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Geomorphology and Reconnaissance Geology of Wilpattu National Park

by

MICHAEL B. KATZ

School of Applied Geology, University of New South Wales
Kensington, N.S.W., Australia

(With one text figure and three plates)

INTRODUCTION

General Information

Wilpattu National Park is located between latitudes 8°25'—8°35' and longitudes 79°45' 80°10' and encompasses an area of about 400 sq. km. It is located in northwestern Ceylon in the Puttalam and Anuradhapura districts of the Northwestern Province. The map area covers the Kudremalai and parts of the Marichchukkadi 1"—1 mile topographical sheets. The Park lies completely within the dry zone of Ceylon. This zone is characterised by a summer drought and a rainy period coinciding, for the most part, with the time of the northeast monsoon. The area may be considered semi-arid, a continuous cover of vegetation is however characteristic.

Although the Park is a wildlife sanctuary with only a few scattered inhabitants ancient ruins and signs of former cultivation testify to its once important past. Its proximity to the well-known archaeologically important center of Anuradhapura also supports the view that this area in the past was a center of civilisation.

The area is accessible by means of the road system serving Puttalam-Anuradhapura as well as the coastal Puttalam-Mannar Road. The Park itself has good dirt roads connecting up most of the villu areas and several jeep tracks makes most of the Park accessible during the dry season.

Purpose of Investigation

In 1968, two projects were initiated by the Smithsonian Institution in the Wilpattu National Park. These projects were undertaken to learn about the behaviour and ecology of the Ceylonese elephant and to describe and analyse the Park vegetation which forms the elephant habitat. Because this area is remote and not the site of any development scheme it has received very little attention in areas of basic research and information on geology and geomorphology is scanty. To provide this information investigations of the Park and its adjacent areas were undertaken and will be complementary to the other studies already in progress.

Methods of Study

Preliminary aerial photo interpretation was followed up by field investigations in April 1970. Most of the Park area under study was covered by ground reconnaissance. Only the coastal regions were relatively inaccessible. The maps are based on air photo interpretations checked with ground surveys along roads and jeep tracks.

Previous Work

The geology of parts of the Wilpattu National Park area and environs was first investigated by Wayland (1914,) and Coates (1935, p. 157). More recent reconnaissance traverses in the Park were undertaken by Caldera (1956). The predominent rocks in this regions are the so-called 'Wanni Gneiss' which is a banded quartzofeldspathic biotite gneiss which makes up part of the Precambrian Vijayan Series (Cooray, 1967, p. 118). In this general vicinity outcrops of the 'Tonigala Granite' have also been noted. Overlying these Precambrian gneisses in the western portion of the Park are the Miocene limestones (Wayland and Davies, 1923). These limestones are well exposed at Kudremalai, Kolankanetta and at the mouth of the Moderagam Aru where sea cliffs as much as 20 m. above sea level are formed. These limestones are capped by a red earth or sandstone (Coates, 1935, p. 105). The unconformity between the basement gneisses and the overlying Miocene limestones have been reported by Caldera (1956, p. 4). Some work has also been done in the past on the unconsolidated deposits, especially, those overlying the limestones (Wayland, 1914). In addition a deposit of monazite beach sand was discovered off Kudremalai Point (Coates, 1935, p. 185).

This region is also eminently suitable for examination of recent uplift. To the south Cooray (1968) has documented the progressive buildup of the shorelines since Miocene times and Deraniyagala (1969) has cited additional evidence that the coastline from Puttalam north through the Park has been uplifted in recent times (see also Vitanage, 1972). All these previous investigations were of a very preliminary nature and there has been no detailed geological map or report on the Wilpattu Park.

General Geology and Geomorphology

Wilpattu National Park is located in the northwestern coastal region of Ceylon and lies in a rather flat terrain of semi-arid country covered mainly in forest except along northern boundary which has forest scrub. The western portion is a doline plain with many shallow basin-shaped lakes or 'villus'. Little evidence of surface drainage is noted and the subsurface circulation of water is expected, as this region is underlain by flat-lying limestones of Miocene age. The eastern part is made up of an irregular plain of Precambrian gneisses which trend NW-SE forming aligned small ridges. Scarce isolated rocky hills or erosion remnants stand up above the general level of the plains. The contact between these two units approximate] y lies to the east of the north-south road from Kattankondal Kulam on the Moderagam Aru (north boundary of the Park) to Mayila Wila to the south. It then turns abruptly southwest in the direction of Tala Wila up to about Puttalam-Mannar road where it again trends south to the south border of the Park.

The limestones of this area are essentially flat-lying with a sandy-conglomeratic facies toward the east. These limestones unconformably overlie the gneisses of the Vijayan Series which are exposed to the east. Although the gneisses are the most common rock in the east part of the Park, massive granites and a few quartzite outcrops are also noted. These gneisses strike N-NW and disappear under the limestone cover toward the west.

GEOMORPHOLOGY

There are three major topographical divisions in the Park. From west to east they are :

1. Coastal landforms ;
2. Limestone—karst plain
3. Gneiss—granite plain.

Coastal Landforms

The most outstanding coastal feature of the Park is a shore about 25 km. long. The shore-line is fairly regular in a north-south direction and is characterised by a narrow beach with a zone of dunes to the landward side. Where the shore is embayed at Kollankanatta and at Kudremalai Point ; sea cliffs of flat-lying limestones are exposed as much as 15 m. high. Just to the east of these coastal forms is found a north-south trending limestone ridge over 30 m. above sea level, reaching a maximum of 60 m. at Kudremalai. This ridge is apparently a continuation of the limestone ridge at Aruakala north of Puttalam. Where this ridge intersects the coastline at embayments, sea cliffs as described above are formed. Resting on top of these ridges and sea cliffs are a deposit of varying thickness (from a meter to about 7 meters) composed of red earth enclosing at least two marine shell beds. Although not in the Park proper the Karaitivi barrier bar islands lie offshore about 5 km. Similar spits and bars are occassionally seen along the coast. The coastal landforms can be classified as follows :

1. Barrier bar islands and spits
2. Beach and dunes
3. Sea cliffs, limestone ridge with mantle of red earth.

Barrier bar islands and spits

The offshore bars of Karaitivu have not been studied, but resemble similar bars and spits described from the northwest coast by Cooray (1967, 79-81 ;1968). These features indicate that the coast is advancing ; the offshore bars later forming spits which enclose the sea to form lagoons. Eventually the lagoons silt up and the coastline is extended. Portugal Bay separating Karaitivu from the mainland is thus an incipient lagoon and in time will

probably resemble the Puttalam lagoon as it exists today (Cooray, 1968). Similar features but on a smaller scale are seen along the coastlines. Small spits and barrier bars enclosing silted up lagoons are seen at Kollankanatta, Pallugaturai and at the mouth of the Moderagam Aru.

Beaches and Dunes

The sandy beaches along the coast are usually narrow and regular with a wide zone of dunes to the east landward side. These dunes, sometimes 7 meters high are often covered with vegetation, and traces extend inland for as much as 2 km. The dune deposits, especially near the coast, are conspicuously aligned in the NE-SW direction, this being the direction of the prevailing winds during the southwest and northeast monsoons. Raised beach ridges or ridge and runnel zones (Cooray, 1968, p. 100) appear as concentric low ridges parallel to the coastline and are seen at only one locality, northeast of Kollankanatta at the site of the ruins and ancient harbour.

Sea cliffs, limestone ridge with mantle of red earth

Where the coastline is embayed, the limestone ridge intersects the shore to form sea-cliffs as much as 15 m. above sea level. The most conspicuous cliffs are those that extend from Kudremalai Point east, as seen from the fishing village of Pukulam at the mouth of the Moderagam Aru. Here the beach is very narrow, as the cliffs come right up to the sea. A section taken about 2 km. south of Pukulam (Fig. 1) shows that the base of the cliff is composed of a grey-massive limestone with many solution cavities and small caves. The only fossils observed at this locality seem to be vaguely defined branching corals. This limestone shows a maximum thickness of about 10 m. overlain by a red deposit enclosing at least two beds of marine oyster shells, which has a maximum thickness of about 7 m. It appears that the red earth, in part, is derived from the weathering of the underlying limestones and is a type of terra rossa. The portions containing the oyster shell beds are apparently raised beaches ; the oyster shell zones demarcating periods below sea level. A good exposure of this shelly deposit is seen at the approach to the village of Pukulam, where the inland ridge is cut by a footpath.

The limestone ridge may be over 30 meters above the surface of the land with a maximum elevation of 70 meters at Kudremalai. A similar stratigraphy to that described for the sea cliffs is evident here (Coates, 1935, p. 105). The best studied locality along this limestone ridge is at Aruakala north of Puttalam and just outside the Park boundaries to the south (Cooray, 1967, p. 137). Similar marine shells are found in the red earths overlying the limestone at Aruakala (Deraniyagala, 1969). This limestone ridge has apparently resisted solution and collapse and thus forms an elevated area relative to the karst plain found to the east ; although Deraniyagla (1969) considers these ridges to be uplifted 'horsts'.

Limestone - Karst Plain

The limestone-karst plain possesses a topography that is dependent on underground solution and diversion of surface waters to subsurface routes. The resulting plain is a flat area characteristically speckled with roughly circular dolines which express themselves as shallow pans, ponds or lakes with sandy shores, locally called villus (wilas), (Fig. 2). A lack of surface streams is noted in the inter-villu areas, which are thus featureless. There are about 50 villus in the Park area, ranging in size from large lakes near the coast over 2 km. wide (Periya Villu and Mail Villu) to small ponds no more than a hundred meters across (Kudapatessa). The average villu such as Mahapatessa is about 400 m. wide. Some of the larger villus, especially near the coast contain brackish water ; but most are fresh water with a high lime content (e.g. Kali Villu).

The so-called 'Parks' marked on the Wilpattu National Park maps are also a type of dry doline usually depressed, with irregular, hummocky topography covered with nodular ironstone and chert gravels, locally called 'wembus' (Fig. 3). Other areas are sandy and resemble dune or desert deposits and thus can be termed desert tracks. Both are covered with a scanty vegetation. Mantling this terrain is a reddish-brown sandy soil known as 'red earth' (Cooray, 1967, pp. 150-152), which apparently is a type of 'terra rossa' usually found masking the limestone in karst regions. Occassionally flat-lying beds of limestone, with a rotten etched and pitted surface are exposed (Fig. 4). Joint patterns in the limestone trend ENE and are expressed on the air photos by white lineaments (desert tracks) and by the alignment of villus.

The following geomorphological features are recognised in this area.

1. Dolines (ponds, lakes or villus)
2. Karst plain with terra rossa
3. Minor relief features, gravelly dolines (wembus) and aligned sandy areas (desert tracks.)
4. Exposed bedrock.

Dolines (lakes, ponds or villus)

The dolines (villus) occupy shallow depressions reflecting subsurface solution-collapse in the underlying limestones. Most of these dolines have become clogged by clay and decomposed vegetation to such an extent that they will hold water above the water table. During the dry season in August most of these dolines dry up ; the ones retaining water are deeper and apparently have intersected the water table during subsidence. Most dolines are surrounded by a yellowish-white sand which occupy the slopes around these depressions (Fig. 2). There appears in some dolines to be a greater accumulation of these sands on the northeast sides of the lakes and this may be due to preferential shore erosion on this side during the winds of the northeast monsoon, where the water levels are the highest. The

sandy shores, are, no doubt, the result of erosion of the banks, which away from the dolines consist of red earth. Thus the doline waters have removed the fine clay material from the red earth leaving behind the coarser sand particles ; apparently some bleaching has also taken place (Cooray, 1967, p. 152). On inspection of the air photos the dolines are often conspicuously aligned in the north east direction (e.g. chain of aligned villus from SW-NE-Kokkare Villu, Kudapatessa, Mahapatessa, Uppu Villu, Lunu Wila (Fig. 6). This probably reflects predominant joint directions in the underlying limestones and these joints are zones of weakness and preferential loci of solution and collpase.

Karst Plain with terra rossa

Most of the area not occupied by dolines and other minor relief features consist of a very flat plain lacking in any surface streams or drainage, mantled by a red earth or terra rossa. The transition from the limestone to the red earth is best seen at the sea cliffs near the village of Pukalam (Fig. 1). The red earth is formed by surface to near surface solution of limestone by descending groundwaters leaving an insoluble residue of red clay soil, which mantles the surface. This soil varies in thickness from a meter to a few meters where it extends down into joints or areas of preferential drainage in the limestone. Where this red earth is resting on or near loci of vertical drainage (villus, joints, minor collapse structures) the red earth is sorted and bleached and a fine white-yellow sandy deposit is produced.

Minor relief features, gravely depressions of wembus, aligned sandy areas or desert tracks

Interspersed throughout the karst plain are assorted minor relief features due to local pitting by vertical drainage and solution. These areas were first studied by Wayland (1914) who thought they were incipient deserts, caused mainly by wind action. There are essentially two types : 1) circular-elliptical dry dolines with gravely floors made up of limonite-hematite nodules or ironstone, and chert concretions, sometimes resting on bedrock (Fig. 5 and 2) aligned linear sandy areas that resemble inland sand dunes. The circular-elliptical dry dolines or wembus are formed under conditions similar to those of the villus (Fig. 3). These occupy depressions bound by scarp faces but are not filled with water ; although the agency of water through vertical drainage has formed these features. In this case there has been solution collapse in the underlying limestone but the subsidence has not intersected the water table and the vertical drainage has not been impeded by clogging. Thus the water acts to dissolve all soluble material leaving behind the insoluble residues that are found in the parent limestone, nodular hematite and limonite, and chert (Fig. 5). Often the bedrock itself is exposed and usually has a rotten-pitted appearance (Karren or Lapies) (Fig. 4.) An excellent example of a wembu is seen on the Puttalam-Mannar road about 1 km. south of the Moderagam Aru (Fig. 3).

Related features are slightly depressed areas or valleys covered with a fine white sand. On aerial photos these features or sand tracks appear aligned sometimes with a rough polygonal pattern, although there is a preferential linear alignment in the NE direction. They appear to be parallel to some of the aligned villus and a set of these sand tracks are found trending NE from Kudapatessa. They no doubt appear to be controlled by joint patterns

in the underlying limestone and basement rocks and reflect vertical drainage along linear-polygonal paths (Fig. 6). The red earth along these lineaments have been bleached and sorted by the vertical drainage and the residue is a white sand similar in composition to the sands around the shores of the villus. Sandy channels in the vicinity of these sand tracks resemble dried up stream beds, which indicate that there is probably some local surface drainage.

Exposed bedrock

Flat lying calcareous sedimentary rocks are rarely observed in the Park proper. When found they occur as floors of wembus, or in beds of streams, otherwise in areas where the top unconsolidated deposits have been removed to uncover the underlying rock. There are several types of sedimentary rocks exposed of which the limestones are the most common. Near the coast and inland the limestone is massive and reddish to grey in colour. Exposures are found on the Puttalam-Mannar road at Konda Tokku Devale and at Eranopola Motai. A sandstone facies is found 1 km. south of the Moderagam Aru on the Puttalam-Mannar road. A conglomerate is found in the eastern exposures.

Gneiss - Granite Plain

Lying east of the limestone - karst plain is a more irregular gneiss - granite plain with a few scattered steep-sided rocky hills. The surface is drained by several streams which are tributaries of the Moderagam Aru, which forms the northern boundary of the Park. This general area can be subdivided into the following geomorphological divisisons.

(1) Plain

(2) Rocky erosion remnants

(3) Streams

Plains

The plains are flat to slightly undulating and are usually mantled by a red earth soil containing nodular limonite-hematite or ironstone of variable thickness. Outcrops of rocks are rare, although in general, where gneisses occur a gently undulating ridge-like topography is formed. Where more massive granites occur, rounded boulders and outcrops are found in a generally featureless area.

Rocky erosion remnants

A few scattered rocky knobs and turtle-backs (inselbergs) are found in the Park. The largest inselberg is that of Occapu Kallu which rises about 30 m. above the surface of the plain. Smaller turtle backs, some meters in elevation are sporadically scattered throughout the Park. In all, these features make up an insignificant proportion of the surface area.

Streams

The Moderagam Aru is the largest river in the Park and makes up the northern boundary of Wilpattu. It follows a general eastwest course ; more tortuous when traversing the gneiss-granite terrain. At Mallimadu the Moderagam Aru shows a rather narrow valley with extensive alluvial sand deposits. The valley becomes much broader to the west, especially when the river crosses the limestone-karst plain. Where the Puttalam-Mannar road crosses the Moderagam Aru an extensive alluvial plain about 1 km wide is observed.

The major tributaries of the Moderagam are found in the gneiss-granite terrain and consists of N-NE flowing Eeribge Ela and Moragolle Ela with many other smaller tributaries. During the rainy season of the southwest monsoon these rivers are torrents. In the dry season only the Moderagam Aru has water, the rest have entirely dried up. In all, the drainage system is not well developed owing to the semi-arid climate.

In places these streams have been dammed to produce artificial lakes or tanks which resemble the natural lakes or villus in the limestone-karst plain. Some of these artificial tanks are at Maradanmaduwa and Kandugomuwa.

GEOLOGY

The basement crystalline rocks of Wilpattu National Park belong to the Vijayan Series (Cooray, 1967, p. 116) which consist, in this area, of hornblende and biotite gneisses, some quartzites and massive granites. This basement of gneisses and granites are unconformably overlain by flat lying limestones of Miocene Age in the west-half of the Park region. This general two-fold stratigraphy has been recognised since Wayland (1914) and Coates (1935) and more recently by Caldera (1956). The boundary between these two units have now been refined on the basis of rock showings and topography, and a geological, geomorphological map is presented for the first time. The major geological, geomorphological and structural domains have been separated with intentions of possible correlation with other disciplinary studies.

The hornblende-biotite gneisses and the granites are the most common rock units in the Precambrian crystalline terrain. The gneisses are found exposed on the Park gate about 5 km. from the Park office at Maradanmaduwa Wewa. Similar gneisses are seen in the vicinity of Occapu Kallu where they form a large rocky erosion remnant. The gneisses are usually expressed as undulating ridges of low relief parallel to the strike of the rock. The massive granites, with some syenites make up large areas around Maradanmaduwa Wewa and to the north at Galbendi Niraviya. These granites underly areas that are expressed topographically by rather featureless terrain. A few small exposures of quartzite were observed around Kandegamuwa Wewa.

The overlying limestones are found best exposed as sea cliffs near the village of Pukalam at the mouth of the Modcragam Aru. Occassional exposures are found inland, flooring wembus and along dried up stream channels. Most exposures consist of a grey, sometimes massive limestone although sandstone and conglomeratic facies are also present. The lithostratigraphic units are listed in Table I.

TABLE 1

Lithostratigraphy of Wilpattu National Park

Recent—Red earth, terra rossa, ironstone, chert gravels	
Miocene—limestone with sandstone and conglomerate facies	
Precambrian Vijayan —	Granite-pegmatite
	Hornblende-biotite gneiss
	Quartzite

LITHOLOGY

Vijayan Series

Quartzite (# 9, 10, 11)*

The quartzites are grey-blue, medium grained, dense, well-foliated rocks, which weather brownish. These rocks consist mainly of quartz arranged as fine layers, with less than 5% opaque ilmenite-magnetite concentrated in the interlayers. The best outcrop of this nature was found just west of Kandegamuwa Wewa.

Hornblende - biotite gneiss (# 3, 5, 6, 13, 15)*

These rocks are medium-coarse grained, foliated-phacoidal, grey-pink quartzofeldspathic gneisses which weather in shades of brown. The rocks consist of quartz and feldspar which make up at least 70% of the constituents. The dark minerals are mainly hornblende and biotite ; although some may contain pyroxene. A large outcrop of this rock is found well exposed at Occapu Kallu.

One sample (#5) taken from the Kokmota Bungalow on the Moneragala River shows definite charnockitic affinities (see section on metamorphic history). In this section it consists of a lobate mosaic of microcline microperthite, quartz and oligoclase. The chief dark minerals are diopside in association with a dark green hornblende, hypersthene and a trace of garnet. Ilmenite-magnetite and apatite are present in accessory amounts.

Granite (#7, 8, 12, 14)

Massive, medium-coarse grained, grey-pink granites with less than 5% dark minerals are best observed near the Park office at Maradanmaduwa Wewa. They are composed of about 60-65% feldspar (plagioclase), 35% quartz and less than 5% magnetite, biotite and

*Samples refer to collection in Dept. of Geology, University of Ceylon, Peradeniya.

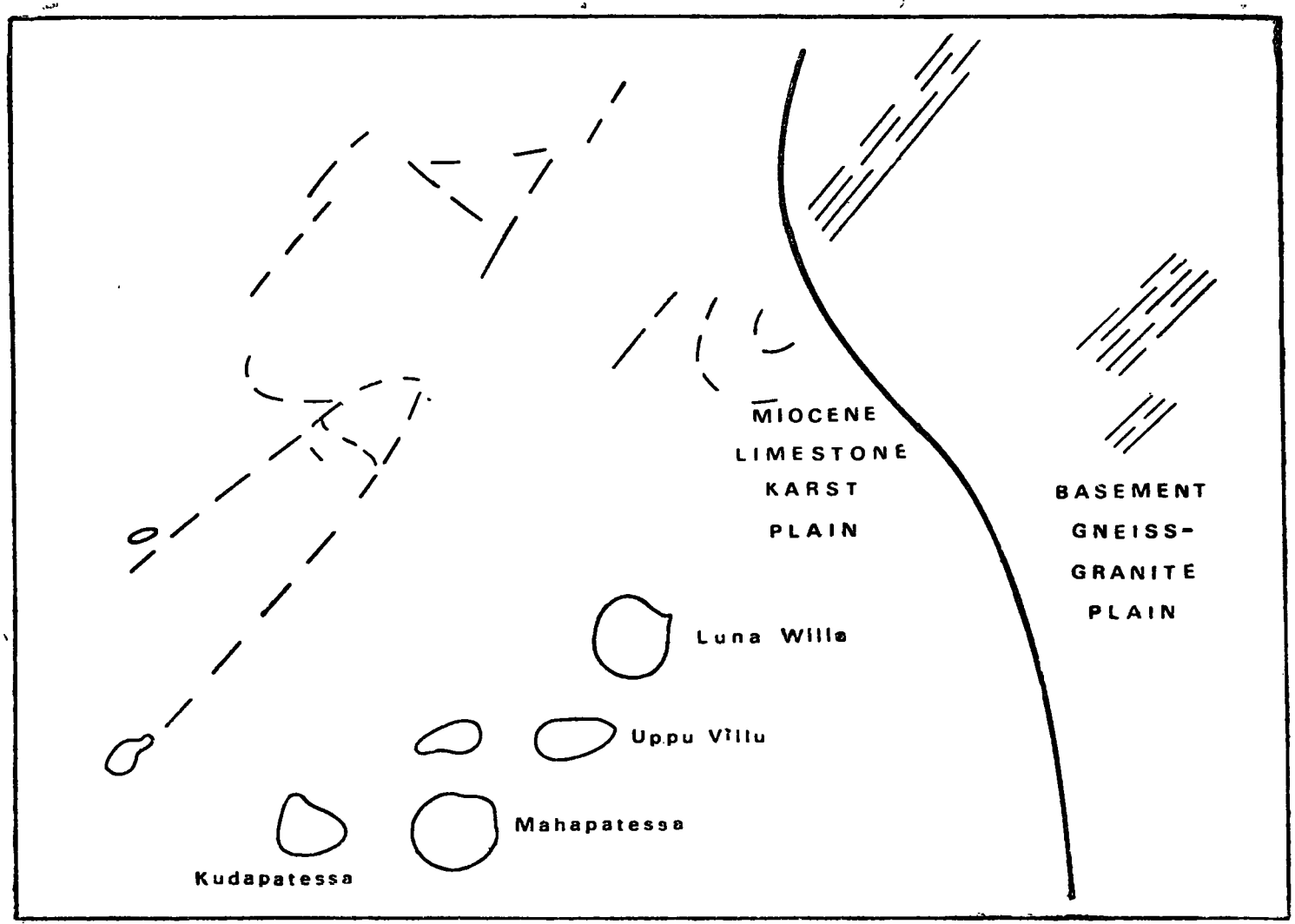

FIG. 6 — NE trending aligned dolines and desert tracts (dashed lines) in karst plain reflects underlying joint patternsin limestone, possibly controlled by NE structures in the basement. Scale—1 : 31,680.

muscovite. Some varieties contain essentially feldspars and can be termed a syenite. A few pegmatites of similar composition are found throughout this region. The granites and syenites are probably related to the Tonigala granites found just to the south (Cooray, 1967).

Miocene

Limestone, Sandstone, Conglomerate (# 4)

The limestones are fine-grained, massive, on the whole non-fossiliferous. They are either brown or grey in colour. Spatially associated with these rocks are other sedimentary types which are considered to be facies of the limestone. The sandstone is grey with a greenish tinge, quite friable and is composed of angular-subrounded grains of quartz embedded in a clay-rich matrix. The exact relationship of this rock with the limestone is not known. The conglomerate occurs at the extreme east end of the limestone area close to outcrops of gneiss. It appears to be similar to the sandstone described above, except that the quartz grains are much coarser, as much as 2 cm. across.

Quaternary

Recent

Resting on the bedrock is a mantle of unconsolidated deposits of varying thickness. A deposit of terra rossa, a meter or so thick, overlies the limestones ; similar red earths with nodular ironstone are found overlying the Vijayan gneisses and granites, as can be seen in the pits at Maradanmaduwa Wewa, which have been excavated to depths about 2 meters. Coarser sand, gravel and cobble deposits are mainly residual in origin, although wide zones of alluvial sands are found along the Moderagam Aru.

Metamorphic History

The Precambrian rocks of this area have been assigned to the Vijayan Series and were thought to consist mainly of amphibolite facies rocks (Cooray, 1967, p. 116). The appearance of hypersthene in some of these gneisses and the presence of quartzites, make these rocks akin to the granulite facies rocks of the Highland Series. (Katz, 1971, 1973).

Structural Geology

The structure of the Vijayan gneisses appear to be dominated by trends, which from folds, whose axis strike NNW with dips to the east. The dimensional orientation of minerals define a lineation, which is most frequent at moderate angles to the north. Although this data is meagre, it suggests that the large fold structures found north of the Moderagam Aru, out of the Park, and smaller similar structures near Maradanmaduwa are northward plunging antiforms overturned to the west.

The limestones are essentially flat lying and display no discernible structural pattern.

Lineaments

Faults and Joints

Lineaments in the limestone terrain which may be related to subsurface joint patterns trend NE (Fig. 6). Many joint patterns are also seen on the gneiss exposures, such as the outcrop on the Moderagam Aru at Kokmotai where there is an orthogonal set of vertical joints ; the dominent set in the EW direction and a subsidiary joint trending NS. Outcrops of limestone often display a complex polygonal joint pattern.

Economic Geology

Limestone—Limestones of similar nature are presently being used for the cement factory at Puttalam.

Ironstone—Nodular hematite-limonite has been used in the past as a source for iron ore. In the Park it is used extensively for road metal.

ACKNOWLEDGMENTS

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EXPLANATION OF PLATES

PLATE I

FIG. 1 — Sea cliff showing shell beds in dark terra rossa overlying massive limestones with small caves at the beach level—Pukulam.

FIG. 2 — Typical doline or villu – Marai Villu

PLATE II

FIG. 3 — Dry doline or wembu with limestone floor displaying karren or lapies—Puttalam – Mannar Road south of the Moderagam Aru.

FIG. 4 — Karren or lapies—Puttalam – Mannar Road south of the Moderagam Aru.

PLATE III

FIG. 5 — Cobbles and gravels of ironstone on the floor of a dry doline of wembu—south of Eranapola Motai.

(MS. received 20.5.74.)

Fig: 1

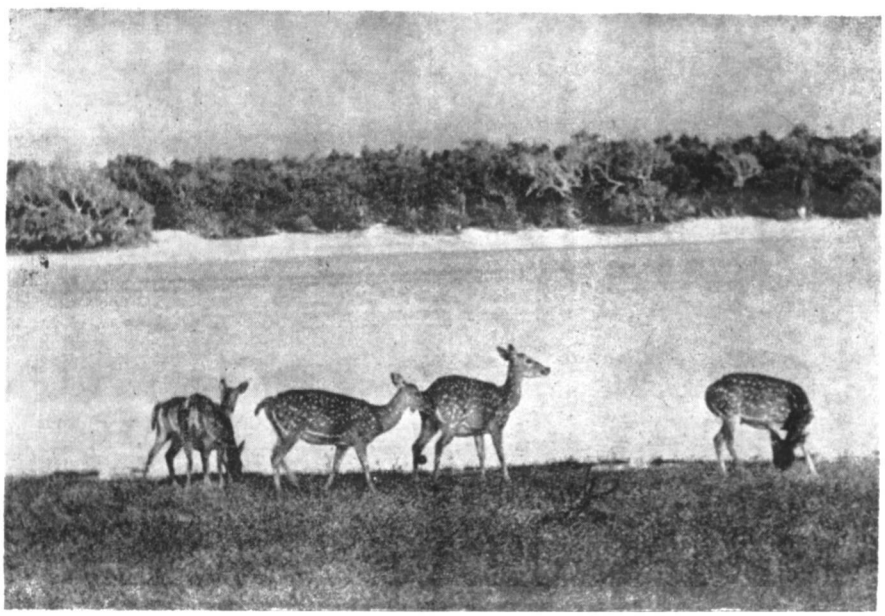

Fig: 2

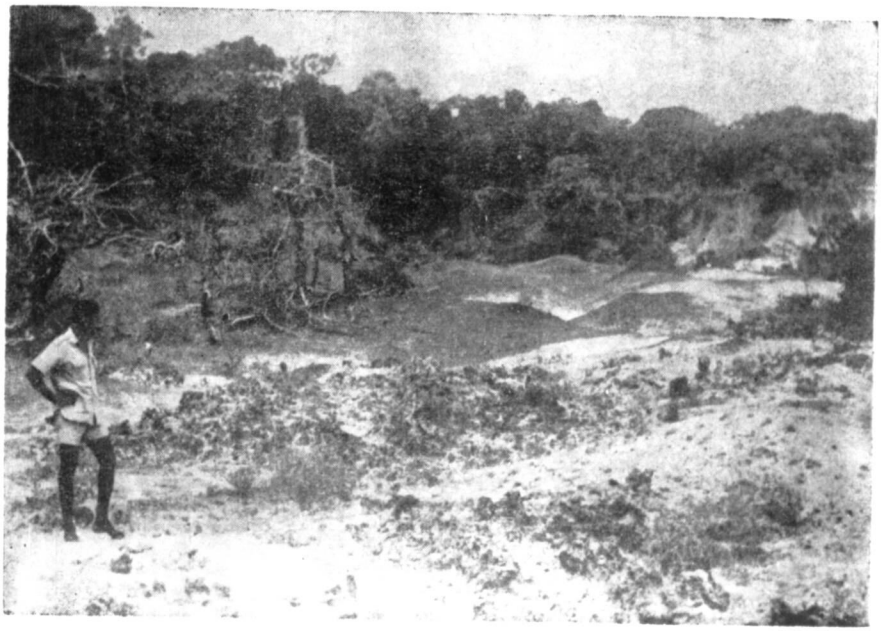

Fig: 3

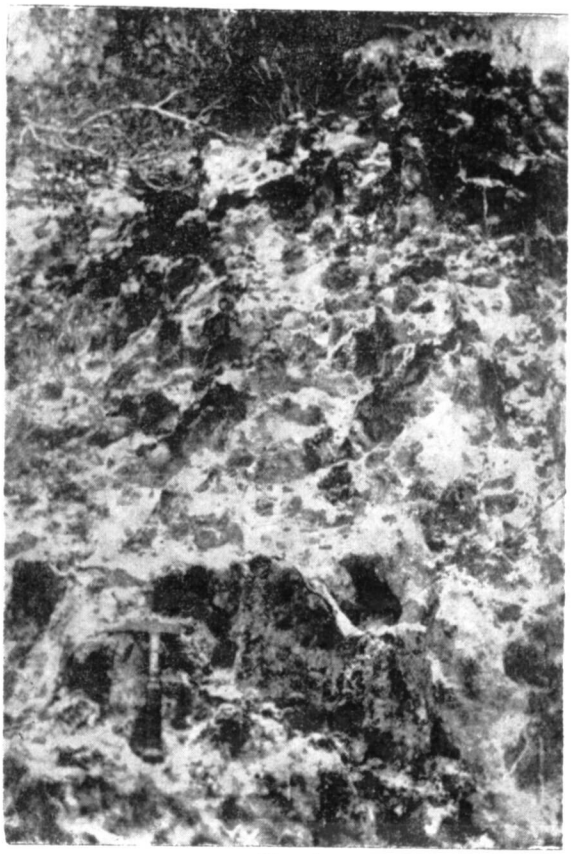

Fig: 4