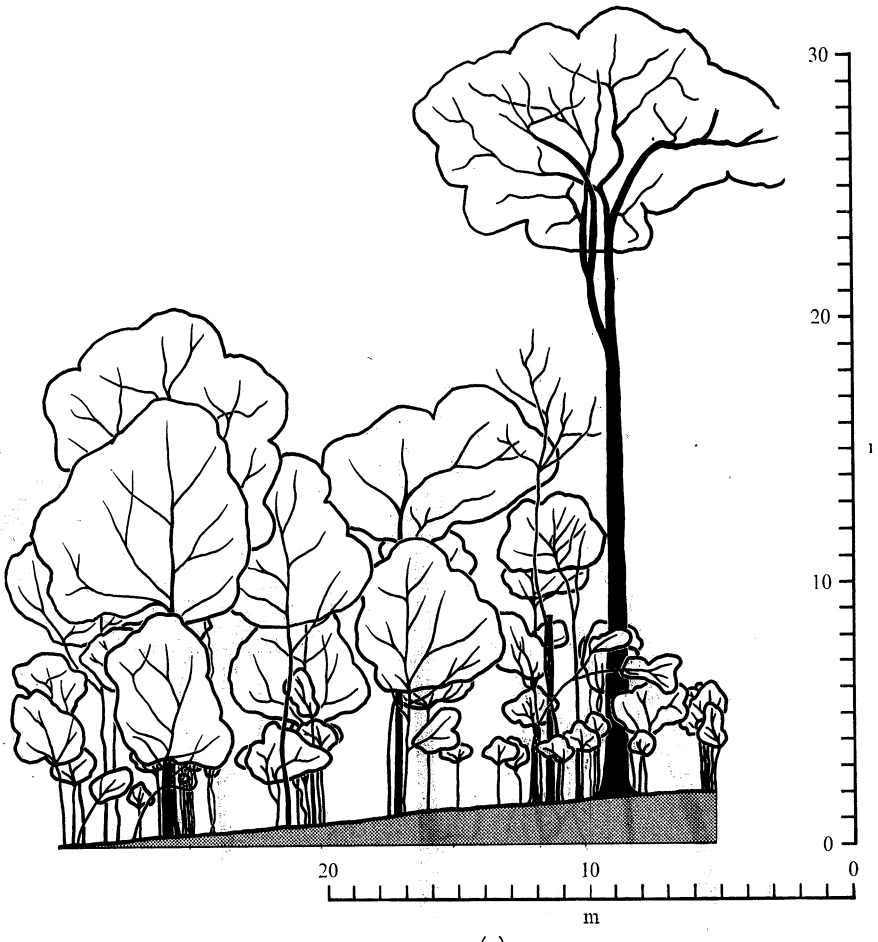
(*Facing p.* 460)


Qi
Prl
Et
Po
Sl
Mc
Ri
Tp
Oul
Ps
Lap
Hn
Pu
Upo
Si
Up
Lk
Br
Ct
Us
To
Lad
Sh
Ce
Pi
Vc
Qw
St
Vi
campo
30
20
10
m

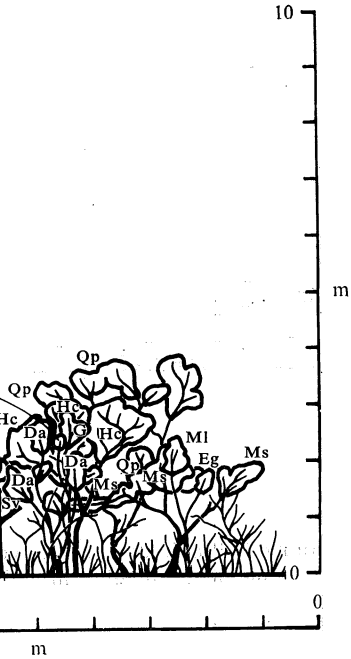
(*a*)


Sv
Co
Sy
Eg
Da
Pm
Bs
Bp
Ve
Bl
Qm
G
Qp
At
Hc
Mr
10
m



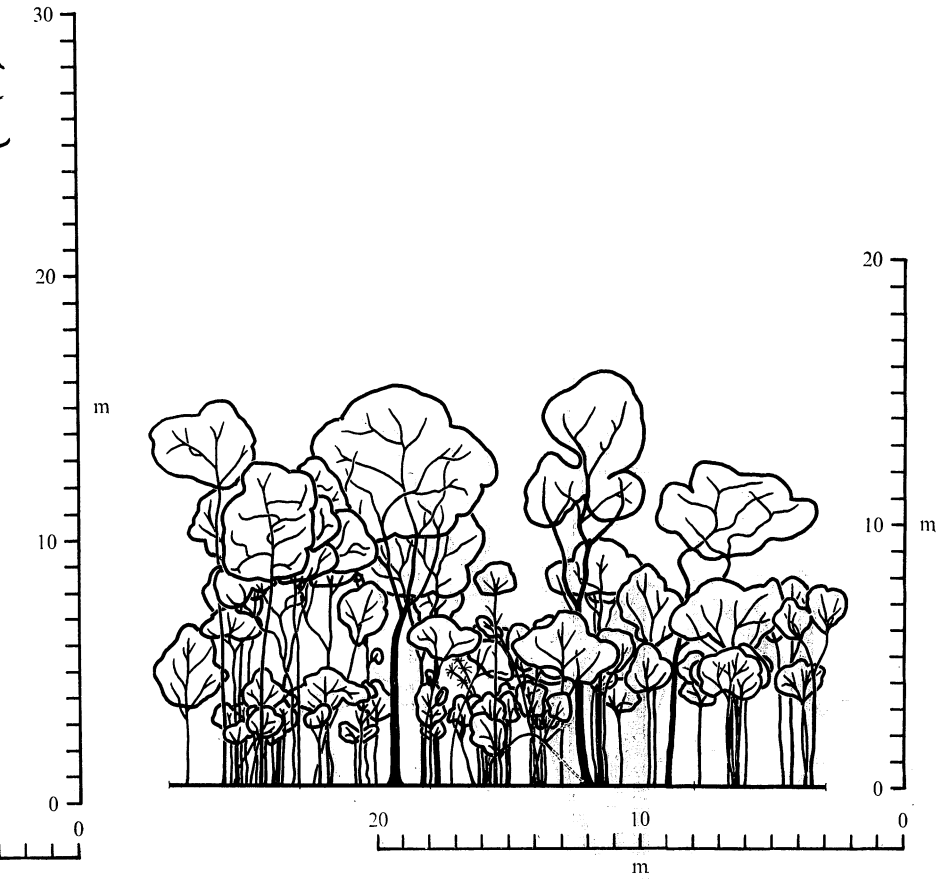


(*a*)

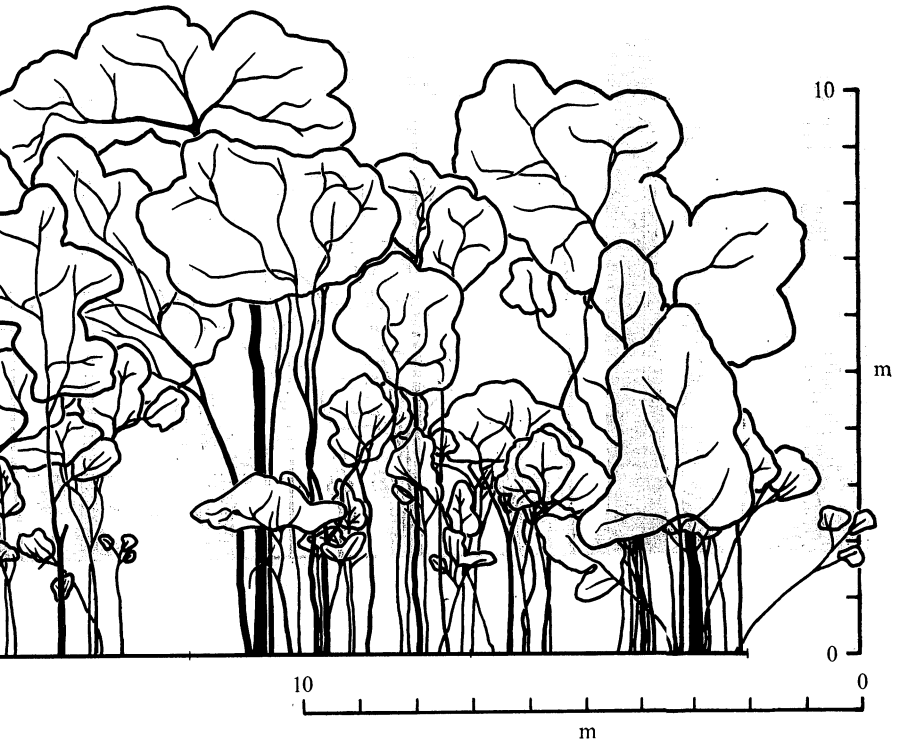


(*c*)

FIGURE 6. Profile diagrams of Valley forest, Dry forest
(transect B.C. 1). (*a*) Valley forest; (*b*) Dry forest; (*c*



(*b*)



(*c*)

Dry forest and Dry forest–cerradão transition near base camp
forest; (*c*) Dry forest–cerradão transition. (Each 25 m × 8 m.)

(*b*)

FIGURE 5. Profile diagrams of Swampy Gallery forest and cerrado near base camp (transect B.C. 1). (*a*) Sw
Gallery forest (40 m × 8 m); (*b*) cerrado (25 m × 8 m). (Grassy undergrowth only indicated for right hand

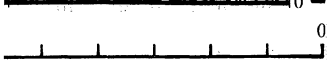
key to species

(*a*)

Br	Indet. (Bacurí, R 6920)
Ce	*Cecropia pachystachya*
Ct	Indet. (Catoarí, R 6986)
Et	*Euterpe* sp. (Ra 2044)
Gt	*Guatteria* sp. (Invireira, Ra 1143)
Hn	*Henriettella ovata*
Lad	Lauraceae (Louro cobra or Louro dorado, indet.)
Lap	Lauraceae (Louro precioso, R 6916)
Lb	*Licania blackii*
Lk	*L. kunthiana*
Mc	*Myrcia* sp. (Pixuna)
Me	Melastomataceae (R 6915, Ra 583)
Ou1	*Ouratea* sp. (1) (Bacurí)
Ou2	*Ouratea* sp. (2)
Ou3	*Ouratea* sp. (3)
Pi	*Piper arboreum*
Po	*Pouteria* sp.? (Jará, Ra 599)
Pr1	*Protium* sp. (1) (Almécega breu)
Pr2	*Protium* sp. (2) (Ra 1840)
Pr3	*Protium* sp. (3) (Ra 2049)
Ps	*Pseudolmedia laevigata*
Pu	Myrtaceae (Purú, indet.)
Qi	*Qualea ingens*
Qw	*Q. wittrockii*
Ri	*Richeria grandis*
Sh	*Schoepfia obliquifolia*
Si	*Siparuna guianensis*
Sl	*Sloanea sinemariensis* and/or *S. eichleri*
St	*Strychnos* sp.
To	*Tococa formicaria*
Tp	Indet. (Trapiá de mata, R 6917)
Vi	*Virola albidiflora*
Uc	Unknown (liane)
Upo	Unknown (Pau pombo?)
Us	Unknown (shrub)

(*b*)

At	*Aspidosperma tomentosum*
Bl	*Byrsonima basiloba*
Bp	*B. pachyphylla*
Bs	*B. crassa*
Co	*Connarus fulvus*
Da	*Davilla elliptica*
Eg	Myrtaceae (Murtinha, Ra 2075)
Hc	*Hancornia speciosa*
G	*Aspidosperma tomentosum*
Ml	Malpighiaceae (indet. Ra 2092)
Mr	*Myrcia* sp. (Ra. 1983 V)
Ms	*Myrcia* sp.
Qm	*Qualea multiflora*
Qp	*Q. parviflora*
Pm	*Pouteria ramiflora*
Sv	*Salvertia convallariodora*
Sy	*Syagrus* sp. Gariroba (Ra 1987
Ve	Compositae Veludo (Ra 1926



1). (*a*) Swampy
ight hand 5 m.)

· *S. eichleri*

R 6917)

a 2075)

2092)

1987
1926

(*c*

FIGURE 6. Profile diagrams of Valley forest, Dry fores
(transect B.C. 1). (*a*) Valley forest; (*b*) Dry forest; (*c*

(*c*)

Dry forest and Dry forest–cerradão transition near base camp
forest; (*c*) Dry forest–cerradão transition. (Each 25 m × 8 m.)

grow to about 6 m and are important in the understorey. Saprophytic flowering plants, a group characteristic of the Amazonian rain forest, are represented by *Leiphaimos calycina* sp. (R 6631), found once in the gallery near base camp.

Tall lianes such as *Uncaria guianensis* and *Bauhinia guianensis*, the latter with a characteristic scalariform stem, are common in most galleries and sometimes found in the crowns of the taller trees, but their stems are not generally of large diameter. Other lianes are various Bignoniaceae, Araceae (root climbers on tree trunks), the climbing fern *Polybotrya caudata*, and the thorny scrambling palm *Desmoncus* sp. (AR 6479). Vascular epiphytes include Bromeliaceae, Orchidaceae, Cactaceae and ferns (including *Trichomanes cristatum* and *T. punctatum* subsp. *labiatum*), but they are few in individuals and species and are seldom found above 2 m from ground level. Epiphytic mosses and Hepaticae are also present but the number of species is relatively small. Epiphyllae (Lejeuneaceae and lichens) are found very sparingly on leaves in the undergrowth of the moister galleries.

Larger Swampy Gallery forests which are surrounded by other forest associations are generally more complex in structure and species composition than the small 'cabeceira' woods surrounded by open campo. The latter frequently consist almost entirely of a central region dominated by the two *Qualea* species surrounded by a fringe in which *Mauritia* palms, the thick-trunked *Richeria grandis*, *Cecropia pachystachya* and sometimes the spectacular red-flowered small tree, *Ferdinandusa speciosa*, are conspicuous. Such narrow Swampy Galleries have a luxuriant undergrowth probably owing to the additional light penetrating from the margins. The more complex galleries which are surrounded by other types of forest have various tree species in their marginal zone which are also found in the latter, e.g. *Aspidosperma nitidum*, *Didymopanax morototoni* and *Unonopsis lindmannii*. *Tabebuia avellanedae* also occurs in the marginal zone of such galleries, probably where soils are somewhat richer in nutrients.

Most of the tree species of the Swampy Gallery forest (Table 3) are confined to this community, at least in the Expedition's area, but some are also found in other associations, e.g. *Aspidosperma nitidum*, *Didymopanax morototoni*, *Cariniana rubra* and *Jacaranda copaia* are found in the damper Valley forests and the three *Protium* species and *Unonopsis lindmannii* are also common in both Valley and Dry forests. *Licania blackii*, *L. kunthiana*, *Chaetocarpus echinocarpus* and *Sacoglottis guianensis* are examples of species characteristic of the drier types of evergreen forest which occasionally occur under swampy conditions.

Table 3 lists the tree species in five plots in Swampy Gallery forest. The figures for trees 120 and 190 cm in girth and over at breast height represent fairly accurately the characteristic larger species, although, in addition large specimens of a number of species are common but did not occur in the plots, e.g. *Aspidosperma nitidum*, *Sloanea* spp.

In structure and physiognomy the Swampy Gallery forest resembles some types of Swampy Tropical Rain forest, although some rain forest features such as cauliflory and buttressing are absent or poorly developed and species diversity in all synusiae is much less. Floristically the Swampy Gallery forests also have much in common with the Amazonian rain forest. In addition to *Symphonia*, mentioned above, many other trees and undergrowth species occur in the Amazon forest or are nearly related to Amazonian species. Further examples are *Virola albidiflora*, originally described from river banks in Amazonia, *Cariniana rubra*, said by Ducke & Black (1953) to be one of the largest trees of the hylaea, and *Phenakospermum guyanensis*. *Qualea wittrockii* is widespread in 'igapó' (permanently swampy) forest in Pará and Amazonas. *Q. ingens* var. *ingens* has only been previously collected in Mato Grosso (Rio Aterrado, near Cuiabá, coll. Riedel), but

TABLE 3. TREE SPECIES IN SWAMPY GALLERY FOREST

Plot 1: Xavantina (100 m × 100 m). Trees 30 cm girth and over at breast height.
Plots 2 and 3: base camp (50 m × 25 m). Trees 10 cm and over at breast height.
Plot 4: base camp (100 m × 5 m). Trees 7 cm and over at breast height.
Plot 5: base camp (25 m × 8 m). Trees 7 cm and over at breast height.

Numbers of individuals 120 cm girth and over shown in parentheses.

Species represented on the plots by three individuals or less have not been listed separately unless they included trees of 120 cm girth or over, or were considered particularly characteristic of the community; 27 species belonged to this category of which 13 were recorded only once.

species	plots 1	2	3	4	5	total (all plots)	total with girth ⩾120 cm	⩾190 cm
(*a*) Species represented by more than 10 individuals (all plots)								
Bombax sp. (Embiruçú R 6595)	9 (1)	—	25	—	—	34	1	—
Calophyllum brasiliense	9 (1)	1	11	—	—	21	1	—
Cariniana rubra	8 (2)	2	2	—	—	12	2	1
Cecropia pachystachya	28	1	—	—	—	29	—	—
Euterpe sp. (Ra 2044)	—	36	15	1	11	63	—	—
Guarea trichilioides	6	4	6	—	—	16	—	—
Hieronyma alchorneoides	18	3 (1)	1	1	—	23	1	—
Jacaranda copaia	2	—	—	11	—	13	—	—
Licania blackii	—	14	3	1	—	18		—
Luheopsis sp. (Jangada R 6898)	8 (4)	1	7 (3)	—	—	16	7	2
Mauritia flexuosa	12 (5)	—	2	—	—	14	5	—
Miconia splendens / *M. tomentosa*	17	1	—	9	—	27	—	—
Pouteria sp. (Jará Ra 599)	54 (1)	5	—	—	3	62	—	—
Protium sp. (Almécega Branca Ra 1810)		—	21	3	3		—	—
Protium sp. (Breu Branco Ra 1840)	140 (6)†	—	12	—	—	249	6	—
Protium sp. (Almécega Vermelha Ra 2049)		27	40	3	—		—	—
Pseudolmedia laevigata	36	46	4	7	28	121	—	—
Qualea ingens	32 (22)	5 (3)	32 (5)	—‡	2 (1)	71	31	23
Q. wittrockii	14 (11)	2 (2)	17 (3)	—‡	—	33	16	12
Sloanea guianensis	10	6	8	—	—	24	—	—
S. eichleri / *S. sinemariensis*	77	—	—	2 (1)	16	95	1	—
Symphonia globulifera	—	6	6	—	—	12	—	—
Virola albidiflora	9	7 (2)	7	—	—	23	2	1
Vismia magnoliaefolia	12	—	—	—	—	12	—	—
Xylopia amazonica	—	2	54	—	—	56	—	—
(*b*) Species represented by less than 10 individuals (all plots)								
Aspidosperma nitidum	1	—	—	—	—	1	—	—
Bauhinia dubia	—	—	2	—	—	2	—	—
Didymopanax morototoni	3	—	2 (1)	—	—	5	1	1
Hirtella gracilipes	1	—	—	—	1	2	—	—
Licania kunthiana	—	5	2 (1)	—	—	7	1	—
Liriosma singularis	—	—	—	—	1	1	—	—
Miconia ampla	—	—	3	1	—	4	—	—
Myrcia sp. (Pixuna)	—	4	3	—	—	7	—	—
Siparuna guianensis	—	—	—	2§	—	2	—	—
Tabebuia avellanedae	—	—	—	—	3	3	—	—
Unonopsis lindmannii	—	—	—	5	—	5	—	—
Vochysia pyramidalis	—	—	1	—	—	1	—	—
Lauraceae (Louro Rosa Ra 2024)	—	3	1	—	—	4	—	—
Leguminosae (Sicupira do Brejo R 6910)	—	1 (1)	—	—	—	1	1	—
Sapotaceae (Maceranduba do Brejo)	—	5 (1)	—	—	—	5	1	—
unidentified (Cambará R 6702)	1 (1)	—	—	—	—	1	1	—
unidentified (Catoarí R 6896)	—	—	5	—	1	6	—	—
trees not listed separately (see note above)								
individuals	7	13	9	12	2	—	—	—
species	5	10	4	11	2	—	—	—
total								
individuals	524	200	301	58	71	*	79	40
species	28	33	31	24	12	71	17	6

* Total for individuals on all plots were not given since minimum girth sizes used to qualify for scoring were different.

† The three *Protium* spp. were not scored separately on plot 1; they are totalled together.

‡ Specimens of this species occurred just outside the plot. § Common but seldom reaching 7 cm girth.

the variety *duckei* is found associated with *Q. wittrockii* in marshy forests on the Rio Cauhy (Pará) (Ducke 1922, p. 197, Stafleu 1953).

(*b*) *Valley forest* (1.2)

For want of a better name this term is used for a distinctive forest community characteristic of habitats in the dystrophic soil landscape where there is a permanent water table not far below the ground level but not as near the surface as in Swampy Gallery forest. Valley forest is moister than Dry forest and better drained than Swampy Gallery forest; in structure and in the species composition of the taller trees it is quite distinct from either. Valley forest tends to occur as a rather narrow band on the gently sloping sides of valleys and sometimes in other sites where conditions are suitable. It is often adjoined below by Gallery forest and above by Dry forest and though the transition from one type to the next is often quite well marked, the three parts form a continuum.

The soil is either of a light-coloured hydromorphic type or is a more reddish automorphic soil such as is found in other rather low-lying sites. The humose surface layer characteristic of the Swampy Gallery forest is absent.

The trees are indistinctly stratified into three layers (figure 6*a*, facing p. 461) and, in addition, there is a lowermost layer of shrubs and very small trees. Although stratification is more uniform than in Swampy Gallery forest, the physiognomy of Valley forests is nevertheless very variable, especially as regards crown cover. The top storey of trees is very tall, often reaching 35 to 40 m, and is characteristically composed of four leguminous species: *Hymenaea stilbocarpa*, *Copaifera langsdorfii*, *Ormosia* sp. (Tento), and *Apuleia molaris*. These trees frequently have trunks more than 1.5 m in diameter and long, straight boles valuable as timber. *H. stilbocarpa*, the *Ormosia* sp. and *A. molaris* are more or less exclusive to the Valley forest association, at least in our area, but *C. langsdorfii* also occurs in the Dry forest and cerradão and even extends into the cerrado; in no other community, however, does this tree attain such massive dimensions as in the Valley forest. *Vitex polygama* also occurs occasionally as a top-storey tree of this association, but it is commoner on richer soils. The second tree storey, often with crowns at about 15 m, is made up of species which also occur in the Dry forest, among which *Licania blackii* and *Ephederanthus* sp. (H 10553) are particularly important. Most of the Dry forest trees, apart from some species more typical of cerradão, are able to thrive in the valley forest, and the lower tree strata are generally composed of species common to the two communities: there is usually a layer of trees about 8 to 9 m tall in which two *Protium* species (Ra 1810 and Ra 1840) are very common, and a lowermost tree and shrub layer 2 to 3 m tall consisting predominantly of *Siparuna guianensis*, together with many young trees.

In damper parts of Valley forests a number of additional species occur, including, amongst the tallest trees, *Aspidosperma nitidum*, *Didymopanax morototoni*, *Manilkara* sp. (Maceranduba), *Terminalia* sp. (Ra 2033), *Cariniana rubra* and *Unonopsis lindmannii*. *Tabebuia avellanedae* also occurs sometimes in such places: this, as will be mentioned later (p. 472), is a common tree of mesotrophic soils and possibly indicates sites where the soil is somewhat richer than usual. Some of these species have already been mentioned as occurring in the similar conditions of the Swampy Gallery/Drier Gallery transition: clearly they thrive in damper places in the dystrophic soil landscape, but not where conditions are too swampy. Other species, which usually do not reach the top storey, belong to this group: two unidentified Lauraceae, Louro Rosa and Louro Precioso, are common in the second (*ca.* 15 m) storey, as is *Jacaranda copaia*, whilst *Physocallyma scaberrimum*

a species whose requirements seem difficult to define, reaches heights of 20 m; it also occurs in other quite different habitats (pp. 474, 479).

The ground vegetation varies in density according to the shade cast by the upper layers, but it is usually much sparser than in Swampy Gallery forest and is never difficult to walk through. It consists chiefly of young trees and an unusually large number of young lianas awaiting a supporting tree to carry them skywards; but a few grasses and the little Rubiaceous herb *Psychotria prunifolia* also occur, and in the damper parts there are some ferns and Marantaceae as well. Tall lianas are common in the denser forms of Valley forest but epiphytes are very rare.

(*c*) *Dry forest* (1.3)

Dry forest (in our sense) covers an enormous area to the north of the base camp where it is the dominant type of vegetation on the poorer soils, just as cerrado is to the south. Near base camp the Dry forest varies from about 12 to 18 m in height, but farther north it becomes taller and more luxuriant and species such as *Aspidosperma nitidum* and a large *Protium* (Almécega Verdadeira) are present, perhaps indicating more favourable conditions. Our detailed observations were made only in the base camp area and we saw little of this more luxuriant type of Dry forest.

TABLE 4. ANALYTICAL DATA FOR SURFACE HORIZONS (0–10 cm) OF CERRADO, CERRADÃO AND FOREST SOILS

(From G. P. Askew, D. J. Moffatt, R. F. Montgomery & P. L. Searl (personal communication).)

	pH in H_2O	Ca	Mg	K	extractable phosphorus
		me/100 g soil			10^{-6}
cerrado, Xavantina	4.9	1.2	0.8	0.5	—
cerrado, base camp area	4.8	0.05	0.19	0.07	14
undifferentiated cerradão, Xavantina	5.2	1.5	1.2	0.15	—
undifferentiated cerradão, base camp area	4.8	0.11	0.04	0.01	14
Hirtella glandulosa cerradão, base camp area	4.1	0.07	0.02	0.04	27
Magonia–Callisthene cerradão, Xavantina	6.1	8.6	2.1	0.53	133
Magonia–Callisthene cerradão, base camp area	5.5	2.32	0.23	0.16	76
Magonia–Callisthene cerradão, transitional to low cerrado, Xavantina	5.2	2.7	0.91	0.20	64
Dry forest, base camp area	4.2	0.02	0.10	0.03	20
Deciduous Seasonal forest, base camp area	5.2	6.4	7.6	1.09	65

Near the base camp the soil under Dry forest on the extensive central interfluves is typically a deep reddish coloured, dystrophic (oxisolic) sandy clay loam. Such soils are of low nutrient content and availability (see table 1, p. 455 and table 4 above). A characteristic feature, in contrast to the cerrado soils, is the presence of a continuous superficial layer of organic material: this is composed of a layer of loose litter 2–3 cm thick, overlying a somewhat laminated, partly decomposed fermentation layer 0.5–2.0 cm thick, containing abundant fibrous roots, below which a thin (0.5–1.0 cm) granular, dark-coloured humification layer is sometimes present. The underlying 12–18 cm thick A 1 mineral horizons are granular and subangular blocky-structured porous sandy to sandy clay loams. The A horizons merge at a depth of about 50 cm into thick, more brightly coloured, structureless but friable, porous sandy clay loam B horizons which continue without much apparent change to below 4 m.

At somewhat lower levels, away from the centre of the interfluves, the soils may become coarser in texture so that in some lower interfluve sites Dry forest may be present on loamy sand

soils. The soils also change in colour downslope through yellowish to pale brownish colours, while where Dry forest borders Gallery forests the soil may be hydromorphic, showing a pattern of grey or ochreous colours within 50 cm of the surface.

The surface of the soil is covered by a fair amount of fallen tree trunks, branches and leaves, among which are numerous trails of leaf-cutting ants (Attidae) whose nests, several metres across, are sometimes encountered. Termitaria are built round the larger litter components and these become invaded by masses of fine tree roots.

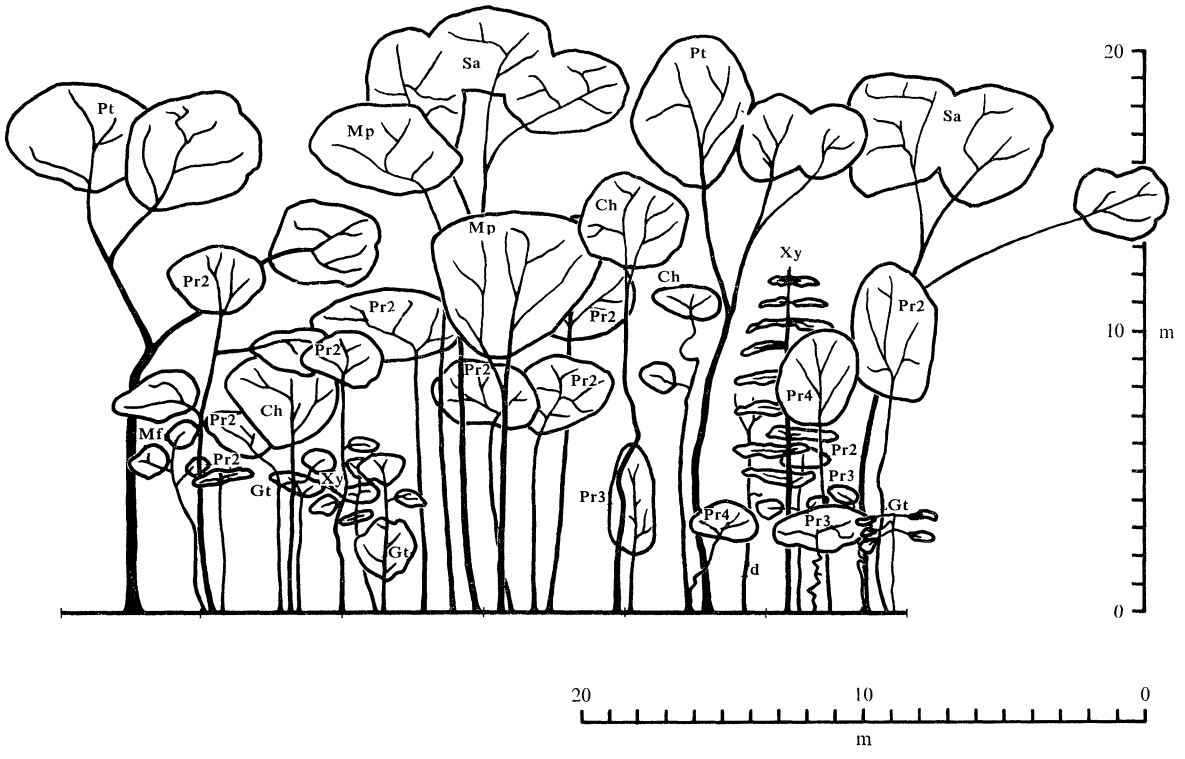
The structure of the tree layers of tall Dry forest approximately 3 km from the transition into *Hirtella glandulosa* cerradão is shown in figure 7*a*. As the figure shows, the trees in Dry forest are usually very crowded; their boles are straight and slender and rarely attain even 50 cm in diameter giving the stand the aspect of a pole forest. Important species in the main upper layer, at 15–18 m, are the broad-crowned *Licania blackii*, *L. kunthii*, *Sacoglottis guianensis* and *Chaetocarpus echinocarpus*. Other common trees in the same storey are *Miconia pyrifolia*, *Ocotea guianensis*, and the rather narrow-crowned Annonaceous *Xylopia amazonica* and *Unonopsis lindmannii*. A number of less frequent trees found in this upper stratum are listed in table 5.

Two tree species which characteristically emerge above the rest of the upper storey are *Pterodon pubescens* and *Copaifera langsdorfii*; they occur scattered through the Dry forest but are never very frequent; *C. langsdorfii* can be as tall as 28 m in forest where the top of the main canopy is about 18 m, whilst *P. pubescens* is usually somewhat smaller. It is interesting that these two species, both of wide ecological tolerance, seem always to be the largest trees in the communities where they are found. In the Valley forests *C. langsdorfii* reaches about 40 m and its form is sometimes not unlike that of a beech (*Fagus*) in an English park: in both Dry forest and cerradão it is strongly emergent and probably the largest species, while *P. pubescens* is a conspicuous emergent in Dry forest, cerradão and cerrado.

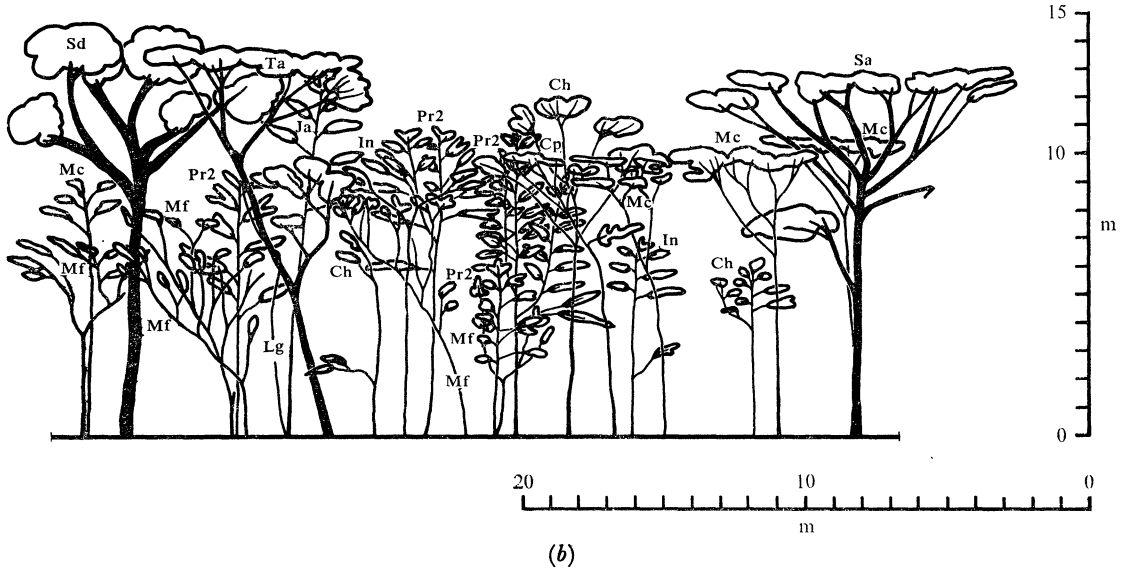
In the taller Dry forest there is a fairly distinct second tree storey at 8–11 m. It consists of three *Protium* spp. (Ra 1810, Ra 1840 and Ra 2049), *Miconia lepidota*, *Trichilia* sp. aff. *roraimana*, and a few other species (see table 5); *Hirtella glandulosa*, when it is present, also belongs to this storey, its significance will be discussed later. The crowns of the trees of this layer are of rather variable shape; the three *Protium* spp., and most particularly Breu Branco (Ra 1840), have narrow conical crowns and small leaflets, whilst the *Miconia* has a broad, flat, umbrella-shaped crown and much larger, broader leaves.

The third tree layer at *ca.* 4–7 m is dominated by *Myrciaria floribunda* which as regards number of individuals must be the most abundant species in this community: its trunk, often lobed or flattened in cross-section, and its silvery bark are very distinctive and its habit of branching low down, so that the broad crown is supported by a number of ascending limbs, suggests a species of the open cerrado rather than a member of a closed forest community. Beneath this layer the bushy *Siparuna guianensis*, 1.5–3 m tall, is abundant.

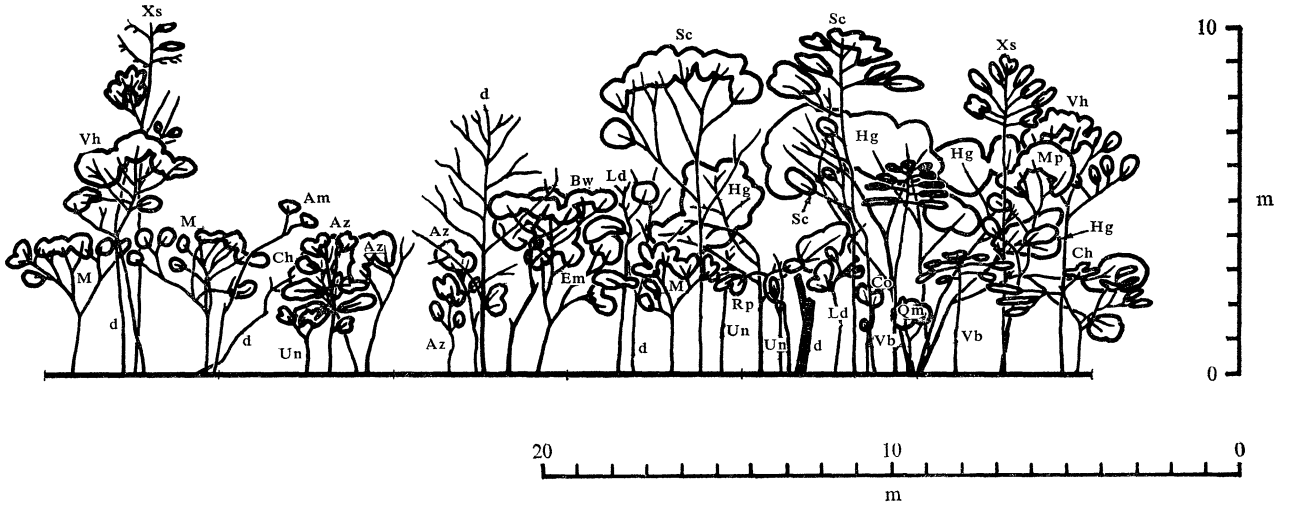
The shade is deep and the ground vegetation very sparse so that tall Dry forest is easy to penetrate on foot. The ground flora consists almost entirely of young trees and lianes: young individuals of the latter, particularly *Serjania* sp. (Cipó Cururú) and *Memora* sp. aff. *allamandiflora*, are strikingly commoner than mature plants. The most abundant young trees are *Protium* sp. (Ra 1840) and *Xylopia amazonica*, both of which are also very common as mature individuals. In other tree species, however, there is no correlation between numbers of young and adult individuals, for instance, small individuals of *Roupala montana* are common, but larger trees infrequent. On the other hand, we never saw young plants of *Pterodon pubescens* and were assured



(*a*)

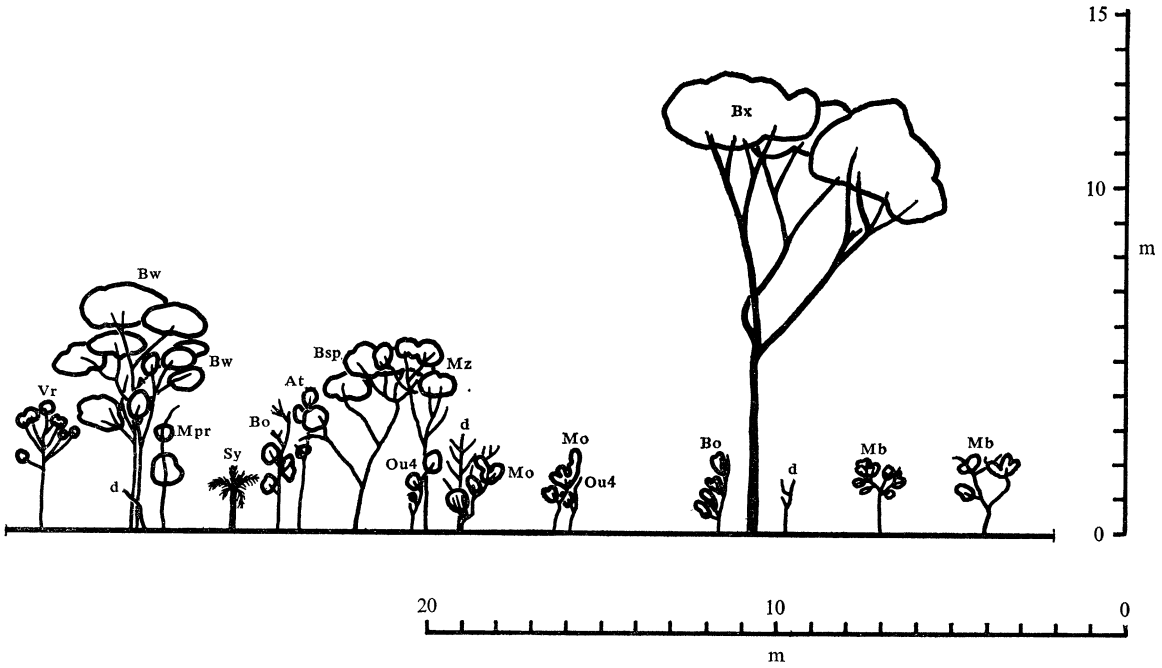


(*b*)



(*c*)

FIGURE 7 (*a*) to (*c*). For legend see facing page.



(*d*)

FIGURE 7. Profile diagrams showing transition from tall Dry forest to cerrado on transect R 14, base camp area. (*a*) Tall Dry forest (30 m × 5 m); (*b*) low Dry forest (30 m × 5 m); (*c*) *Hirtella glandulosa* cerradão (30 m × 3 m); (*d*) cerrado (30 m × 5 m).

key to species

(*a*) tall Dry forest

Ch	*Chaetocarpus echinocarpus*	Pr4	*Protium* sp. (Ra 1810)
Gt	*Guatteria* sp. Embireira (Ra 1143)	Pt	*Pterodon pubescens*
Mp	*Miconia pyrifolia*	Sa	*Sacoglottis guianensis*
Mf	*Myrciaria floribunda*	Xy	*Xylopia amazonica*
Pr2	*Protium* sp. (Ra 1840)	d	Dead
Pr3	*Protium* sp. (Ra 2049)		

(*b*) low Dry forest

Ch	*Chaetocarpus echinocarpus*	Mf	*Myrciaria floribunda*
Cp	*Copaifera langsdorfii*	Pr2	*Protium* sp. (Ra 1840)
In	*Inga* sp.	Sa	*Sacoglottis guianensis*
Ja	*Jacaranda copaia*	Ta	*Tapirira guianensis*
Lg	*Leguminosae* (indet.) (climber)	Sd	*Sideroxylon* sp. aff. *S. venulosum*
Mc	*Miconia lepidota*		

(*c*) *Hirtella glandulosa* cerradão

Am	*Aspidosperma macrocarpon*	Rp	*Roupala montana*
Az	Unknown (Azeidinho)	Sc	*Sclerolobium paniculatum*
Bw	*Bowdichia virgilioides*	Qm	*Qualea multiflora*
Ch	*Chaetocarpus echinocarpus*	Vb	*Virola sebifera*
Co	*Connarus fulvus*	Vh	*Vochysia haenkeana*
Em	*Emmotum nitens*	Xy	*Xylopia amazonica*
Hg	*Hirtella glandulosa*	Xs	*X. sericea*
Ld	*Lafoensia pacari*	Un	Unknown
M	*Miconia* sp. (Lacre de cerrado)	d	Dead
Mp	*Maprounea guianensis*		

(*d*) Cerrado

At	*Aspidosperma tomentosum*	Mpr	Unknown (Maria preta)
Bo	Unknown (Bordão de velho)	Mz	*Mezilaurus crassiramea*
Bsp	*Byrsonima* sp.	Ou4	*Ouratea acuminata*
Bw	*Bowdichia virgilioides*	Sy	*Syagrus* sp. (Gariroba)
Bx	*Bombax crenulatum*	Vr	*Vochysia rufa*
Mb	*Myrcia pubipetala*	d	Dead
Mo	*Mouriria* sp.		

TABLE 5. TREE SPECIES IN DRY FOREST, *HIRTELLA GLANDULOSA* CERRADÃO AND THE DRY FOREST/*HIRTELLA GLANDULOSA* CERRADÃO TRANSITION

Data from transect R 14 (see figure 3), base camp area. Distances measured from west end of transect.

Each column is based on the frequency of trees on the number of 50 × 5 m sample plots indicated (larger side of plot along transect line) plus a subjective estimate of frequency along the side of the transect through each region. Woody plants with stems less than 4 cm diameter were excluded in columns 1 to 3 and those with stems less than 3 cm in columns 4 and 5. For the Dry forest the storey to which mature individuals belong is indicated as follows:

E, emergent; A, top storey; B, middle storey; C, lower storey.

Frequency symbols: a, abundant; c, common; f, frequent; o, occasional; r, rare; vr, very rare.

(*a*) Species characteristic of Dry forest

species	tall Dry forest 0–700 m (3 plots) (1)	low Dry forest 700–2250 m (8 plots) (2)	low Dry forest verging on cerradão 2250–3100 m (2 plots) (3)	Dry forest/ *Hirtella glandulosa* cerradão transition 3100–3400 m (2 plots) (4)	*Hirtella glandulosa* cerradão 3400–4350 m (2 plots) (5)
Agonandra silvatica	rA	rA	r	—	—
Chaetocarpus echinocarpus	cA	cA	c	c	o
Copaifera langsdorfii	fE	fE	f	f	r
Guatteria sp. (Embireira Ra 1143)	aB	oB	o	c	—
Himatanthus bracteata	oA	oA	o	c	—
Humiria balsamifera	oA	oA	—	—	—
Hymenaea stilbocarpa	rE	—	—	—	—
Inga sp. (Inga xixica Ra 1818)	cB	oB	—	—	—
Licania blackii	aA	aA	c	—	—
L. kunthiana	fA	oA	—	—	—
Mabea fistulifera	oA	rA	o	o	—
Miconia pyrifolia	cA	rA	—	—	—
M. lepidota† / *M. holosericea*†	oB	aB	a	f	f
Myrciaria floribunda	aC	aC	a	a	a
Ocotea guianensis	fA	rA	—	—	—
Ormosia sp. (Tento)	rE	—	—	—	—
Protium sp. (Almécega Branca)	cB	cB	c	f	c
Protium sp. (Almécega Vermelha)	cB	fB	r	o	—
Protium sp. (Breu Branco)	aB	aB	a	r	—
Pterodon pubescens	oE	fE	f	f	o
Roupala montana	rB	fA	f	c	c
Sacoglottis guianensis	aA	aA	a	—	—
Sideroxylon sp. aff. *S. venulosum*	oA	cA	c	—	r
Siparuna guianensis	aC	aC	a	a	—
Tapirira guianensis	—	oB	—	—	o
Trichilia sp. aff. *T. roraimana*‡	+	+	+	—	—
Unonopsis lindmannii	cA	fA	—	—	—
Virola sebifera	oB	oB	o	o	o
Xylopia amazonica	aA	cA	c	—	—

† *M. lepidota* and *M. holosericea* were confused in the field and have been recorded together. Dr R. M. Harley informs us that *M. lepidota* was the commoner tree in the forest whilst *M. holosericea* was commoner in the cerradão.

‡ *Trichilia* sp. aff. *T. roraimana* is also a frequent tree of the forest understorey but due to confusion over its identity its frequency was not separately recorded.

TABLE 5. (*cont.*)

(*b*) Species characteristic of *Hirtella glandulosa* cerradão

species	tall Dry forest 0–700 m (3 plots) (1)	low Dry forest 700–2250 m (8 plots) (2)	low Dry forest verging on cerradão 2250–3100 m (2 plots) (3)	Dry forest/ *Hirtella glandulosa* cerradão transition 3100–3400 m (2 plots) (4)	*Hirtella glandulosa* cerradão 3400–4350 m (2 plots) (5)
Andira stipulacea	—	oA	r	o	o
Byrsonima coriacea	—	—	r	—	—
Clusia sellowii	—	—	—	r	r
Emmotum nitens	r	oA	c	c	c
Hirtella glandulosa	rB	oA	a	a	a
Maprounea guianensis	—	—	f	f	f
Peltogyne confertiflora	—	oE	o	o	—
Sclerolobium paniculatum	—	rB	o	a	c
Simaruba versicolor	—	fA	r	r	f
Vochysia haenkeana	—	—	o	c	c
Xylopia sericea	—	oA	r	f	o
(*c*) Species found in *Hirtella glandulosa* cerradão and also common in cerrado					
Annona coriacea	—	—	—	o	o
Aspidosperma macrocarpon	—	—	—	—	o
A. multiflorum	—	rB	o	f	f
A. tomentosum	—	—	—	r	—
Bombax crenulatum	—	—	—	—	o
Bowdichia virgilioides	—	vrA	—	r	o
Brosimum gaudichaudii	—	—	—	o	o
Caryocar brasiliense	—	—	r	—	r
Dimorphandra mollis	—	—	—	o	o
Euplassa inaequalis	—	o	—	o	o
Heisteria densifrons	—	—	—	o	o
Hymenaea stigonocarpa	—	—	r	r	r
Lafoensia pacari	—	—	—	—	o
Licania humilis	—	—	r	—	r
Machaerium acutifolium	—	—	—	—	o
Mezilaurus crassiramea	—	—	r	r	f
Miconia sp. (Lacre do Cerrado)	—	—	—	o	c
Myrcia pubipetala	—	—	—	r	o
Myrcia sp. (Araçá Ra 1983)	—	—	—	o	o
Qualea parviflora	—	—	—	o	f
Salvertia convallariodora	—	—	—	o	o
Syagrus sp.(?) (Babão)	—	—	—	—	o

by the Expedition's most experienced Brazilian assistants that they were extremely rare despite the tree's copious seed production. Two small rubiaceous subshrubs, *Psychotria prunifolia* and *Rudgea villosa*, are fairly common on the forest floor, and occasional groups of a small bamboo-like grass, *Lasiacis sorghoidea*, and the grass *Streptogyna americana* occur.

Figure 7*b* shows the structure of the less tall type of Dry forest, which lies closer to the cerrado boundary; it is, of course, only arbitrarily divided from taller types and they normally intergrade into each other along a very gradual ecotone. The upper tree layer is lower, 10 to 15 m, and much more broken, and stratification is less clearly defined. *Sacoglottis guianensis* and *Licania blackii* continue as very important top-storey trees, as do *Protium* spp. (Ra 1810 and Ra 1840), *Myrciaria floribunda* and *Siparuna guianensis* in the lower strata. Some species such as *Hirtella*

glandulosa, *Roupala montana*, *Miconia holosericea*, *Sideroxylon* sp. aff. *venulosum* (H 10523) and the emergent *Pterodon pubescens* are much commoner than in the tall Dry forest; some of these species are characteristic of cerradão (see below). *H. glandulosa*, which was an infrequent understorey species in the tall Dry forest, reaches the canopy here. Various cerrado and cerradão species such as *Aspidosperma multiflorum*, *Caryocar brasiliensis*, *Emmotum nitens*, *Hymenaea stigonocarpa*, *Licania humilis*, *Maprounea guianensis*, *Mezilaurus crassiramea*, *Peltogyne confertiflora*, *Sclerolobium paniculatum*, *Vochysia haenkeana* and *Xylopia sericea* are present in varying numbers. The density of ground vegetation increases, as might be expected, as crown cover becomes more broken, it is mainly composed of young trees and lianas but cerrado shrubs such as *Copaifera martii* and *Ryania mansoana* also become important constituents. Young individuals of the following trees were recorded as particularly common in plots in the low Dry forest: *Copaifera langsdorfii*, *Hirtella glandulosa*, *Protium* sp. (Ra 1840), *Roupala montana* and *Xylopia amazonica*.

Transition from low Dry forest to *Hirtella glandulosa* cerradão involves a reduction in crown height to *ca.* 5 to 12 m and a further simplification of structure so that no definite layering can be recognized. As regards species composition (table 5) the transition involves the increase in percentage of the cerradão and cerrado species just mentioned and the appearance of many others, whilst a number of very characteristic Dry Forest trees such as *Licania blackii*, *Sacoglottis guianensis* and *Protium* sp. (Ra 1840) disappear. A few species such as *Myrciaria floribunda* seem equally common in either formation. The width of the transition from 'typical' low Dry forest to 'typical' *Hirtella glandulosa* cerradão on the transect we studied in greatest detail (R 14) was 1200 m, but in many places is much narrower.

Hirtella glandulosa *cerradão*

Since this community is floristically closely related to Dry forest it is appropriate to describe it here. It is found between the Dry forest and the more open types of cerrado, widening in places to a belt 3 to 4 km broad. It is a low broken savanna woodland (figure 7*c*) in which the taller trees vary from 5 to 12 m in height, apart from a few emergents; there is no continuous canopy and the ground vegetation is very dense and difficult to walk through. The most characteristic species is *Hirtella glandulosa* which reaches about 12 m in height and is frequently many-trunked with a very broad crown; other abundant trees are *Emmotum nitens*, *Vochysia haenkeana* and *Sclerolobium paniculatum*. These four are characteristic species of the community and are among the most abundant of the larger trees. At least in the area we studied, *H. glandulosa*, *V. haenkeana* and *S. paniculatum* do not grow in other more open cerrado communities, and *E. nitens* only occurs in them rarely; all, however, occur at varying, generally low, frequencies in the Dry forest. The associates in this type of cerradão are mainly cerrado species, and some of the larger trees present belong to this category, e.g. *Bombax crenulatum*, *Xylopia sericea* and *Mezilaurus crassiramea*, whilst others are species of the Dry forest, e.g. *Myrciaria floribunda*. The tallest emergents of the formation, which grow to about 15 m, are the widely distributed *Copaifera langsdorfii* and *Pterodon pubescens*. *Roupala montana*, another important tree, also has a wide ecological tolerance, from tall Dry forest to low cerrado, but it is a species which seems most at home in the *H. glandulosa* cerradão or in the low Dry forest. *Clusia sellowii* is quite a common strangler in this community and reaches about 10 m.

The ground vegetation is very thick and contains numerous characteristic cerrado ground species, e.g. the stemless palm *Astrocaryum* sp. (Tucumá), *Copaifera martii*, *Rourea induta*, *Ryania mansoana*, ground bromeliads, and various grasses (*Aristida*, *Panicum*, *Paspalum*, *Thrasya* spp. etc.),

whilst young trees of *Hirtella glandulosa*, *Roupala montana*, *Copaifera langsdorfii* and *Protium* sp. (Ra 1810) are very numerous.

The soil of the *Hirtella glandulosa* cerradão is very similar to that of the Dry forest and also belongs to the dystrophic class, analytical data are given in table 4, p. 464.

There was seldom any evidence of fire, as shown by charring of bark, in either the Dry forest or the *Hirtella glandulosa* cerradão, and in fact many of the trees have thin smooth bark apparently ill-adapted to resisting fire. Such barks are a conspicuous feature in species of the *H. glandulosa* cerradão, e.g. *Sclerolobium paniculatum* (smooth, silvery-white), *Vochysia haenkeana* (smooth, yellow) and *Myrciaria floribunda*, which is also abundant in the Dry forest, has silvery, Eucalyptus-like bark. Examples of species with similar barks in the Dry forest are *Sacoglottis guianensis* and *Sideroxylon* sp. aff. *venulosum* (H 10523).

The Dry forest in the Expedition's area forms the southern margin of the Amazonian hylaea, where it borders on the central Brazilian savannas. Owing to its inaccessibility, very little botanical work has been done on this part of the hylaea, and descriptions of similar types of vegetation are not available. Apart from the account by Ratter (1971), *Hirtella glandulosa* cerradão does not seem to have been previously recognized as a distinct community, though some of the species characteristic of it such as *Emmotum nitens*, *Sclerolobium paniculatum* and *Hirtella glandulosa* itself, are mentioned by Rizzini & Heringer (1962) as important in the 'xeromorphic forests' (cerradões) of the Brazilian Planalto.

(*d*) *Carrasco* (*low forest on white sand*) (1.4)

In the western and northwestern parts of the 20 km square there are stands of a plant community which appears to be different from any other in our area, but for lack of time we were unable to study it in detail. In some places it forms narrow bands along the outside of the gallery forest and in one place a narrow band along one side of the valley of a small stream, passing abruptly into cerradão at its upper limit. It consists of small evergreen trees (species not identified), forming an even canopy at about 5 to 8 m above ground level.

The soil is a humic or peaty gley consisting of either black granular peat or humose sandy loam overlying gleyed white sand. At the boundary with Dry forest or cerradão the soil changes to the reddish dystrophic soil characteristic of so much of the area. A Brazilian scientist visiting the expedition termed this community 'carrasco' and in physiognomy it resembles the vegetation type to which Aubréville (1961) gives to the same name.

(*e*) *Deciduous Seasonal forest* (1.5)

Deciduous Seasonal forest occupies a restricted area in the 20 km square and we have also seen remnants of it in various places near Xavantina. It differs strikingly from the other types in that practically all the taller trees lose their leaves completely for a long period in the dry season. In structure and floristic composition it is also very distinct from any other forest type in the area. These differences seem to be correlated with soil conditions: the Deciduous Seasonal forest occurs on mesotrophic soils and the great difference in available nutrients between these and the poor dystrophic soils which support the other forest types is shown in table 1 and 4, pp. 455 and 464. The fertility of the deciduous seasonal forest soils is well known to Brazilian agriculturists: the land is known locally as 'terra preta'† (black earth) and is much in demand for cultivation.

† The same name is used for pockets of fertile soil in Amazonia (Ducke & Black 1953), but these are not necessarily like the 'terra preta' soils of our area.

Figure 8 shows the structure of tall Deciduous Seasonal forest. The top storey trees reach a height of about 30 m, and have straight boles averaging about 30 to 35 cm in diameter (occasionally to over 60 cm). When in leaf they form a very discontinuous canopy (the cover tending

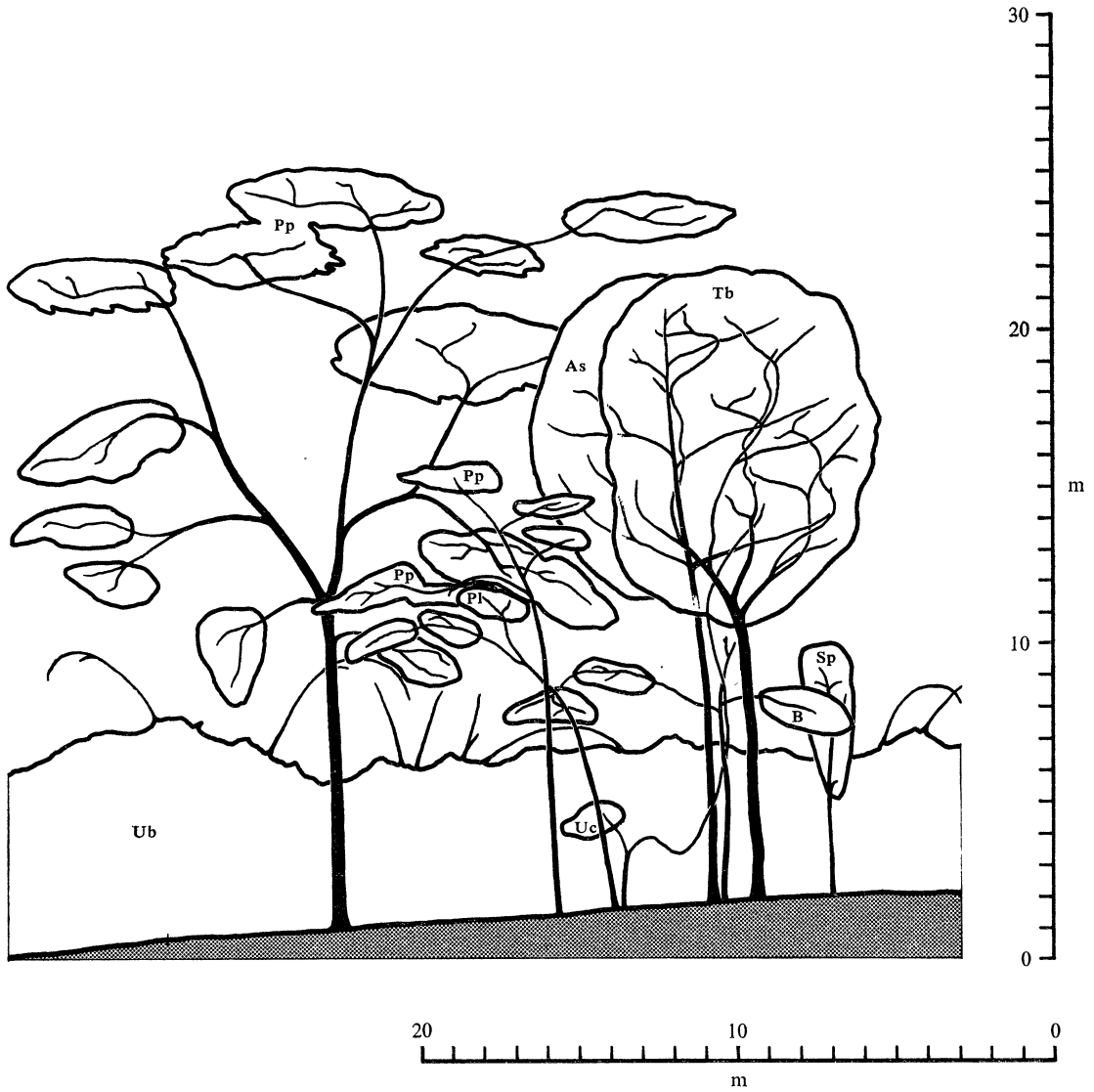


FIGURE 8. Profile diagram of Deciduous forest, base camp area (transect R 4). (30 m × 10 m.)

key to species

As	*Aspidosperma* sp. (Guatambú, Ra 968)	Sp	Sapotaceae (Cutiti branco, Ra 1107)
B	*Bauhinia cupulata*	Tb	*Tabebuia avellanedae*
Pl	*Platypodium elegans*	Ub	Bamboo undergrowth
Pp	*Piptadenia macrocarpa*	Uc	Unknown (liane)

to vary between 25 and 50 %). In the forest which we worked most intensively the species in approximately descending order of frequency were: *Piptadenia macrocarpa*, *Platypodium elegans*, *Tabebuia* sp. (Pau de Arco Amarelo, Ra 1103), *Dilodendron bipinnatum*, *Erythrina ulei*, *Aspidosperma* sp. (Guatambú, Ra 968), *Sterculia striata*, *Tabebuia avellanedae*, *Fagara riedelianum*, *Apeiba tibourbou*, *Cedrela fissilis* and *Vitex polygama*. In another stand with a rather lower canopy *Piptadenia*

FIGURE 9. Swampy Gallery forest, base camp, showing trunks of *Qualea wittrockii* Malme and other trees. (15 August, 1968.)

FIGURE 10. Vegetation types on transect R 1, base camp area. Swampy Gallery forest (left), cerradão (right background), campo (foreground). The grasses in the campo are flowering abundantly, having recovered from burning earlier in the dry season. (7 September, 1968.)

(*Facing p.* 472)

FIGURE 11. Cerrado near base camp in dry season. (July 1968.)

FIGURE 12. Cerrado recovering after light burning earlier in the dry season, base camp area. (7 September, 1968.)

falcata is also present as an important top-storey tree. An interesting feature of these species (which belong to several families) is the preponderance of compound leaves: those of the two Tabebuias and *Vitex polygama* are palmately compound, whilst in the other species, apart from the *Aspidosperma* sp., *Sterculia striata* and *Apeiba tibourbou*, they are large and pinnately divided to varying degrees (with the trifoliolate leaf of the *Erythrina* at one extreme and the bipinnate Acacia-like leaf of the *Piptadenia* spp. at the other).

There is usually a luxuriant understorey of a tall arching bamboo (Ra 1913) about 8 m high which may form impenetrable thickets with little ground vegetation beneath. In the understorey there are also tree species characteristic of this type of forest: *Bauhinia cupulata* and *Acacia polyphylla*, the latter with thorny branches, are particularly common and reach a height of about 10 m, while *Helicteres corylifolia* (to 8 m) and *Guazuma ulmifolia* (to 15 m, but usually much smaller) are also frequent. Small trees of *Zizyphus joazeiro* are present but not common. These understorey trees grow both mixed with dense bamboo and also where it is thin or absent. Lianes are often found on these smaller trees, but in general they are not conspicuous.

Several species of palm occur in the Deciduous forest which were not seen elsewhere in the Expedition's area, e.g. a large stemless *Attalea* sp. (?) (Naja Cabeçuda, Ra 1904), *Syagrus* sp. (?) (Piririma Vasoura, Ra 1903), reaching 3 m in height, and *Acrocomia* sp. (Macaúba, Ra 1084). The last grows to 6 m and was regarded by our Brazilian assistants as a sure indicator of fertile soil: the data of Alvim & Araujo (1952) seem to confirm this.

Where the bamboo is dense the ground flora may be represented only by a small acanthaceous herb and a few sickly looking young trees, particularly *Aspidosperma* sp. (Guatambú), but where it is thinner or absent the ground vegetation includes various herbs such as *Eupatorium odoratum*, several ferns, sparse clumps of the grass *Imperata contracta* (never seen in flower) and the climbers *Dalechampia tiliaefolia*, *Triumfetta althaeoides* and *T. semitriloba*, but is seldom dense enough greatly to impede walking. The charring of the trunks is evidence that this type of forest is liable to burning and a fire actually occurred in one area in August 1968. It burned the dry ground vegetation but did no permanent damage to the bamboos or the trees, some of which, e.g. *Piptadenia falcata*, have thick bark which looks very fire-resistant.

The few observations which we have made of damper situations in the Deciduous Seasonal forest such as streamsides, show that the tree species are similar to those in the drier sites but that they keep their leaves for a longer period in the dry season.

Deciduous forests related to those in our area are probably rather common on soils of high base status in other parts of Brazil. They were seen by one of us (D. R. G.) in several localities, particularly on calcareous soils, in Goiás and Minas Gerais, and there are various references to them in the literature.

Warming (1892) mentions a type of forest on calcareous rocks at Lagoa Santa (Minas Gerais) in which some tree species remain leafless for a long period. Alvim & Araujo (1952) give further details of the composition of this forest, mentioning the occurrence of *Astronium urundeuva*, *Cedrela fissilis*, *Piptadenia* sp., *Zanthoxylon* (*Fagara*) *rhoifolium* (related to *Fagara riedelianum* of our area) and the palm *Acrocomia sclerocarpa*. They also give analyses of the soil, which has a high pH. The 'Piptadenietum macrocarpi Astroniosum' found by Veloso (1948*a*) in Goiás on soils of calcareous origin or of high water-retaining capacity is probably a similar association, as is also the one-storey forest in which *Piptadenia macrocarpa* and *Astronium* sp. were common noted by Aubréville (1958) on the Rio Alma in Goiás.

Rizzini & Heringer's (1962) account of the 'first- and second-class' semi-deciduous forests of

central Brazil (particularly Minas Gerais and Goiás) records a mixture of species some of which, e.g. *Cedrela fissilis*, *Dilodendron bipinnatum* and *Piptadenia falcata*, are common in the Deciduous Seasonal forest in our area, others are more characteristic of the transitional association between the Deciduous forest and the cerrado (*Magonia pubescens–Callisthene fasciculata* cerradão), while yet others are found in our Valley and Dry forests. Rizzini's (1963) figures for soil nutrients in forest of this type in Felixlândia (Minas Gerais) show pH and calcium values more comparable with those in our Deciduous Seasonal forest than with those of the evergreen forest in our area.

Some species found in our Deciduous Seasonal forest are also found in the deciduous caatinga associations described by Magalhães (1961), e.g. *Sterculia striata*, *Cedrela fissilis*, *Piptadenia macrocarpa*, *Erythrina* sp. (Mulungú) and *Zizyphus joazeiro*.

Deciduous forest–cerrado transition

A transition between Deciduous Seasonal forest and cerrado could be seen in many places and was analysed in detail in three localities. In each of these places the forest, or its remnants, occurs in a valley enclosed by open cerrado, with a fairly narrow transition belt of cerradão between the two communities. The soil of the transitional cerradão is always conspicuously pebbly, and in two places the soil surface is partially covered by a rubble of hard laterite. The cerradão trees reach about 13 m in height and the most constant species are the following: *Physocallyma scaberimmum*, *Luhea paniculata*, *Magonia pubescens*, *Astronium fraxinifolium*, *Callisthene fasciculata*, *Bombax martianum*, *Bauhinia cupulata*, and *Tabebuia* sp. (Pau de Arco Amarelo, Ra 1103). The last two extend throughout the Deciduous Seasonal forest, but the others only very rarely penetrate into it (single very large individuals of *Callisthene fasciculata* and *Astronium fraxinifolium* were seen deep in such forests). *Physocallyma scaberrimum*, *Luhea paniculata*, *Bauhinia cupulata* and the *Tabebuia* sp. do not seem to grow in the open cerrado, but all the other species are capable of doing so; with the possible exceptions of *Bombax martianum* and *Astronium fraxinifolium*, however, they are more characteristic of this type of cerradão. Another characteristic species of the community is the small tree *Antonia ovata* which also appears to be confined to cerradão. The habitat preference of some of these species was well known to our Brazilian assistants who said, for instance, that *Bombax martianum*, 'liked the pebbles', i.e. the pebble band lying between the sandstone and the fine-grained rocks (see p. 455). Most of the trees and shrubs of the open cerrado also occur as associated species in this transitional cerradão, amongst the most common are *Byrsonima pachyphylla*, *B. crassifolia*, *Curatella americana*, *Qualea multiflora*, *Tabebuia caraiba*, *Terminalia subsericea* and *Sclerolobium* sp. (Ra 350). The cerrado palm *Syagrus* sp. (?) (Babão, Ra 1873) which reaches *ca.* 2 m in height and the acaulescent *Attalea* sp. (Piaçaba, Ra 654) are both common.

The structure of this cerradão resembles that shown in figure 7*c*. There is an upper layer of trees, up to about 13 m tall, which do not produce more than a sparse cover; between them a host of smaller trees and shrubs occur, and on the floor there is a dense ground vegetation composed of herbs, young trees and shrubs of the usual cerrado species. It is interesting to note that the deciduous character of this cerradão, like that of the forest to which it is related, is very marked; the most characteristic species, e.g. *Physocallyma scaberrimum*, *Magonia pubescens*, *Callisthene fasciculata* and *Bombax martianum* lose their leaves for considerable periods in the dry season, contrasting with the *Hirtella glandulosa* cerradão where the four most characteristic species, *Hirtella glandulosa*, *Emmotum nitens*, *Sclerolobium paniculatum* and *Vochysia haenkeana*, are evergreen.

Transitional cerradão of this type belongs to the *Magonia pubescens–Callisthene fasciculata* community (see below) and is similar to much of the cerradão occurring around Xavantina. Its soil characteristics are considered in the next section.

(*f*) *Cerradão*

In this paper the term *cerradão* is used for plant communities in which trees mainly of fire-tolerant savanna type grow closely aggregated so as to form a more or less continuous canopy and are on the average taller than in open cerrado. They are thus physiognomically comparable to what is termed savanna woodlands in Africa, rather than to 'orchard bush', 'parkland' and other types of open savanna. In northeastern Mato Grosso there are numerous associations with this kind of structure but 'cerradão' is an appropriate term for them all. One type of cerradão, the *Hirtella glandulosa* community, which is clearly distinct from any other, has already been described (pp. 470).

Another type is *Magonia pubescens–Callisthene fasciculata* cerradão named after two of its most characteristic species. A variant of this occurs around the margins of the Deciduous Seasonal forest, as has already been mentioned (p. 474), but it is not confined to such situations. Around Xavantina a type of cerradão is common in which there are large trees of 10 to 15 m with a very dense lower vegetation beneath. A prominent species is *Dipteryx alata* which sometimes reaches 15 m in height and has a thick trunk; it is common to about 40 km north of Xavantina but then becomes extremely rare. Other common tall trees of this community are *Magonia pubescens*, *Callisthene fasciculata*, *Bombax crenulatum*, *Pterodon pubescens*, *Caryocar brasiliensis* and *Euplassa inaequalis*, while many other smaller species typical of cerrado occur amongst them. *Antonia ovata* is also a common tree, usually about 2.5 to 3 m high and, as already mentioned, this species does not seem to grow in more open cerrado. *Physocallyma scaberimmum* is sometimes also present in sites where conditions are transitional to forest; this is also the case with *Luhea paniculata*, although this species seems to tolerate somewhat poorer conditions than *P. scaberimmum*. The ground vegetation tends to be very dense and difficult to walk through; close to Xavantina it frequently includes species such as small shrubby Bauhinias, Cassias, Malpighiaceae, *Vernonia ferruginea*, *Cochlospermum insigne*, *Jatropha vitifolia*, and *Zeyheria digitalis* which probably indicate recent disturbance of the habitat.

'Undifferentiated cerradão' is a community occurring here and there in the cerrado landscape, particularly on ridge crests, and sometimes on lower slopes just above the level of wet campos. Unlike the previously described types of cerradão, it is more or less identical in species composition to open cerrado and differs mainly in the greater height and closer spacing of the trees. Its occurrence is presumably the result of a local improvement in water supply or other conditions important for tree growth. Moffatt (1971, pp. 242–3) suggests that availability of phosphorus may be an important factor.

One example of undifferentiated cerradão examined was on light, reddish coloured, sandy soil on a central interfluve site. It was an open woodland with trees reaching 12 to 13 m which produced quite a dense crown cover giving some shade. Trees over 7 m tall belonged to the following species: *Bombax crenulatum*, *Bowdichia virgilioides*, *Emmotum nitens*, *Euplassa inaequalis*, *Machaerium acutifolium*, *Mezilaurus crassiramea*, *Pterodon pubescens*, *Qualea grandiflora*, *Q. multiflora* and *Q. parviflora*. Beneath the taller trees was a scattered understory of small trees of common cerrado species, and many shrubs. A discontinuous cover of *Andropogon* sp. and another grass occurred on the

ground. It is interesting to note that small trees of *Antonia ovata* and a large tree of *Emmotum nitens* occurred, both of which are species more or less confined to cerradão.

A rather similar cerradão was examined on a rocky ridge-crest near Xavantina; again the species composition was more or less the same as in the surrounding open cerrado. The trees were not as tall as those of the sandy ridge crest, seldom exceeding 7 m, and a number of species additional to those recorded above occurred, namely *Anacardium occidentale*, *Ferdinandusa elliptica* and *Dipteryx alata*.

A plot of cerradão was also examined on the margin of a narrow grassy campo surrounding a strip of gallery forest. The species were similar to those of the adjacent low cerrado, but were taller, the following being over 5 m: *Andira cuyabensis*, *Bombax martianum*, *Byrsonima pachyphylla*, *Curatella americana*, *Euplassa inaequalis*, *Myrcia pubipetala*, *Plathymenia reticulata*, *Qualea grandiflora*, *Q. parviflora* and *Terminalia modesta*. The crown cover was quite dense, but, in addition to the usual shrubs and small trees, the ground was covered by an almost continuous layer of grasses such as *Andropogon* sp., *Thrasya petrosa*, a large species of *Aristida*, and *Imperata contracta*. It is interesting to note that the tree species characteristic of the cerrado-wet campo transition are important here (see p. 479), namely, *Andira cuyabensis*, *Qualea parviflora* and *Curatella americana*.

The soil characteristics of the different types of cerradão are of great interest, and analytical data are shown in table 4, p. 464. The analyses show clearly the differences in pH and levels of exchangeable bases: the *M. pubescens–C. fasciculata* cerradão is of mesotrophic type and has calcium and magnesium levels ten or more times higher than those of the *H. glandulosa* cerradão. The soil from the sparser cerradão transitional to low cerrado but showing some relations to *M. pubescens–C. fasciculata* cerradão is of dystrophic type, but, predictably, shows an affinity with the mesotrophic types in that it has an upper horizon with higher pH and much higher levels of available calcium and magnesium than is normal for dystrophic soils. Data are available from other sites which correspond closely with those given in the table.

Cerradão, apart from the *Hirtella glandulosa* type, always shows evidence of fires in the charring of the barks of the trees; like the cerrado it must be burned frequently, though not necessarily every year.

There are many references to cerradão communities in the literature. A number of workers, e.g. Lund (1892), Löfgren (1898), Rizzini & Heringer (1961) and Rizzini (1963), have described cerradões which appear to represent climax communities and cover large areas in Central Brazil. Rizzini & Heringer (1961) give a full description of such cerradões in Minas Gerais and Goiás which they call 'Floresta Xeromorfa Semidecídua'. Rizzini (1963) stresses that this 'Xeromorphic Semideciduous forest' is a formation distinct from cerrado and strongly dominated by characteristic species. The composition of these widespread and important communities is described by Rizzini and Heringer and seems to have much in common with the *Magonia pubescens–Callisthene fasciculata* cerradão observed by us around Xavantina, although species such as *Emmotum nitens*, *Hirtella glandulosa* and *Sclerolobium paniculatum* characteristic of the *Hirtella glandulosa* cerradão also occur in them.

Veloso (1948*b*) refers to a 'Callisthenetum fasciculati Qualiosum' near Terenos (southern Mato Grosso). This is a type of cerradão occurring between natural campos and small woods dominated by *Piptadenia macrocarpa* (the most frequent tree in Deciduous Seasonal forest in our area).

As already mentioned, there seem to be no descriptions of cerradões in the literature referable to the *Hirtella glandulosa* type, possibly because little previous work has been carried out in the transition between the cerrado and the Amazonian forest.

(*g*) *Cerrado*

The cerrado, a plant formation which occupies about 25 % of the land area of Brazil, shows innumerable regional and local variations. Even in the limited area dealt with in this paper it varies greatly in structure and species composition and its component associations seem almost to defy classification. In structure (figures 4*b*, *c*, 5*b*, 7*d*) it ranges from 'campo sujo' (grassland with scattered small shrubs or trees), through 'low cerrado' (shrubs and trees forming a more or less continuous layer) and cerrado in which the trees may be 10–15 m high but still not forming a complete upper storey, to types grading insensibly into cerradão (see Goodland 1971*a*). The grass and herbaceous cover varies more or less inversely with the density of the tree and shrub layer, but even in the tallest and densest cerrado (as in cerradão) a discontinuous layer of grasses and other herbaceous plants is always present.

The soil under cerrado on the central parts of the interfluves in the base camp area is typically a deep reddish coloured dystrophic (oxysolic) soil of loamy sand to sand texture (see table 4, p. 464, for analyses). Under true cerrado there is no accumulation of organic material on the surface, apart from a few scattered leaves, etc., and the superficial soil horizon consists of a layer 1 to 2 mm thick of red and reddish brown sand brought up from below by the action of the soil fauna: this contrasts with the soil under cerradão in which a continuous layer of loose litter usually covers the surface and, although a distinct fermentation layer is not present, the lower part of the litter may be somewhat matted together by fungal hyphae. The 20 to 45 cm thick A 1 horizons of typical cerrado soils consist of a mass of loose structureless sand with brownish mottles of firmer material due to localized incorporation of organic matter binding the sand grains together into small weak aggregates. At about 75 cm the A horizons merge into thick, brightly coloured, structureless, slightly hard, loamy sand B horizons which continue without much apparent change to below 4 m. Small fragments of charcoal are present in cerrado soils to considerable depth. Hard concretionary ironstone layers are commonly present within the B horizons and less frequently at or near the surface. Downslope towards the streams the soil colour changes from reddish to yellowish or pale brownish, and at low levels where the cerrado adjoins campo or valley forest bleached hydromorphic soils are usually found.

The cerrado everywhere shows evidence of burning, and cerrado trees, unlike those of the galleries and dry forest, show features typical of pyrrhophytes, e.g. thick fissured bark, gnarled sinuous branches and ready production of epicormic shoots from roots and trunks. The smaller perennial dicotyledons of the cerrado usually possess underground perennating structures, often quite massive and woody (xylopods), which enable them to survive the dry season during which fires may destroy the dead remains of the annual aerial shoots. Many of the shrubs also produce shoots of annual duration from a xylopod; such shrubs generally consist of a clump of slender little-branched shoots which may reach heights of 2 or 3 m; Warming describes plants of this sort as 'subshrubs', to distinguish them from normal shrubs with perennial aerial stems. Such subshrubs only differ from perennial herbs in the degree of lignification of their shoots, and it is frequently difficult to distinguish between the two categories, examples of this type of subshrub are: *Cochlospermum insigne*, *Jatropha vitifolia*, many *Bauhinias*, etc. Many of the trees also have xylopods which allow rapid regeneration if the aerial trunk is destroyed. Another growth form of the cerrado is the 'subterranean tree' discussed at some length by Liais (1872) and Warming (1892). In these there are well-developed and often massive woody underground organs which may spread over a considerable area and produce many very short aerial shoots, each bearin

only a few leaves at ground level. *Anacardium pumilum* and *Byrsonima verbascifolia* are species of this type in the Expedition's area.

The monocotyledons of the cerrado, in addition to perennial grasses and Cyperaceae, include small palms, Amaryllidaceae, terrestrial bromeliads, Hypoxidaceae, Liliaceae, vellozias and orchids. Some of the palms have short trunks (to *ca.* 3 m), e.g. *Syagrus* spp. (Babão, Gariroba), while others are acaulescent, e.g. *Attalea* sp. (Piaçaba) and *Astrocaryum* sp. (Tucumá). Most of the grasses are more or less tufted narrow-leaved perennials. During the dry season the monocotyledons survive by strategies similar to those of the dicotyledons: some have aerial stems able to survive all but the fiercest fires (e.g. the caulescent palms, *Vellozia* spp., the sedge *Bulbostylis paradoxa*) but the majority, including all the grasses, depend on perennating buds at or below the soil surface. Specialized underground organs (bulbs, tubers, corms, etc.) are found in Amaryllidaceae, Hypoxidaceae, Liliaceae and orchids. In the sedge *Dichromena* sp. (R 6508) the internodes of the rhizome are swollen to form corm-like sections.

A surprising feature of cerrado vegetation is the rarity of annual plants. We observed only two species in the base camp area – the grass *Aristida capillacea* and a small dicotyledon (possibly *Paronychia* sp.); near Xavantina a *Borreria* sp. and also *Aristida capillacea* were noted. None of these species was common. Warming (1892) estimated that at Lagoa Santa annuals formed 5.7 % of the herbaceous species and attributed their scarcity to the difficulty of seedling establishment due to hard, dry soil, fires and competition by taller woody plants. It should be noted here that the establishment in cerrado vegetation of seedlings of any kind, including those of the trees and shrubs, has often been regarded as a very rare occurrence, but more recent work (Labouriau *et al.* 1963, Labouriau, Valio & Heringer 1964, Valio & Moraes 1966) suggests that it is probably commoner than was previously supposed. Whether the rarity of annuals can be accounted for by difficulties of seedling establishment can therefore be doubted but it should also be remembered that cerrado soils are notably oligotrophic, a condition which in many parts of the world seems unfavourable for the growth of annuals.

Loranthaceous parasites (*Phoradendron* and *Psittacanthus* spp.) are common on cerrado trees and the dodder-like *Cassytha* often scrambles over the lower layers, attacking a great variety of hosts. Vascular epiphytes, on the other hand, are normally absent, except sometimes on stream sides: a *Cattleya* sp. was seen on *Hirtella glandulosa* and *H. gracilipes* near Xavantina. Epiphytic lichens are numerous and abundant but bryophytes are very rare.

The trees and shrubs of the cerrado vary considerably in their leafing habits. Some are completely evergreen, e.g. *Anacardium occidentale*, *Hancornia speciosa* and *Mezilaurus crassiramea*, others become partly or completely bare for a longer or shorter period in the dry season. The cerrado as a whole looks more or less green at all times of year when seen from ground level, but from a hill or from an aeroplane in July or August it appears distinctly less leafy than at other seasons. In most woody species flushes of young leaves, often bright red, purple or of some other distinctive colour, begin to appear some weeks in advance of the rains; in many cerrado trees the young leaves are already conspicuous in late August or early September. This expansion of young foliage before the end of the dry season when day temperatures are high and atmospheric humidity very low supports the view, for which there is other evidence (Rawitscher 1948; Ferri 1963) that water is still available deep in the soil in spite of the parched appearance of the ground surface and herbaceous plants. A similar outburst of growth, independent of rain, takes place in the grasses and small dicotyledons of the cerrado and campos after a fire long before the end of the dry season.

In part the complexity of the cerrado reflects its great richness in woody species, none of which normally attains single-species dominance (table 6). The variations in its composition seem to be correlated with slope, drainage and other soil factors and it may be surmised that in addition to these conditions the varying incidence of fires (correlated with accessibility from roads and fazendas, and with site factors such as exposure to prevailing winds) is important.

Although we spent much time studying it, the cerrado in our area seemed to be so complex and variable that well-defined associations correlated with particular habitat conditions could seldom be recognized. An exception to this is the transitional community found where cerrado meets seasonally wet campo. Some cerrado species, e.g. *Andira cuyabensis*, *Qualea parviflora*, *Curatella americana* and *Xylopia aromatica*, seem to be more tolerant than others of low-lying situations with a high water table in the wet season and tend to become abundant under such conditions, though they are by no means confined to them. Small bushes of the first two of these species are commonly found scattered to form 'campo sujo' in the marginal zone of wet campos, each bush growing on a tiny elevation. On some campos, as at Córrego de Gato, about 15 km south of base camp, larger mounds covered with trees and shrubs, each carrying one or more termitaria, form regularly scattered 'islands' rising to a metre or more above the surrounding level. The chief trees on these 'islands' are the four species mentioned above and *Didymopanax distractiflorus* often accompanies them. On the largest 'islands' there are even quite large trees such as *Physocallyma scaberrimum* and *Tabebuia avellanedae* which also occur in cerradão or forest. This transitional type of vegetation is in fact a small-scale development of the 'pantanal' or termite–savanna formation which covers extensive areas in the flood plain of the Araguaia and near Xavantina (see p. 458).

Other examples of cerrado species with clear habitat preferences are *Ferdinandusa elliptica*, a tree up to 10 m high, common on rocky scarps, etc., which is rarely encountered on level sites, and *Anacardium occidentale*, abundant on heavier soils near Xavantina but absent on the sandy soils around base camp. On well-drained flattish ground, as along the road from Xavantina to base camp, *Aspidospermum nobile*, *Dimorphandra mollis*, *Vochysia rufa*, *Mezilaurus crassiramea* and *Mouriria pusa* are conspicuous by their size and/or abundance. The tallest trees here are *Bombax crenulatum* and *Pterodon pubescens* which reach 12–14 m even in low cerrado.

The trees and shrubs on sample plots at eleven stations (parts of transects) in cerradão and cerrado near Xavantina and in the base camp area are listed in table 6. The areas sampled at each station vary in size and while in some cases subjective frequency estimations were made, in others only presence and absence were recorded, but we believe that the lists give a fair picture of the composition of the cerradão and cerrado communities in our area.

The Xavantina plots (stations 1, 10 and 11) show considerable similarity in species composition as might be expected from their nearness to each other. *Anacardium occidentale* and *Dipteryx alata*, two species which are very common round Xavantina but extremely rare in the base camp area, are present in all three of these stations. The close relation between the composition of the vegetation at station 1, a fringe of *Magonia pubescens–Callisthene fasciculata* cerradão transitional to Deciduous Seasonal forest, to that at a similar site near base camp (station 2) is shown by the occurrence in both places of a number of species most of which do not occur in the other stations sampled; these include in addition to *M. pubescens* and *C. fasciculata*, *Bauhinia cupulata*, *Bombax martianum*, *Calliandra microphylla*, *Luhea paniculata*, *Platypodium elegans* and the bamboo Ra 1913.

Stations 3–5 belong to the *Hirtella glandulosa* cerradão community described above (pp. 470, 471). The vegetation at stations 4 and 5, both situated on transect R 14, is very similar in

TABLE 6. TREES AND SHRUBS IN CERRADÃO AND CERRADO

Stations

Xavantina

(1) Fringe of *Magonia pubescens–Callisthene fasciculata* cerradão transitional to Deciduous forest; 25 m × 10 m plots

base camp area

(2) *Magonia pubescens–Callisthene fasciculata* cerradão fringing Deciduous Seasonal forest; four 25 m × 10 m plots
(3) *Hirtella glandulosa* cerradão; transect BC 1; two 25 m × 8 m plots
(4) *H. glandulosa* cerradão; transect R 14; two 50 m × 5 m plots
(5) *H. glandulosa* cerradão and cerrado; transect R 14; two 50 m × 5 m plots
(6) Cerrado in flat rather open area; transect R 14; three 50 m × 5 m plots
(7) low cerrado on very sandy soil; three 25 m × 8 m plots
(8) low cerrado on very sandy soil; four 25 m × 8 m plots
(9) low cerrado on poorly drained sandy ground on interfluve; nine 25 m × 10 m plots

Xavantina

(10) cerrado on flat, gently sloping area; 25 m × 10 m plots
(11) cerrado on rocky ridge and slope; 25 m × 10 m plots

Frequency

Frequencies, where given, were estimated by using the data from the plots and making a more cursory examination along the length of the transects. a, abundant; c, common; f, frequent; o, occasional; r, rare; +, present.

species	stations 1	2	3	4	5	6	7	8	9	10	11
Dicotyledons											
Alibertia edulis	–	–	–	–	r	–	–	–	–	–	–
Anacardium occidentale	o	–	–	–	–	–	–	–	–	c	c
A. pumilum	–	–	–	–	–	–	–	+	r	–	–
Andira cuyabensis	c	–	–	–	–	–	+	+	a	c	–
A. stipulacea	–	–	+	o	o	+	+	+	–	–	+
Andira sp. (Angelim Amarelo)	–	–	–	–	–	–	+	–	–	–	–
Annona coriacea	f	–	–	–	–	–	+	–	r	o	a
Antonia ovata	–	o	+	–	o	–	+	+	–	–	–
Aspidosperma macrocarpon	r	–	–	–	o	+	+	+	o	–	c
A. multiflorum	–	–	–	f	f	+	+	+	–	–	–
A. nobile	–	–	–	–	–	–	+	+	–	r	–
A. tomentosum	–	–	–	r	–	+	+	+	c	–	–
Astronium fraxinifolium	f	f	–	–	–	–	–	–	–	o	o
Bauhinia bongardi	a	–	–	–	–	–	–	–	–	a	–
Bauhinia sp. aff. *B. cheilantha*	–	–	–	–	–	–	+	+	c	–	–
B. cupulata	f	a	–	–	–	–	–	–	–	–	–
B. goyazensis	–	–	–	–	–	+	+	+	c	o	f
Bombax crenulatum	o	–	–	–	–	+	+	+	o	o	–
B. gracilipes	–	–	–	–	o	+	–	–	–	–	–
B. martianum	o	o	c	–	–	+	–	–	–	r	–
Bowdichia virgilioides	o	–	+	r	–	+	+	+	–	f	c
Brosimum gaudichaudii	o	–	–	o	o	–	–	+	r	r	–
Buchenavia tomentosa	f	–	–	–	–	–	–	–	–	–	o
Byrsonima basiloba	–	–	–	–	–	+	–	+	–	–	–
B. coriacea	–	–	+	–	–	–	–	–	–	–	–
B. crassa	–	–	+	–	–	–	+	+	f	–	–
B. crassifolia and *B. pachyphylla* (Muricí)	f	f	–	–	–	+	+	+	a	f	c
Calliandra microphylla	o	c	–	–	–	–	–	–	–	–	–
Callisthene fasciculata	o	f	–	–	–	–	–	–	–	–	–
Caryocar brasiliense	–	–	–	–	–	+	–	–	–	–	r
Cassia sp. (Ra 48)	f	–	–	–	–	–	–	–	–	o	o
Casearia sylvestris	f	–	–	–	f	–	+	+	o	f	a
Chaetocarpus echinocarpus	–	–	–	c	o	–	–	–	–	–	–

TABLE 6. (*cont.*)

species	stations 1	2	3	4	5	6	7	8	9	10	11
Clusia sellowii	–	–	–	o	o	–	–	–	–	–	–
Connarus fulvus	f	–	–	–	–	–	+	+	o	c	a
Copaifera langsdorfii	–	–	+	o	o	+	–	–	–	–	–
C. martii	f	c	+	o	a	+	+	+	c	f	a
Cordia insignis	o	–	–	–	–	–	–	–	–	o	–
Curatella americana	c	–	–	–	–	–	+	–	f	c	–
Davilla elliptica	c	c	–	–	–	+	+	+	a	c	a
Didymopanax distractiflorus	–	–	–	–	–	–	–	+	r	–	–
Dilodendron bipinnatum	–	c	–	–	–	–	–	–	–	–	–
Dimorphandra mollis	c	–	+	o	o	–	–	+	r	–	o
Dipteryx alata	o	–	–	–	–	–	–	–	–	o	f
Duguetia furfuracea	r	–	+	–	–	+	+	+	o	–	o
Emmotum nitens	–	–	+	c	c	–	+	–	–	–	–
Erythroxylum deciduum	–	–	–	–	–	+	+	+	a	–	–
E. suberosum	f	–	–	–	–	–	–	–	–	f	a
Eugenia sp. (Cagaiteiro Ra 2144)	–	–	–	–	–	+	+	–	–	–	–
Euplassa inaequalis	–	–	–	o	o	+	+	–	o	–	–
Fagara riedelianum	–	o	–	–	–	–	–	–	–	–	–
Ferdinandusa elliptica	o	–	–	–	–	+	–	–	–	f	c
Guatteria sp. (Embireira Ra 1143)	–	–	–	r	–	–	–	–	–	–	–
Guazuma ulmifolia	–	f	–	–	–	–	–	–	–	–	–
Hancornia speciosa	o	–	–	–	–	–	–	+	–	o	f
Heisteria densifrons	–	–	–	–	o	–	–	–	–	–	–
Himatanthus bracteata	–	–	–	f	–	–	–	–	–	–	–
H. obovata	f	–	+	–	–	+	+	+	c	r	c
Hirtella glandulosa	–	–	+	a	a	–	–	+	–	–	–
Hymenaea stigonocarpa	f	–	–	–	–	+	–	+	–	f	c
Jatropha vitifolia	c	–	–	–	–	–	–	–	–	f	–
Kielmeyera coriacea	–	–	–	–	–	–	–	–	–	o	–
K. rubriflora	o	–	–	–	–	–	–	–	–	f	f
Krameria tomentosa	–	–	–	–	–	–	–	–	–	–	o
Lafoensia pacari	f	o	+	–	o	+	–	+	a	f	f
Licania blackii	–	–	+	o	–	–	–	–	–	–	–
L. humilis	–	o	–	–	r	+	+	+	–	–	–
Luhea paniculata	f	a	–	–	–	–	–	–	–	–	–
Mabea fistulifera	–	–	–	o	–	–	–	–	–	–	–
Machaerium acutifolium	–	–	+	–	o	+	+	+	–	–	–
Machaerium sp. (Ra 671)	o	–	–	–	–	–	–	–	–	o	o
Magonia glabrata	–	–	–	–	–	–	–	–	–	r	o
M. pubescens	o	c	–	–	–	–	–	–	–	o	–
Maprounea guianensis	–	–	–	f	f	–	–	–	–	–	–
Matayba guianensis	–	o	+	–	o	–	–	–	–	–	–
Mezilaurus crassiramea	o	–	+	r	f	+	+	+	–	f	f
Miconia cuspidata	–	–	+	–	–	–	–	–	–	–	–
M. holosericea	–	–	+	c	c	–	–	–	–	–	–
Miconia sp. (Lacre do Cerrado)	–	–	–	o	c	–	–	–	–	–	–
Mouriria elliptica	–	–	–	–	o	+	–	–	–	–	–
Mouriria sp. (Criolí Ra 2060)	–	–	–	–	–	+	–	+	–	–	–
Myrcia canescens	f	–	–	–	–	–	–	–	–	c	a
M. pubipetala	–	–	–	+	o	+	+	+	–	–	–
M. rorida	–	–	–	–	–	–	+	+	–	–	–
M. schottiana	–	–	+	–	o	+	+	+	a	–	–
M. superba	–	–	–	–	–	–	–	+	a	–	–
M. uberavensis	–	–	+	o	o	–	–	+	–	–	–
Myrcia sp. (Araçá Ra 1983)	–	–	–	–	–	–	–	–	a	–	–

TABLE 6. (*cont.*)

species	stations 1	2	3	4	5	6	7	8	9	10	11
Myrcia sp. aff. *M. ternifolia* (Ra 260)	c	–	–	–	–	–	–	–	–	c	c
Myrciaria floribunda	–	f	+	a	a	–	–	–	–	–	–
Ouratea acuminata	f	r	+	–	o	+	+	+	o	f	a
O. confertiflora	o	–	–	–	r	–	–	–	–	o	o
O. nana	o	–	–	–	–	–	+	+	–	f	a
Palicourea rigida	–	–	–	–	–	–	–	+	o	–	–
Peltogyne confertiflora	–	–	+	o	–	+	–	+	–	–	–
Peritassa campestris	–	–	–	–	–	–	–	+	–	–	–
Physocallyma scaberrimum	–	c	–	–	–	–	–	–	–	–	–
Piptocarpha sp. (Ra 646)	–	–	–	–	–	–	–	–	–	r	–
Plathymenia reticulata	–	f	+	–	–	+	+	+	c	–	–
Platypodium elegans	f	o	–	–	–	–	–	–	–	–	–
Plenckia populnea	–	–	–	–	–	–	–	–	–	f	–
Pouteria ramiflora	–	–	–	–	–	+	+	+	f	–	o
Protium heptaphyllum	o	–	–	–	–	–	–	+	–	a	–
Protium sp. (Almécega Branca Ra 1997)	–	–	+	f	c	–	–	–	–	–	–
Protium sp. (Almécega Vermelha Ra 2049)	–	–	–	o	–	–	–	–	–	–	–
Pterodon pubescens	–	–	–	f	–	–	+	+	–	–	c
Qualea grandiflora	f	–	–	–	–	+	+	–	f	f	f
Q. multiflora	f	f	–	–	–	+	+	+	o	f	–
Q. parviflora	c	o	+	o	f	+	+	+	a	c	c
Roupala montana	f	f	+	c	c	+	+	+	c	f	r
Rourea induta	f	–	+	–	o	–	–	+	f	f	a
Rudgea amazonica	–	f	–	–	–	–	–	–	–	–	–
R. viburnioides	–	f	–	–	–	–	–	–	–	–	–
Ryania mansoana	–	–	+	c	c	–	+	+	–	–	–
Sacoglottis guianensis	–	–	–	f	r	–	–	–	–	–	–
Salvertia convallariodora	r	–	–	o	o	+	–	+	c	f	–
Sclerolobium paniculatum	–	–	+	a	c	–	–	–	–	–	–
Sclerolobium sp. (Pau Para Tudo Ra 350)	f	r	–	–	–	+	+	+	–	o	f
Sideroxylon sp. aff. *S. venulosum*	–	–	–	–	r	–	–	–	–	–	–
Simaruba versicolor	o	–	–	–	f	–	+	–	–	r	f
Siparuna guianensis	–	–	+	a	–	–	–	–	–	–	–
Strychnos pseudoquina	–	–	–	–	–	+	–	+	–	–	–
Tabebuia caraiba	f	–	–	–	–	+	+	+	f	–	–
Tabebuia sp. (Pau de Arco Amarelo Ra 1103)	–	c	–	–	–	–	–	–	–	–	–
Tapirira guianensis	–	–	+	–	o	–	–	–	–	–	–
Terminalia brasiliensis	–	–	–	–	–	+	+	+	–	–	–
T. modesta	f	r	+	–	r	–	+	–	–	–	–
T. subsericea	f	r	+	–	r	–	+	–	–	–	–
Tocoyena formosa	–	–	–	–	–	–	+	+	–	r	o
Veronia ferruginea	o	o	–	–	–	–	–	–	–	–	–
Virola sebifera	–	–	+	o	o	–	–	–	–	–	–
Vitex polygama	–	–	+	–	–	–	–	–	–	–	–
Vochysia haenkeana	–	–	+	a	a	–	–	–	–	–	–
V. herbacea	–	–	–	–	–	–	–	–	–	o	–
V. rufa	–	–	–	–	o	+	–	+	c	o	f
Waltheria polyanthos	–	–	–	–	–	–	–	+	–	–	–
Xylopia aromatica	–	–	+	–	o	+	–	+	r	–	–
X. sericea	–	–	+	f	o	–	–	–	–	–	–
Zehyera digitalis	–	–	–	–	–	–	–	+	–	–	–
Compositae (Veludo do Cerrado (Ra 1926))	–	c	–	–	–	–	+	+	–	–	–

TABLE 6. (*cont.*)

species	stations 1	2	3	4	5	6	7	8	9	10	11
Myrtaceae (Puruhê)	–	–	+	–	–	–	–	–	–	–	–
Nyctaginaceae (Juá Molle Ra 2020)	–	–	+	–	o	+	+	+	–	–	–
unidentified											
Bordão de Velho	–	–	–	–	o	+	–	–	–	–	–
Carvão Vermelho Ra 2027	–	–	+	–	o	–	–	–	–	–	–
Cafezinho do Cerrado	–	–	–	–	–	+	–	–	–	–	–
Chapeudinho Ra 2058	–	–	–	–	o	–	–	+	–	–	–
Chifre de Galheiro	–	–	–	–	–	–	–	+	–	–	–
Olho de Boi Ra 2126	–	r	–	–	–	–	+	+	–	–	–
Pajujurana	–	–	–	–	–	+	–	–	–	–	–
Monocotyledons											
Astrocaryum sp. (Tucumá)	–	–	+	o	a	+	–	+	–	–	–
Attalea sp. (Piaçaba Ra 654)	o	c	–	–	–	+	+	+	a	f	o
Syagrus sp. (?) (Piririma Vasoura Ra 1903)	–	c	–	–	–	–	–	–	–	–	–
Syagrus sp. (?) (Gariroba Ra 1987)	o	–	+	–	–	+	+	+	c	o	a
Syagrus sp. (?) (Babão Ra 1873)	–	c	–	–	o	+	–	–	o	–	–
Bamboo Ra 1913	r	c	–	–	–	–	+	–	–	–	–
number of species	59	39	45	40	56	53	55	70	42	54	46
										total	156

composition, but station 4 is situated closer to the margin of the Dry forest and includes several species characteristic of the latter community, e.g. *Guatteria* sp. (Ra 1143), *Himatanthus bracteata*, *Licania blackii* and *Mabea fistulifera*. The resemblance of the *Hirtella glandulosa* cerradão at station 3 to that at stations 4 and 5, some 9 km distant, is obvious in the field and is clearly shown in the table. Characteristic species common to stations 3–5 include, as well as *H. glandulosa* itself, *Emmotum nitens*, *Myrciaria floribunda*, *Sclerolobium paniculatum* and *Vochysia haenkeana*.

Stations 6 to 9 represent open cerrado communities of the base camp area. Station 9 is in a poorly drained site where *Andira cuyabensis* and *Qualea parviflora*, both often associated with damp conditions (see p. 479 above), are abundant.

3. DISCUSSION AND CONCLUSIONS

The most striking feature of the plant cover of the base camp area, and of the northeastern Mato Grosso generally, is the presence of three physiognomically and floristically very distinct types of vegetation, forest, cerrado (of which cerradão can be regarded as a variant) and campo. Over the eastern and southern parts of the area, including about three-quarters of the Expedition's 20 km square, the three types occur in a characteristic pattern: gallery forest, often bordered by narrow strips of campo, follows the streams and cerrado and cerradão covers all the intervening higher ground. To the north and west, as has already been pointed out, this three-fold pattern gives way to a landscape of continuous Dry forest. Even more remarkable than the contrasts between forest, cerrado and campo is the sharpness of the boundaries between them; only where cerrado adjoins Dry forest is it at all common to find anything like a gradual transition.

The area shows no great differences in elevation, no striking features of relief and the climate, as far as can be guessed from the very inadequate information available, shows no clearly marked local differences (apart from the microclimates due to the vegetation itself), only a gradual trend

from south to north (or perhaps from southeast to northwest) towards higher annual rainfall and a less severe seasonal drought. Therefore in seeking for habitat differences correlated with the occurrence of the different vegetation types and possibly causally related to them, we have to fall back on edaphic factors and, because other anthropogenic influences are minimal, the incidence of fires.

The very thorough soil survey of the base camp area carried out by Askew *et al.* (1970*a*) recognizes three 'soil landscapes', the freely draining dystrophic and mesotrophic soils of the higher ground and the hydromorphic soils of stream valleys with impeded drainage. Considerable differences in soil texture, pH and nutrient status between the relatively fertile mesotrophic soils and the poorer (and much more widespread) dystrophic soils were revealed. The hydromorphic soils, characterized by permanent or seasonal waterlogging and recognizable by their greyish or whitish colour, generally have a low base status and differ little chemically from the dystrophic soils except in having less iron and more organic matter.

Superimposed on their other differences, the various soil types show great differences in the depth of the water table, which cannot but be important in a climate in which for more than half the year there is a large excess of evaporation over precipitation. Field observations in the base camp area suggest that the depth of the water table below the soil surface in the wet and dry seasons may be of critical importance to the vegetation in two ways: first by influencing the ability of plants to take up water, especially in drought periods, and secondly, by restricting root activity in the wet season to the comparatively well oxygenated superficial layers of the soil, except for plants like those of the gallery forests which seem to have root systems specially adapted to waterlogged and anaerobic conditions. The former effect is likely to be important on interfluves and higher ground generally, where during the dry season water is available only at great depths in the soil; the latter seems to operate in the campos and at the cerrado/campo boundaries.

Since the Serra do Roncador is the meeting place of a vast area of forest stretching north to the Amazon and an almost equally extensive area of cerrado and cerradão extending to the south and east, it is plausible to suggest that it lies in a tension zone in which the climate permits forest and cerrado to exist together. Under such conditions very small local differences of soil or topography may be sufficient to tilt the balance in favour of one type of vegetation or the other. This view is accepted by Askew *et al.* (1970*b*, pp. 58–59) whose conclusions about the boundary between forest and cerrado in our area are expressed as follows:

'On the Serra do Roncador both Dry forest and cerrado occur on dystrophic soils so that in this area there are no major differences in soil chemical or mineralogical properties influencing the boundary between these two types of vegetation. Neither is the boundary between Dry forest and cerrado related to topographical conditions as is the case in certain other parts of central Brazil (Cole 1960).

'The outstanding primary (i.e. inherited) difference between the dystrophic soils on central interfluve sites under the two types of vegetation is that the soils under forest are finer in texture than those under cerrado; the former are sandy clay loams whilst the latter are sands or loamy sands. No coarse textured soils occur on central interfluves within the Dry forest area and no fine or medium textured dystrophic soils occur under cerrado, except for one area adjacent to the vegetation boundary. In this latter area it is of interest that the vegetation consists predominantly of cerradão. Investigations outside the base camp study area showed that this textural correlation does not hold away from the regional vegetation boundary. Farther south, around

Xavantina, for instance, cerrado occurs on clay soils, whilst farther north Dry forest occurs on a range of soil textural types. Although Dry forest is not generally found on very sandy soils, there is a limited occurrence of this forest within the base camp area on coarse textured, well-drained, lower interfluve sites. The occurrence of Dry forest as a broad zone between the equatorial rain forests and the cerrado plains of central Brazil would indicate that climate is an important factor limiting the spread of this forest southwards. In this tension zone at the climatic limit of Dry forest on the Serra do Roncador it seems likely that soil texture is affecting the position of the boundary through its influence on soil moisture status.'

It is possible that fires as well as soil factors play a part in determining the position of the forest/cerrado boundary. As previously mentioned (p. 457) a given area of cerrado is probably not burnt every year but perhaps as often as once every four or five years: cerrado fires do not usually penetrate more than a few metres into forest. Fires will tend to prevent fire-susceptible forest species from spreading into the neighbouring cerrado. Since fires do not recur at regular intervals, the situation may well be a dynamic one in which the cerrado sometimes advances into the forest and sometimes retreats. For example, if at a particular moment the Dry forest were tending to expand and the transitional *Hirtella glandulosa* cerradão represented its advancing front, there could be a dynamic situation in which forest, cerradão and cerrado all occur together on soils which are similar except for differences due to the effects of the plant cover itself.

The only actual evidence we have of movement in the forest/cerrado boundary comes from the distribution of certain tree species. Thus at one place in tall Dry forest 3 km from the boundary the common cerrado tree *Pterodon pubescens* is found as tall, usually emergent, trees unaccompanied by younger individuals. If, like many cerrado plants, the seedlings of this species require full light for their development, the failure to regenerate may indicate that the tall trees are relics which originally established themselves in a cerrado community. The occasional occurrence in the Dry forest of large individuals of other cerrado species such as *Bowdichia virgilioides* and *Peltogyne confertiflora* could be interpreted in a similar way. On the other hand, the remarkable abundance of seedlings of *Roupala montana* and the sparsity of mature individuals may mean no more than the failure of a characteristic cerradão species to establish itself under Dry forest conditions. Evidence suggesting that Swampy Gallery forest near Xavantina is invading the surrounding campo was mentioned on p. 460.

If differences in the water-supplying capacity of the soil can determine the boundary between cerrado and Dry forest, they may well also be responsible, at least in part, for differences between 'low cerrado', 'high cerrado' and 'undifferentiated cerradão'. Some support for this suggestion is given by the observation that in the cerrado in the base camp area the height and density of the trees and, somewhat unexpectedly, the moisture content of the soil in the dry season, were greater on the crests of interfluves than on the neighbouring slopes (see Askew *et al.* 1971, pp. 157–158).

It seems evident that both Swampy Gallery forest and Valley forest require a high water table throughout the year. In the former it never falls far below the surface even at the height of the dry season; in the latter it is deeper but never as deep as in the cerrado and dry forest.

The cerrado/campo boundary also seems to depend on a difference in water level, but in our opinion it is the highest level reached by the water table in the wet season which is critical.* The

* *Note added in proof* 13 *September* 1973. Since the paper was written, an extensive review of the cerrado vegetation of Brazil has appeared (Eiten 1972). Eiten's views on the influence of water level on campo/cerrado boundaries correspond with ours.

cerrado grows mainly on red or reddish freely drained dystrophic soils and the campos on whitish hydromorphic soils, but the boundary between the two vegetation types does not usually coincide with the change from one soil type to the other. Commonly the change of soil takes place at a slightly higher level than the change of vegetation; when walking down a slope towards a campo the change in soil colour, together with the appearance of indicator species (*Anacardium pumilum* etc.) heralds the change from cerrado to open campo.

Askew *et al.* (1971) have published observations on the ground water level along transects sited to cross the cerrado/campo/gallery forest boundaries in several places in the base camp area. The measurements were made weekly from the late dry season of 1968 to the end of the wet season in 1969. These showed that on any one transect the cerrado has a deeper water table than the campo, but on different transects it may happen that cerrado is present on one transect at a water level which has campo on another. The authors conclude from this that it 'seems unlikely that ground water table levels are the decisive factors influencing the precise location of the very sharply defined cerrado/campo boundaries' though they believe that *in general* the distribution of cerrado, campo and gallery forest depends on water level. We would maintain, however, that in most places the ground water level probably has a *very precise* relation to the campo/cerrado boundary. The relation of water level to the boundary is much clearer if only the high water levels in the wet season are taken into account. The observations that cerrado species tolerant of 'transitional' (i.e. high water level) conditions are able to grow on open campos in places close to the cerrado boundary where the soil level is only a few centimetres higher than elsewhere, and that larger 'islands' such as the termite mounds on 'pantanal' are thickly clothed with cerrado vegetation, support the view that ground water level exerts a precise control on the boundary. Further evidence is given by studies of the root systems of small isolated cerrado trees growing on campos; these will be reported in a later paper (Richards). The fact that the cerrado/campo boundary occurs at different levels on different transects could well be due to other differences in local conditions, e.g. rate of flow of water, supply of mineral nutrients etc. The suggestion of Askew *et al.* (1971, p. 159) that allelopathic interactions between plant species may make the boundary sharper than the environmental boundary is plausible but it does not seem necessary to make such an assumption.

Water is certainly not the only edaphic factor affecting the distribution of types of vegetation in the base camp area: one of the most striking soil–vegetation inter-relations is the restriction of the very distinctive Deciduous Seasonal forest to areas of relatively nutrient-rich mesotrophic soil (tables 1 and 4, pp. 455 and 464). This type of forest has almost no tree species in common with the evergreen forests on the poor dystrophic and hydromorphic soils. Similar soil relations are shown by the cerradão communities: the *Magonia pubescens–Callisthene fasciculata* cerradão with its characteristic deciduous species is associated with relatively fertile soils, often in the transition between Deciduous Seasonal forest and cerrado, while the more evergreen *Hirtella glandulosa* cerradão occurs on poor dystrophic soils in the dry forest/cerrado transition (table 4, p. 464). Thus in our area the type of vegetation fairly clearly reflects the nutrient status of the soil.

It is interesting to note that there seems to be a definite link between soil nutrients and the deciduous or evergreen habit of the dominant trees. For lack of more than fragmentary information about the leafing habit of trees in our area this relation cannot be demonstrated quantitatively, but our observations showed that throughout the northeastern Mato Grosso trees with a deciduous habit and mesophyll type of foliage tend to occur on soils of relatively high nutrient status, while on the nutrient-poor dystrophic and hydromorphic soils the foliage is predomi-

nantly evergreen and often sclerophyllous. This correlation between the type of foliage and relatively eutrophic or relatively oligotrophic conditions is in no way peculiar to the Mato Grosso: it seems to be found throughout tropical and subtropical America and also in the Old World tropics. The occurrence of sclerophylly and other manifestations of xeromorphy in the cerrado and various other Brazilian plant formations such as the 'Rio Negro caatinga' ('pseudo-caatinga' of Aubréville 1961) has been discussed at length by Ferri (1960, 1962, 1963) and his associates and by Arens (1963). A striking example of the same relation is found in Costa Rica where in the seasonally dry climate of Guanacaste Province the forests, except for streamside galleries, are dominated by mainly deciduous mesophyllous trees but on areas of very poor volcanic ash there are nearly pure stands of *Quercus oleoides* which has evergreen sclerophyllous foliage (Richards). Similar examples could be quoted from other parts of the American tropics, Borneo and elsewhere. Monk (1965) has shown that in subtropical Florida where the forests are mixtures of evergreen and deciduous trees the proportion of evergreens is significantly greater on poor sandy soils than on more fertile sites.

Though the frequency of sclerophylly and other xeromorphic features in cerrado and other vegetation types on oliogotrophic soils has often been regarded as an adaptation to actual or 'physiological' drought there is good evidence to connect it with a need to conserve mineral nutrients. Evergreen leaves, because of their greater longevity, require a less frequent recycling of nutrient ions and probably lose less nutrients by foliar leaching (D. Wood, private communication). Both Ferri (1960, 1962, 1963) and Arens (1963) have argued that cerrado species are only rarely subject to serious water stress in the dry season; on the other hand, they found much evidence that they normally suffer from a deficiency of mineral nutrients. Moraes & Arens (1971) found that under similar conditions the leaves of a number of cerrado species lose less potassium by cuticular leaching than those of mesophyllous plants such as *Phaseolus vulgaris*.

We wish to record our thanks to the Royal Society and the Royal Geographical Society for the opportunity of taking part in the Expedition, and to the Fundacão Brasil Central (later replaced by SUDECO) and the University of Brasilía for the facilities they afforded to us.

Sr Raimundo A. de Castro, a funcionário of SUDECO seconded to the Expedition, gave us the benefit of his immense practical knowledge of the woody plants of the Mato Grosso and of its natural history generally. The collecting and preparation of plant material was very ably carried out for us by Srs R. de Santos, R. Souza, A. Ferreira and J. Ramos, all funcionários or associates of IPEAN, Belém. We should also like to thank our colleagues on the Expedition for their co-operation. In particular we are much indebted to Mr I. R. Bishop, the leader of the Expedition, for his help and continual interest in our work and to the soil science team (Mr G. P. Askew, Dr D. J. Moffatt, Mr R. F. Montgomery and Dr P. L. Searl) who have been an unfailing source of information and advice for the preparation of this paper and have provided figure 3. Mr S. Daultrey kindly helped in preparing the section on climate, Mr S. R. Edwards undertook the difficult task of preparing the profile diagrams from the field drawings, while Dr R. M. Harley, Dr T. Pennington and Mr D. Philcox, Royal Botanic Gardens, Kew, have unstintingly provided identifications and much other assistance. We wish to record our appreciation to the Royal Geographical Society for permission to reproduce figure 3, and particular thanks are due to Mr G. S. Holland of the Royal Geographical Society for technical advice and assistance in preparing it for publication.

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Appendix. List of species mentioned

The following families were identified by specialists: Combretaceae (A. W. Exell), Compositae (C. Jeffrey), Euphorbiaceae (A. R. Smith), Gramineae (S. A. Renvoize), Melastomataceae (J. J. Wurdack), Rosaceae (G. T. Prance). All other identifications were by R. M. Harley, T. Pennington, D. Philcox and J. A. Ratter.

Only one collection is cited for each species, but in most cases numerous collections were made and a full list is available at the Kew and Edinburgh herbaria. The first set of the Expedition's collection is at Kew, the second at the University of Brasília. Other sets have been distributed to the Royal Botanic Garden, Edinburgh, the New York Botanical Garden and other herbaria.

The collector's names are abbreviated as follows:

AR	G. C. G. Argent and P. W. Richards
G	D. R. Gifford
H	R. M. Harley
Ra	J. A. Ratter
R	P. W. Richards

Species mentioned in references to literature, etc., but not observed in the Expedition's area are indicated *.

Acacia polyphylla DC	Ra 1078	*Andropogon* sp.	—
**Acrocomia sclerocarpa* Mart.	—	*Annona coriacea* Mart.	Ra 99
Acrocomia sp. (Macaúba)	Ra 1084	*Antonia ovata* Pohl	Ra 180
Agonandra silvatica Ducke	AR 6583	*Apeiba tibourbou* Aubl.	Ra 1063
Alibertia edulis (L. Rich.) A. Rich.	Ra 363	*Apuleia molaris* Spruce ex Benth.	AR 6743
Anacardium occidentale L.	Ra 253	*Aristida capillacea* Lam.	Ra 79
A. pumilum St Hil.	Ra 159	*Aspidosperma macrocarpon* Mart.	Ra 254
Andira cuyabensis Benth.	Ra 1043	*A. multiflorum* A. DC.	Ra 2130
A. stipulacea Benth.	Ra 2018	*A. nitidum* Benth.	Ra 2039
Andira sp. (Angelim amarelo)	—	*A. nobile* Muell. Arg.	Ra 2096

A. tomentosum Mart.	Ra	1576
Aspidosperma sp. (Guatambú)	Ra	968
Astrocaryum sp. (Tucumá)		—
Astronium fraxinifolium Schott.	Ra	506
**A. urundueva* (Fr. All.) Engl.		—
Attalea sp. (Piaçaba)	Ra	654
Attalea sp. (?) (Naja Cabeçuda)	Ra	1904
Bauhinia bongardi Steud.	Ra	33
Bauhinia sp. aff. B. *cheilantha* (Bong.) Steud.	Ra	440
B. cupulata Benth.	Ra	1054
B. curvula Benth.	Ra	2123
B. dubia G. Don	Ra	2045
B. goyazensis Harms	Ra	907
B. guianensis Aubl.	H	10927
B. punctata Burch.	Ra	399
Bombax crenulatum K. Schum	Ra	62
B. gracilipes K. Schum.	Ra	129
B. martianum K. Schum.	Ra	1856
Bombax sp. (Embiruçú)	R	6595
Borreria sp.		—
Bowdichia virgilioides H.B.K.	Ra	152
Brosimum gaudichaudii Trec.	Ra	2011
Buchenavia tomentosa Eichl.	Ra	368
Bulbostylis paradoxa (Spreng.) Standl.	Ra	316
Byrsonima basiloba Juss.	G	40
B. coriacea DC	Ra	1303
B. crassa Ndz.	Ra	2131
B. crassifolia (L.) H.B.K.	Ra	190
B. pachyphylla Juss.	Ra	1244
B. verbascifolia Juss.	Ra	533
Calliandra microphylla Benth.	Ra	1898
Callisthene fasciculata (Spr.) Mart.	Ra	156
Calophyllum brasiliense Camb.	Ra	550
Cariniana rubra Miers.	Ra	1655
Caryocar brasiliensis Camb.	Ra	616
Casearia sylvestris Sw.	Ra	142
Cassia sp.	Ra	48
Cassytha sp.	Ra	1277
Cattleya sp.	Ra	128
Cecropia pachystachya Trec.	R	6705
Cedrela fissilis Vell.	Ra	1108
Cephaelis tomentosa Vahl	Ra	42
Chaetocarpus echinocarpus (Baill.) Ducke	Ra	1433
Clusia sellowii Schlecht.	Ra	1312
Cochlospermum insigne St Hil.	Ra	394
Connarus fulvus Planch.	Ra	176
Copaifera langsdorfii Desf.	Ra	345
C. martii Hayne	Ra	294
Cordia insignis Cham.	Ra	1267
Costus sp.		—
Curatella americana L.	Ra	188
Dalechampia tiliaefolia Lam.	Ra	1861
Davilla elliptica St Hil.	Ra	899
Desmoncus sp.	AR	6479
Dichromena sp.	R	6508
Didymopanax distractiflorum Harms	Ra	116
D. morototoni Decne. & Planch.	Ra	978
Dilodendron bipinnatum Radlk.	Ra	1874
Dimorphandra mollis Benth.	Ra	1561
Dipteryx alata Vog.	Ra	312
Duguetia furfuracea (St Hil.) Benth. & Hook.	Ra	852
Emmotum nitens (Benth.) Miers.	Ra	1282
Ephederanthus sp.	H	10553
Erythrina ulei Harms	Ra	226
Erythroxylum deciduum St. Hil.	R	6928
E. suberosum St. Hil.	Ra	603
Eugenia sp. (Cagaiteiro)	Ra	2144
Eupatorium odoratum L.	Ra	1857
Euplassa inaequalis (Pohl) Engler	Ra	435
Euterpe sp. (Açaí)	Ra	2044
**Fagara rhoifolia* (Lam.) Engl. (*Zanthoxylum rhoifolium* Lam.)		—
F. riedelianum Engl.	Ra	1900
Faramea salicifolia Bresl.	Ra	1885
Ferdinandusa elliptica Pohl	Ra	270
F. speciosa Pohl	Ra	1042
Ficus sp.		—
Guarea trichiloides L.	Ra	601
Guatteria sp. (Embireira)	Ra	1143
Guazuma ulmifolia L.	Ra	1100
Hancornia speciosa Gomez	Ra	330
Heisteria densifrons Engl.	Ra	2022
Heliconia hirsuta L.f.	Ra	41
Helicteres corylifolia Nees & Mart.	Ra	1102
Henrietella ovata Cogn.	Ra	1865
Heteropteris sp.	Ra	280
Hieronyma alchorneoides Allem.	Ra	1975
Himatanthus bracteata (A. DC.) Woods.	Ra	1390
H. obovata (M. Arg.) Woods.	Ra	256
Hirtella glandulosa Spreng.	Ra	28
H. gracilipes (Hook.) Prance	Ra	36
H. hispidula Steud.	Ra	1209
Humiria balsamifera (Aubl.) St. Hil.	Ra	1139
Hymenaea stigonocarpa Mart.	Ra	175
H. stilbocarpa Hayne	Ra	1231
Imperata contracta (H.B.K.) Hitch.	Ra	1905
Inga sp. (Inga xixica)	Ra	1818
Jacaranda copaia (Aubl.) D. Don	R	6775
Jatropha vitifolia Mill.	Ra	54
Kielmeyera coriacea (Spr.) Mart.	Ra	293
K. rubriflora St Hil.	Ra	1514
Krameria tomentosa St Hil.	Ra	812
Lafoensia pacari St Hil.	Ra	269
Lasiacis sorghoidea (Desv.) Hitchc. & Chase	Ra	2120
Leiphaimos calycina (Splitg. ex A.DC) Miq.	R	6631
Licania blackii Prance	Ra	1796
L. humilis Cham. & Schlecht.	Ra	191
L. kunthiana Hook. f.	Ra	1824
Liriosma singularis (Vell.) Mackr.	Ra	1222
Luhea paniculata Mart.	Ra	157
Luheopsis sp. (Jangada)	R	6898
Lycopodium eichleri Glaz. ex Fée	Ra	561
Mabea fistulifera Mart.	Ra	1417
Machaerium acutifolium Vog.	Ra	668

Machaerium sp. Ra 671
Magonia glabrata St Hil. Ra 267
M. pubescens St Hil. Ra 107
Manilkara sp. (?) (Maceranduba) —
Maprounea guianensis Aubl. Ra 1817
Matayba guianensis Aubl. Ra 1851
Mauritia flexuosa L.f. —
Memora sp. aff. *allamandiflora* Bur. ex K. Sch. Ra 2238
Mezilaurus crassiramea (Meissn.) Taubert Ra 805
Miconia ampla Triana Ra 2038
M. cuspidata Naud. Ra 1376
M. holosericea (L.) DC Ra 1136
M. lepidota DC Ra 1145
M. pyrifolia Naud. Ra 2052
M. splendens (Sw.) Griseb. Ra 2041
M. tomentosa (Rich.) Don Ra 556
Miconia sp. (Lacre do Cerrado) —
Mimosa obovata Benth. Ra 187
Mouriria elliptica Mart. Ra 2110
M. pusa Gardner Ra 1521
Mouriria sp. (Criolí) Ra 2060
Myrcia canescens Berg. Ra 576
M. pubipetala Miq. Ra 2030
M. rorida Berg. Ra 1974
M. schottiana Berg. Ra 2076
M. superba Berg. Ra 1988
Myrcia sp. aff. *M. ternifolia* Berg. Ra 260
M. uberavensis Berg. Ra 2129
Myrcia sp. (Araçá) Ra 1983
Myrcia sp. (Pixuna) —
Myrciaria floribunda (West) Berg. H 10844
Myrmidone macrosperma Mart. —

Neea spruceana Heim. —

Ocotea guianensis Aubl. Ra 1204
Olyra latifolia L. Ra 976
Ormosia sp. (Tento) —
Ouratea acuminata (DC.) Engl. Ra 101
Ouratea sp. aff. *O. confertiflora* (Pohl) Engl. Ra 358
O. nana (St Hil.) Engl. Ra 139

Palicourea rigida H.B.K. Ra 865
Panicum maximum Jacq. —
Peltogyne confertiflora (Hayne) Benth. Ra 1246
Peritassa campestris A.M.W.M. Ra 369
**Phaseolus vulgaris* L. —
Phenakospermum guyanensis Engl. —
Physocallyma scaberrimum Pohl Ra 148
Piper arboreum Aubl. Ra 586
Piptadenia falcata Benth. —
P. macrocarpa Benth. Ra 1651
Piptocarpha sp. Ra 646
Plathymenia reticulata Benth. Ra 836
Platypodium elegans Vog. Ra 1105
Plenckia populnea Reiss Ra 651
Polybotrya caudata Kuntze AR 6336
Pouteria ramiflora (Mart.) Radlk. Ra 1953
Pouteria sp. (Jará) Ra 599
Protium heptaphyllum March. Ra 272
P. krukoffii Swart. Ra 597
Protium sp. (Almécega Branca) Ra 1810
Protium sp. (Almécega Verdadeira) Ra 2363
Protium sp. (Almécega Vermelha) Ra 2049
Protium sp. (Breu Branco) Ra 1840
Pseudolmedia laevigata Tréc. R 6534
Psychotria prunifolia (H.B.K.) Steyermark Ra 1140
Pterodon pubescens Benth. Ra 1153

Qualea grandiflora Mart. Ra 1248
**Q. ingens* Warm. var. *duckei* Stafl. —
Q. ingens Warm. var. *ingens* Ra 658
Q. multiflora Mart. Ra 802
Q. parviflora Mart. Ra 88
Q. wittrockii Malme AR 6399
**Quercus oleoides* Cham. & Schlecht. —

Rapatea sp. —
Richeria grandis Müll. Arg. Ra 1498
Roupala montana Aubl. Ra 24
Rourea induta Planch. Ra 647
Rudgea sp. aff. *R. amazonica* Müll. Arg. —
R. viburnioides (Cham.) Benth. Ra 1870
R. villosa Benth. Ra 1141
Ryania mansoana Eichl. Ra 1306

Sacoglottis guianensis Benth. Ra 1814
Salvertia convallariodora St Hil. Ra 124
Scleria sp. Ra 2118
Sclerolobium paniculatum Benth. Ra 1232
Sclerolobium sp. (Pau para tudo) Ra 350
Schoepfia obliquifolia Turez Ra 1548
Serjania spp. (Cipó Cururú) Ra 27, Ra 982
Sideroxylon sp. aff. *S. venulosum* H 10523
Simaruba versicolor St Hil. Ra 357
Siparuna guianensis Aubl. Ra 2050
Sloanea eichleri S. Schum. AR 6382
S. guianensis (Aubl.) Benth. Ra 631
S. sinemariensis Aubl. Ra 525
Sorocea illicifolia Miq. —
Sterculia striata St Hil. & Naud. Ra 1075
Streptogyna americana C. E. Hubbard Ra 974
Strychnos araguaensis Kr. & Barn. Ra 1199
S. pseudoquina St Hil. Ra 614
Syagrus sp. (Gariroba) Ra 1987
Syagrus sp. (Babão) Ra 1873
Syagrus sp. (?) (Piririma Vasoura) Ra 1903
Symphonia globulifera L.f. Ra 1999

Tabebuia avellanedae Lor. ex Griseb Ra 1584
T. caraiba (Mart.) Bur. Ra 1046
Tabebuia sp. (Pau de Arco Amarelo) Ra 1103
Tapirira guianensis Aubl. Ra 1504
Terminalia brasiliensis Camb. Ra 278
T. modesta Eichl. Ra 2148
T. subsericea Eichl. Ra 1117
Terminalia sp. (Mirimdiba da Mata) Ra 2033
Thrasya petrosa (Trin.) Chase Ra 943
Tococa formicaria Mart. Ra 204
Tocoyena formosa K. Schum. Ra 1097
Trichilia sp. aff. *T. roraimana* CDC Ra 1144
Trichomanes cristatum Kaulf. R 6624
T. pinnatum Hedw. R 6635
T. punctatum Poir. subsp. *labiatum* (Jenm.) Wessels-Boer R 6593

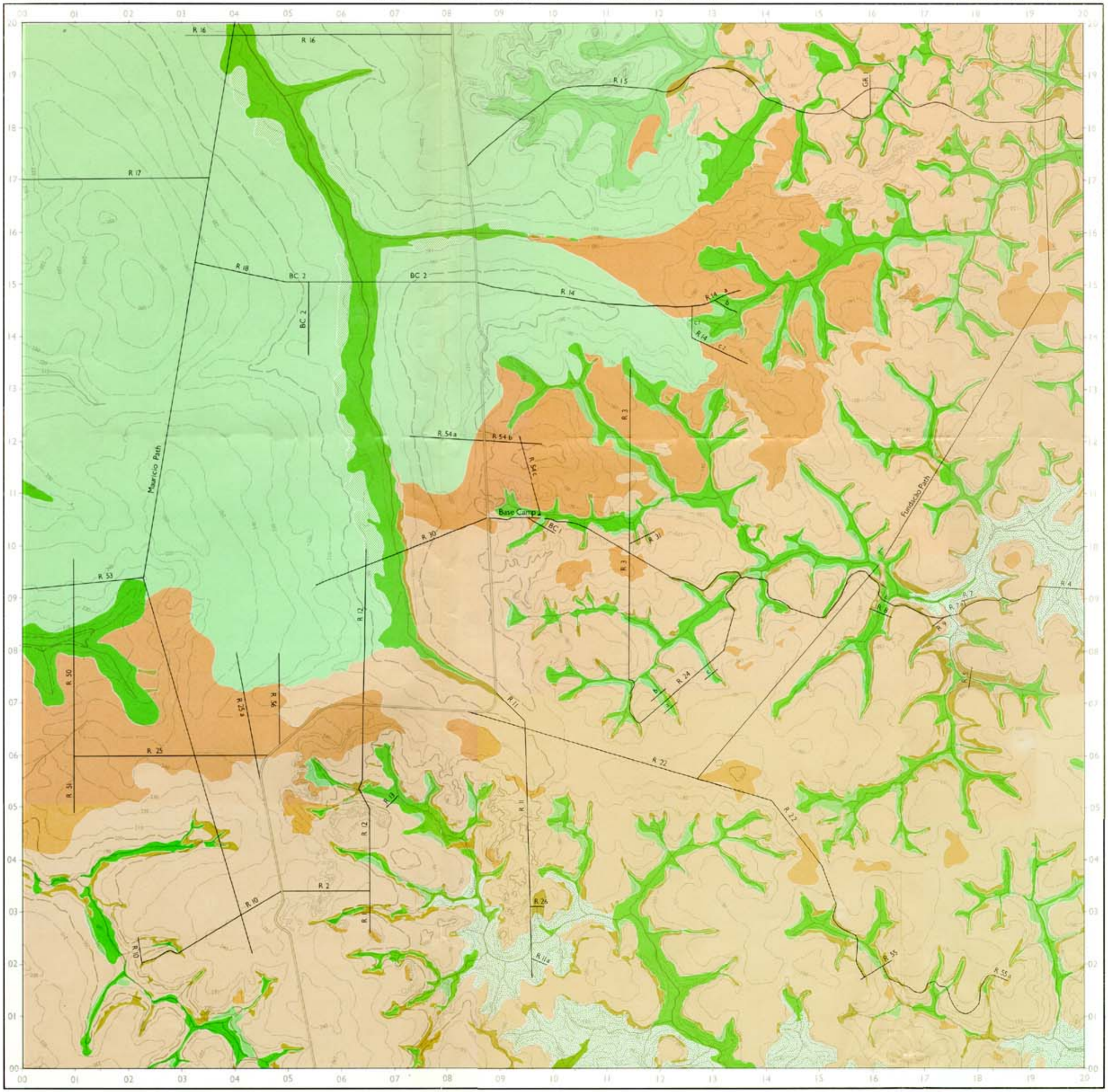
Triumfetta althaeoides Lam.	Ra 1023	*Zeyheria digitalis* (Vell.) Hoehne	Ra 356
T. semitriloba L.	Ra 1860	*Zizyphus joazeiro* Mart.	Ra 1060
Uncaria guianensis (Aubl.) Willd.	Ra 1679		
Unonopsis lindmannii R. E. Fries	Ra 1660	Compositae (Veludo do Cerrado)	Ra 1926
		Gramineae (Bamboo)	Ra 1913V
Vellozia sp.	Ra 573	Lauraceae (Louro Precioso)	R 6916
Vernonia ferruginea Less.	Ra 117	Lauraceae (Louro Rosa)	Ra 2024
Vismia magnoliaefolia C. & S.	R 6700	Leguminosae (Sicupira do Brejo)	R 6910
Virola albidiflora Ducke	Ra 600	Malpighiaceae	Ra 2092
V. sebifera Aubl.	Ra 1201	Melastomataceae	Ra 583
Vitex polygama Cham.	Ra 501	Myrtaceae (Mortinha)	Ra 2075
Vochysia haenkeana Mart.	Ra 1547	Nyctaginaceae (Jua Molle)†	Ra 2020
V. herbacea Pohl	Ra 1629	Sapotaceae (Cutiti Branco)	Ra 1107
V. pyramidalis Mart.	R 6650		
V. rufa Mart.	Ra 1287	Unidentified	
		Bacurí	Ra 6920
Waltheria polyanthos K. Schum.	Ra 814	Cambará	R 6702
		Carvão Vermelho	Ra 2027
Xylopia amazonica R. E. Fries	Ra 1177	Catoarí	R 6896
X. aromatica (Lam.) Mart.		Chapeudinho	Ra 2058
(*X. grandiflora* St Hil.)	Ra 170	Olho de Boi	Ra 2126
X. sericea St Hil.	Ra 1435	Trapiá de Mata	R 6917

† Dr R. M. Harley's collections include two Nyctaginaceous species under this vernacular name, *Neea spruceana* and *Pisonia graciliflora* Mart., and it is possible that we have recorded the two species, which were both in vegetative condition, under the same name.

VEGETATION MAP OF PART OF THE SERRA DO RONCADOR

XAVANTINA-CACHIMBO EXPEDITION TO CENTRAL BRAZIL

Phil. Trans. R. Soc. Lond. B. vol. 266



FOREST

Evergreen Seasonal Forest

- SWAMPY GALLERY FOREST
- VALLEY FOREST
- DRY FOREST
- CARRASCO

Deciduous Seasonal Forest

SAVANNA

- CERRADÃO
- CERRADO

GRASSLAND (CAMPO)

Transect lines R 56

SCALE 1:50000

Kilometres 1 0 1 2

Approximate position of Base Camp 12° 49'S 51° 46'W

Formline vertical interval 10 metres

Location of map in Brazil

COMPILATION NOTE

The base details for this map were produced photogrammetrically in 1968 by Fairey Surveys Ltd. from 1:45000 scale photography. At that time no ground control was available and an arbitrary datum of 90 metres was given to the lowest formline. The road, soil transects and access paths have been added subsequently. The vegetation boundaries, as interpreted on the 1:45000 scale air photographs by the authors, were transferred photogrammetrically to the base map by the Department of Surveying, University of Newcastle upon Tyne.

G.P.Askew, D.J.Moffatt, R.F.Montgomery & P.L.Searl.

FIGURE 3

VEGETATION MAP O

Ratter et al.)

XAVANTINA-CA

00 01 02 03 04 05 06 07 08

20 19 18 17 16 15 14 13 12 11 10 09

R 16 R 16

R 17

R 18

BC 2 BC 2

BC 2

R 54 a

R 30

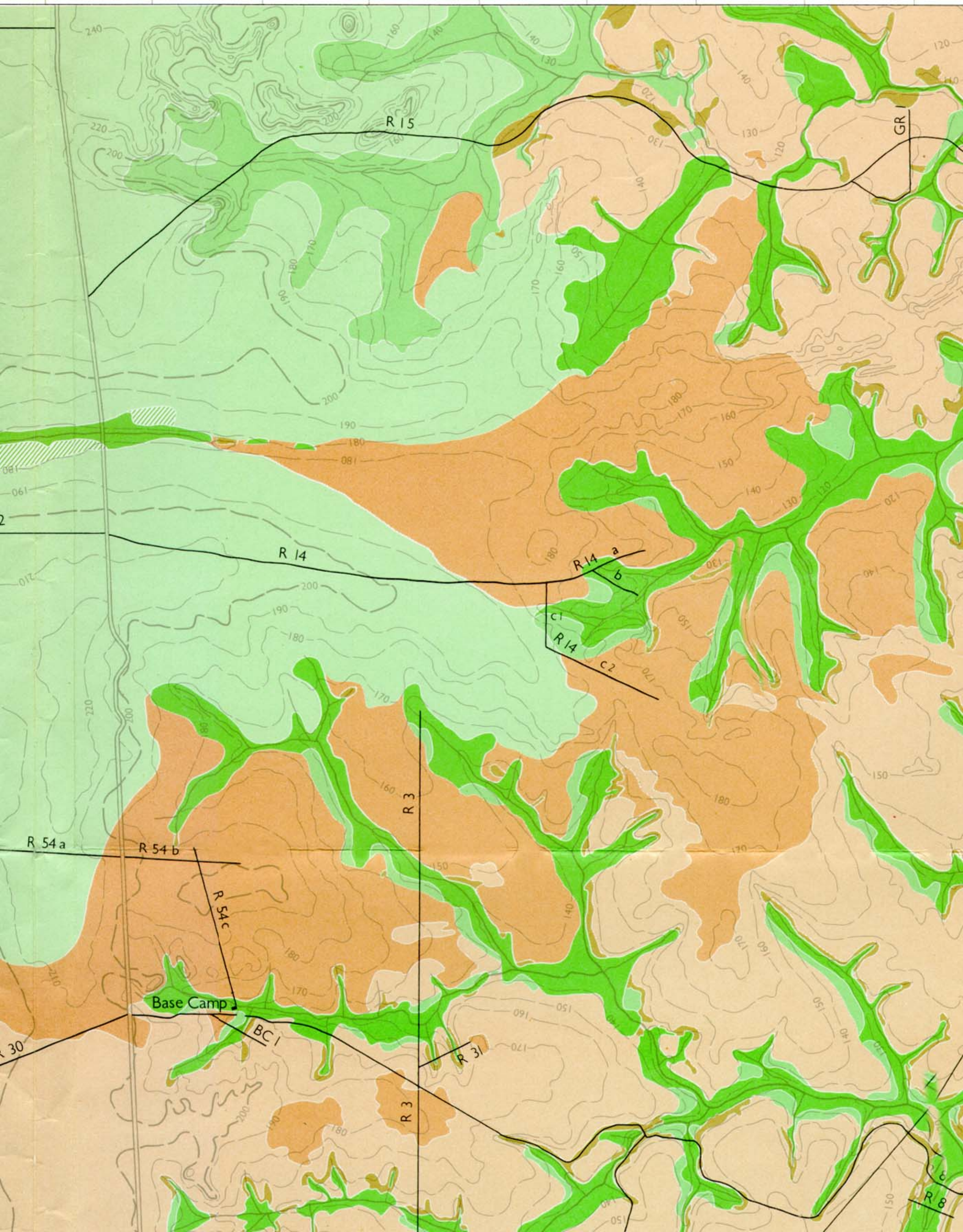
R 53

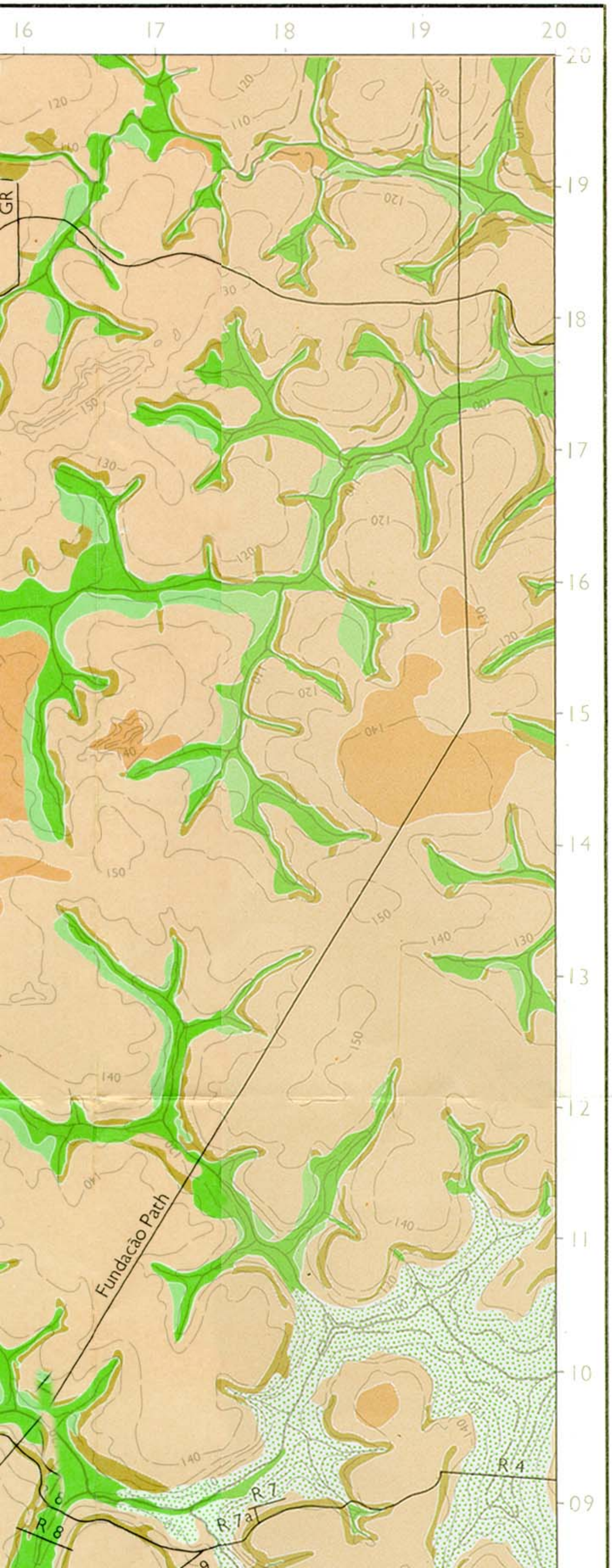
R 12

Mauricio Path

AP OF PART OF THE SERRA DO RONCADOR

NA-CACHIMBO EXPEDITION TO CENTRAL BRAZIL





FOREST

Evergreen Seasonal Forest

SWAMPY GALLERY FOREST

VALLEY FOREST

DRY FOREST

CARRASCO

Deciduous Seasonal Forest

SAVANNA

CERRADÃO

CERRADO

GRASSLAND (CAMPO)

Transect lines R 56

SCALE 1 : 50 000

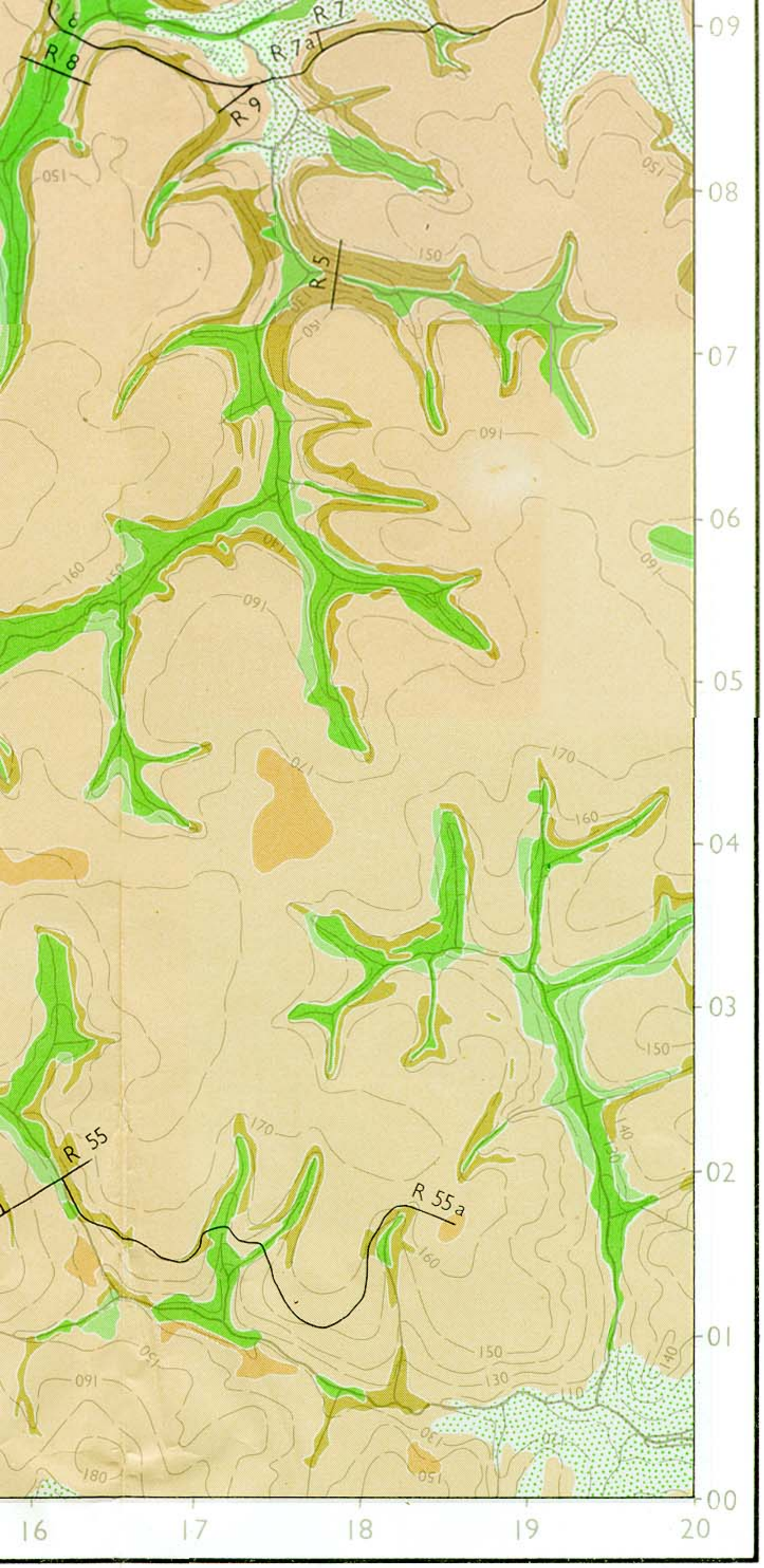
Kilometres

1 0 1 2

G.P.Askew, D.J.Moffatt, R.F.Montgomery & P.L.Searl.

FIGURE 3

Repr



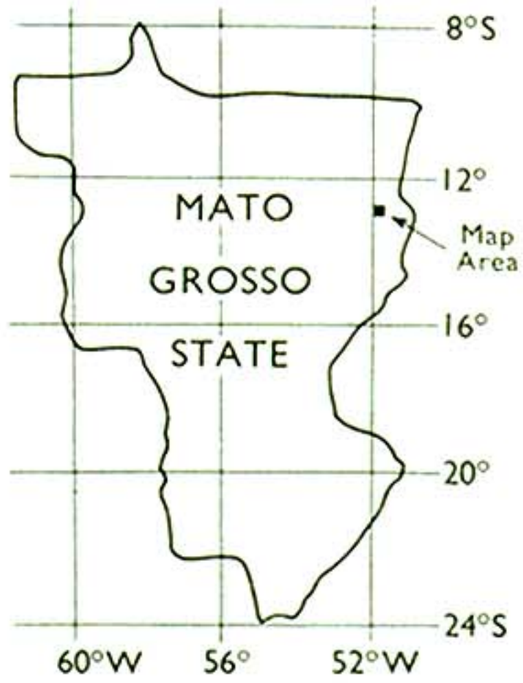
SCALE 1 : 50 000

Kilometres

1 0 1 2

Approximate position of Base Camp 12° 49'S 51° 46'W

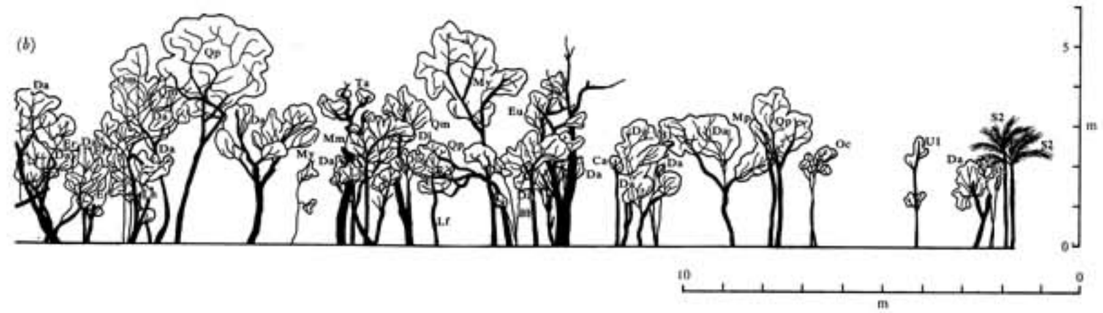
Formline vertical interval 10 metres



Location of map in Brazil

COMPILATION NOTE

The base details for this map were produced photogrammetrically in 1968 by Fairey Surveys Ltd. from 1 : 45 000 scale photography. At that time no ground control was available and an arbitrary datum of 90 metres was given to the lowest formline. The road, soil transects and access paths have been added subsequently. The vegetation boundaries, as interpreted on the 1 : 45 000 scale air photographs by the authors, were transferred photogrammetrically to the base map by the Department of Surveying, University of Newcastle upon Tyne.



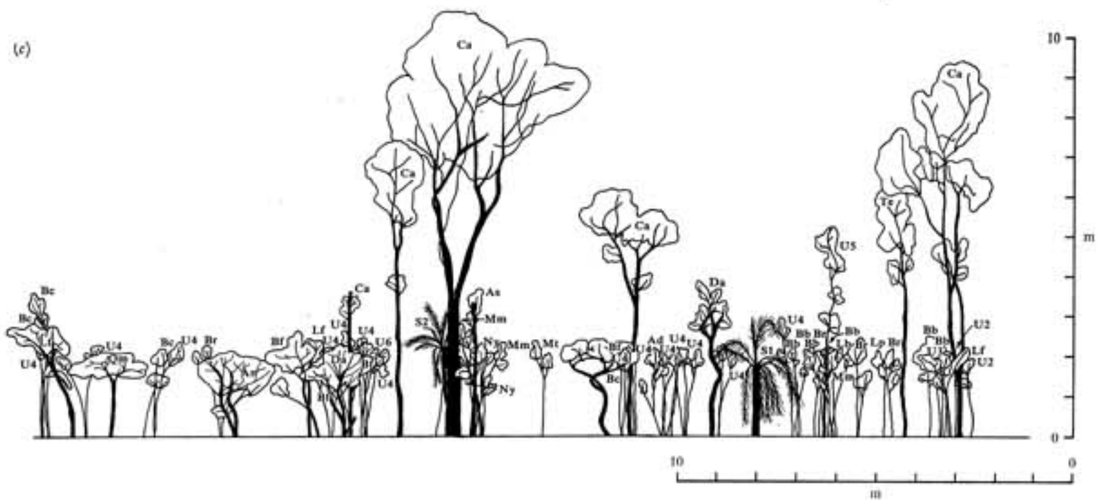


FIGURE 4. Profile diagrams of vegetation at Xavantina. All plants 2 m high and over shown. (*a*) section (running longitudinally) through strip of Swampy Gallery forest to margin of pantanal (grassland with termite mounds) (90 m × 8 m); (*b*) cerrado on low-lying site close to margin of pantanal (25 m × 8 m); (*c*) cerrado with affinities to *Magonia-Callisthene* cerradão at slightly higher level (400 m further from pantanal) (25 m × 8 m).

key to species

(*a*)

Ap	*Aperiba tibourbou*
Ce	*Cecropia pachystachya*
Fi	*Ficus* sp.
Gu	*Guarea trichilioides*
He	*Heliconia hirsuta*
Hi	*Hieronyma alchorneoides*
La	*Lauraceae* (indet.)
Lu	*Luheoptris* sp. (Jangada, R 6898)
Ma	*Mauritia flexuosa*
Me	Melastomaceae (Ra 583)
Me2	*Miconia tomentosa*
Pi	*Piper arboreum*
Po	*Pouteria* sp.? (Jará, Ra 599)
Pk	*Protium krukoffii*
Ps	*Pseudolmedia laevigata*
Qi	*Qualea ingens*
Qw	*Q. wittrockii*
Sl	*Sloanea sinemariensis* (and *S. eichleri*?)
Un	*Uncaria guianensis*
Vi	*Virola albidiflora*
Vs	*Vismia magnolaefolia*
U1	Unknown (Mororo)
U2	Unknown
U3	Unknown (liane)
U4	Unknown (Guache)
U5	Unknown
U6	Unknown (Pau chorão)
U7	Unknown

(*b*), (*c*)

Ad	*Andira cuyabensis*
An	*Annona coriacea*
As	*Aspidosperma nobile*
Bb	*Bauhinia bongardi*
Bc	*Bauhinia curvula* (?)
Br	*Brosimum gaudichaudii*
Bf	*Byrsonima crassifolia*
Ca	*Callisthene fasciculata*
Da	*Davilla elliptica*
Di	*Dimorphandra mollis*
Er	*Erythroxylum suberosum*
Eu	*Euplassa inaequalis*
Ht	*Heisteria densifrons*
Lb	Labiatae (indet.)
Lf	*Lafoensia pacari*
Lh	*Licania humilis*
Lp	*Luhea paniculata*
Mt	*Matayba guianensis*
Mm	*Mimosa obovata*
Mp	Malpighiaceae (indet.)
My	*Myrcia* sp
Ny	Nyctaginaceae (indet.)
Oc	Ochnaceae (?) (indet.)
Qm	*Qualea multiflora*
Qp	*Q. parviflora*
S1	*Syagrus* sp. (1)
S2	*Syagrus* sp. (2)
Ta	*Tabebuia caraiba*
Te	*Terminalia* sp.
U1	Unknown (1)
U2	Unknown (2)
U3	Unknown (3)
U4	Unknown (4)
U5	Unknown (5)
U6	Unknown (6)

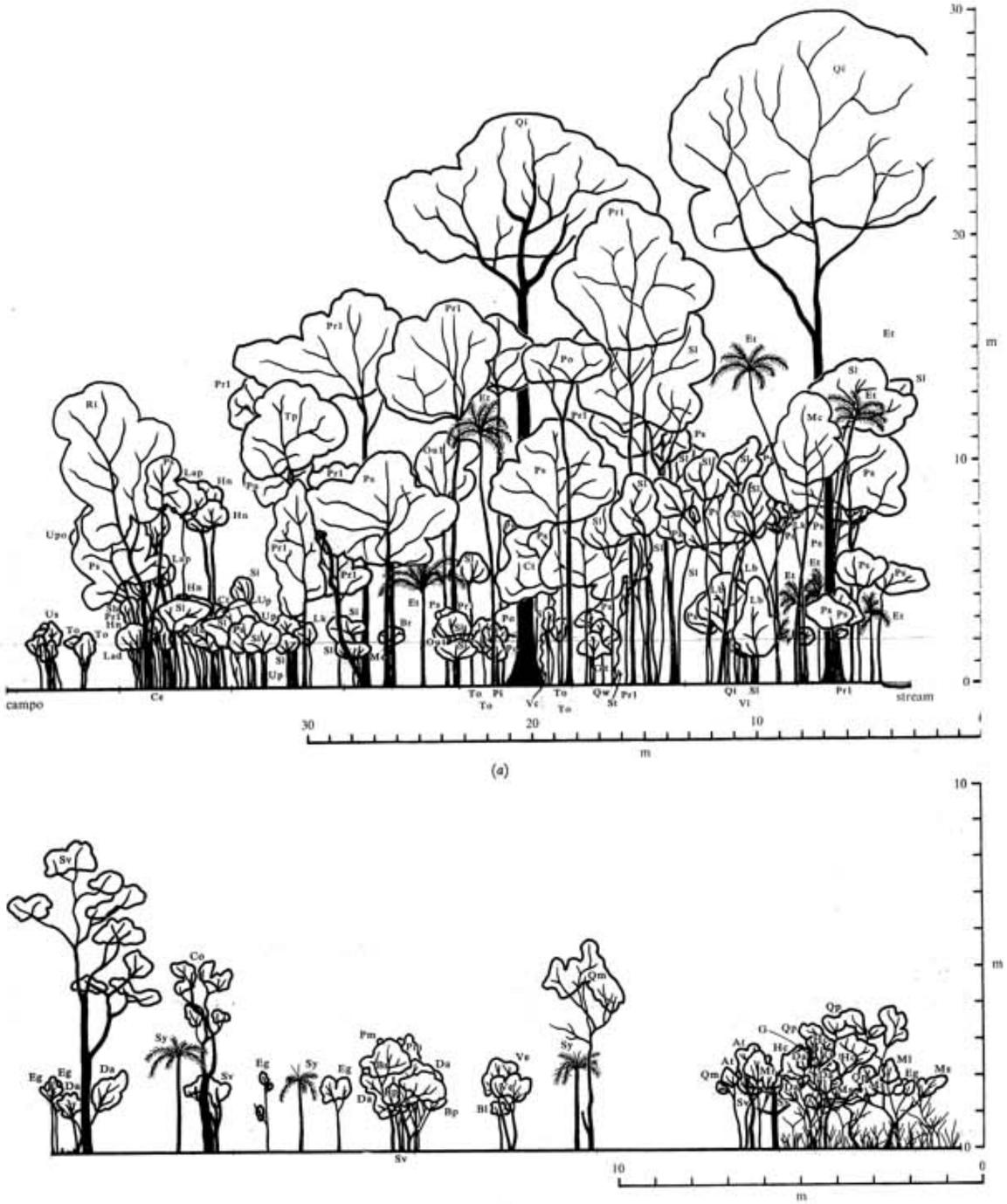
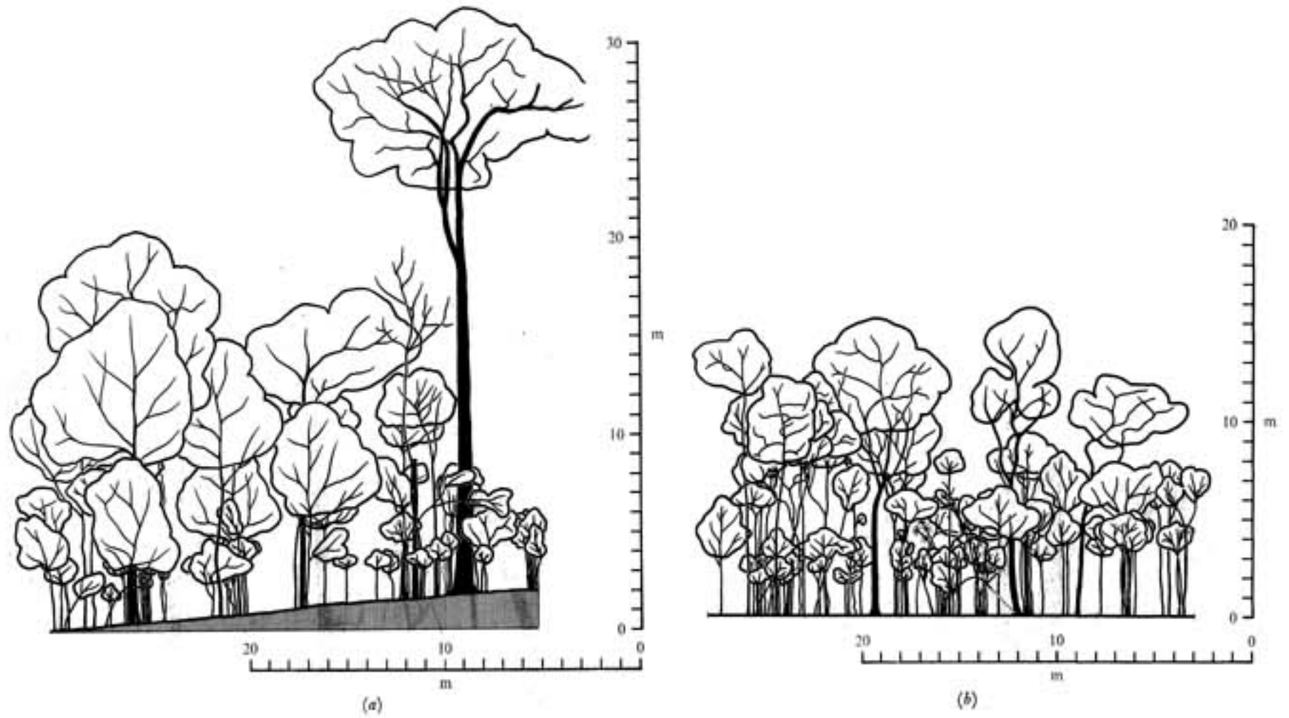


FIGURE 5. Profile diagrams of Swampy Gallery forest and cerrado near base camp (transect B.C. 1). (*a*) Swampy Gallery forest (40 m × 8 m); (*b*) cerrado (25 m × 8 m). (Grassy undergrowth only indicated for right hand 5 m.)

key to species

(*a*)
- Br Indet. (Bacuri, R 6920)
- Ce *Cecropia pachystachya*
- Ct Indet. (Catoari, R 6986)
- Et *Euterpe* sp. (Ra 2044)
- Gt *Guatteria* sp. (Invireira, Ra 1143)
- Hn *Henriettella ovata*
- Lad Lauraceae (Louro cobra or Louro dorado, indet.)
- Lap Lauraceae (Louro precioso, R 6916)
- Lb *Licania blackii*
- Lk *L. kunthiana*
- Mc *Myrcia* sp. (Pixuna)
- Me Melastomataceae (R 6915, Ra 583)
- Ou1 *Ouratea* sp. (1) (Bacuri)
- Ou2 *Ouratea* sp. (2)
- Ou3 *Ouratea* sp. (3)
- Pi *Piper arboreum*
- Po *Pouteria* sp.? (Jará, Ra 599)
- Pr1 *Protium* sp. (1) (Almécega breu)
- Pr2 *Protium* sp. (2) (Ra 1840)
- Pr3 *Protium* sp. (3) (Ra 2049)
- Ps *Pseudolmedia laevigata*
- Pu Myrtaceae (Purú, indet.)
- Qi *Qualea ingens*
- Qw *Q. wittrockii*
- Ri *Richeria grandis*
- Sh *Schoepfia obliquifolia*
- Si *Siparuna guianensis*
- Sl *Sloanea sinemariensis* and/or *S. eichleri*
- St *Strychnos* sp.
- To *Tococa formicaria*
- Tp Indet. (Trapiá de mata, R 6917)
- Vi *Virola albidiflora*
- Uc Unknown (liane)
- Upo Unknown (Pau pombo?)
- Us Unknown (shrub)

(*b*)
- At *Aspidosperma tomentosum*
- Bl *Byrsonima basiloba*
- Bp *B. pachyphylla*
- Bs *B. crassa*
- Co *Connarus fulvus*
- Da *Davilla elliptica*
- Eg Myrtaceae (Murtinha, Ra 2075)
- Hc *Hancornia speciosa*
- G *Aspidosperma tomentosum*
- Ml Malpighiaceae (indet. Ra 2092)
- Mr *Myrcia* sp. (Ra. 1983 V)
- Ms *Myrcia* sp.
- Qm *Qualea multiflora*
- Qp *Q. parviflora*
- Pm *Pouteria ramiflora*
- Sv *Salvertia convallariodora*
- Sy *Syagrus* sp. Gariroba (Ra 1987
- Ve Compositae Veludo (Ra 1926



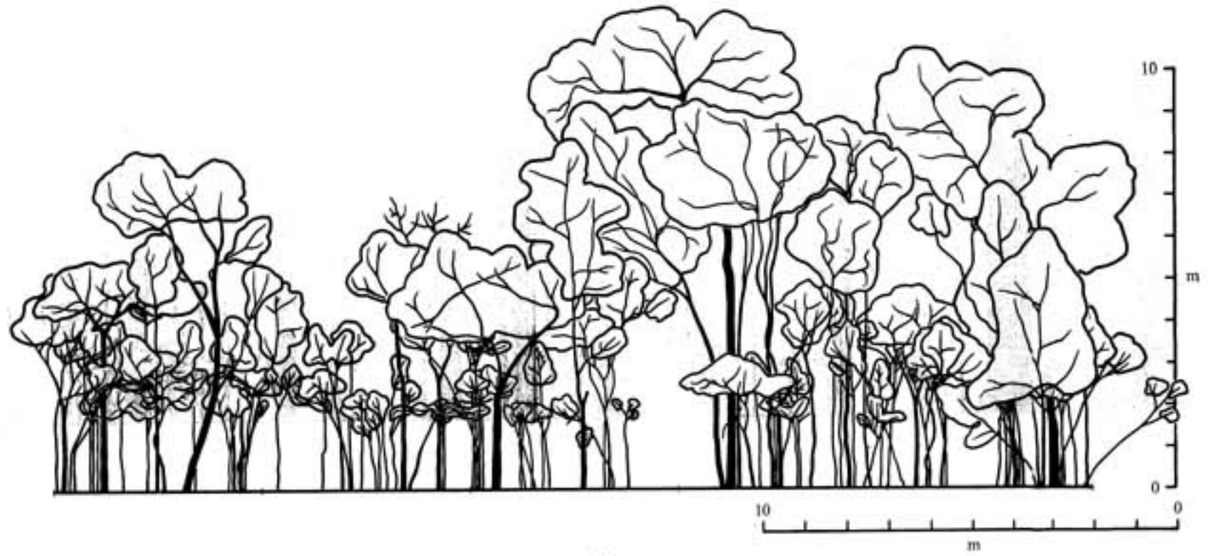


FIGURE 6. Profile diagrams of Valley forest, Dry forest and Dry forest–cerradão transition near base camp (transect B.C. 1). (*a*) Valley forest; (*b*) Dry forest; (*c*) Dry forest–cerradão transition. (Each 25 m × 8 m.)

FIGURE 9. Swampy Gallery forest, base camp, showing trunks of *Qualea wittrockii* Malme and other trees. (15 August, 1968.)

FIGURE 10. Vegetation types on transect R 1, base camp area. Swampy Gallery forest (left), cerradão (right background), campo (foreground). The grasses in the campo are flowering abundantly, having recovered from burning earlier in the dry season. (7 September, 1968.)

FIGURE 11. Cerrado near base camp in dry season. (July 1968.)

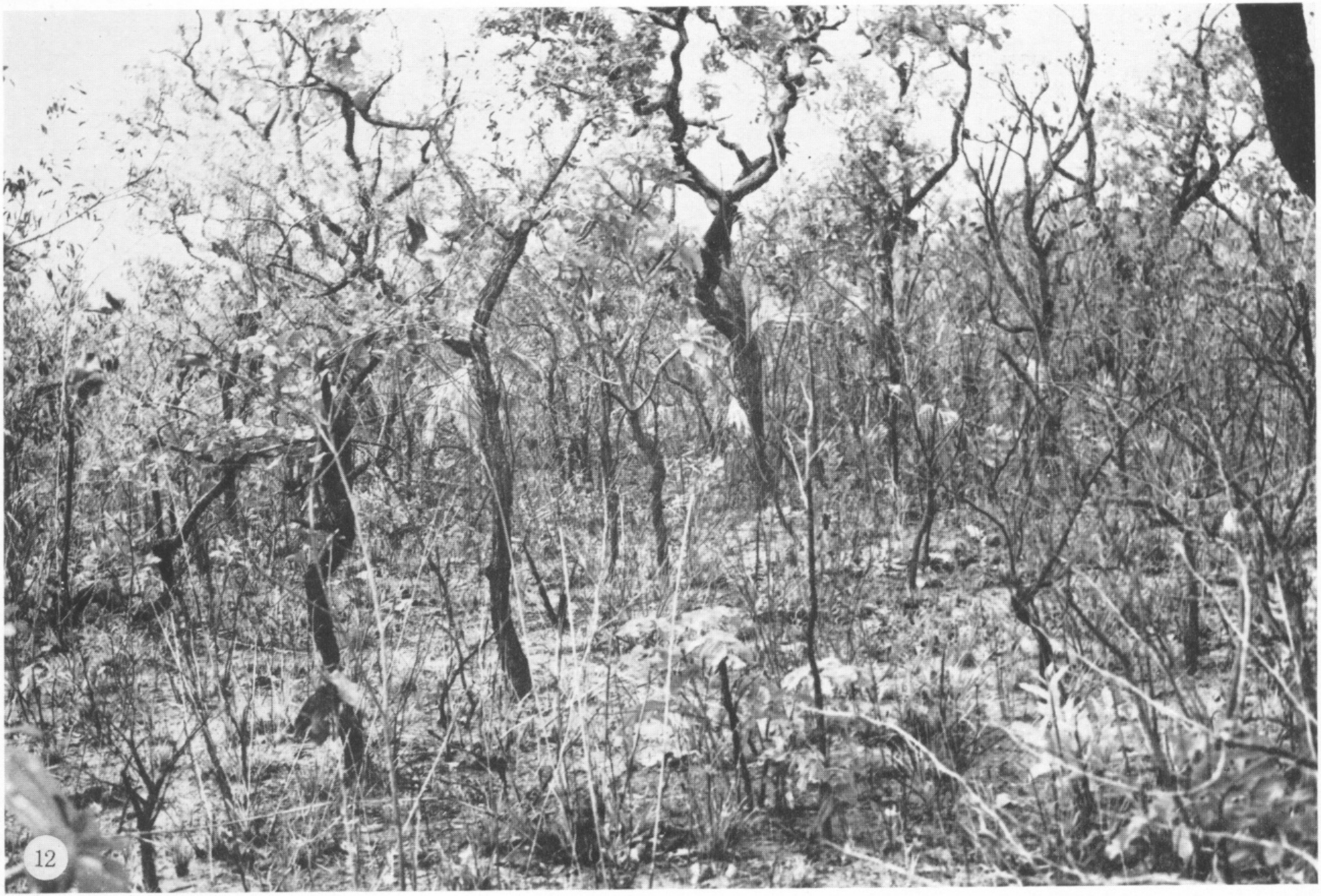


FIGURE 12. Cerrado recovering after light burning earlier in the dry season, base camp area.
(7 September, 1968.)