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NYASALAND LATERITES AND THEIR INDICATIONS ON AERIAL PHOTOGRAPHS

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THE ROAD RESEARCH LABORATORY of the Department of Scientific and Industrial Research is a government organization for studying problems that arise in designing, building, maintaining and using the public highways. The primary objectives of the work are to improve the road as a channel for traffic, to reduce the overall costs of construction and maintenance, and to promote safety and comfort in travel. The work is organized in close co-operation with the Ministry of Transport and Civil Aviation in the United Kingdom, and in matters relating to overseas roads close collaboration is maintained with the Public Works Departments of the Colonial Governments, in the case of the colonial territories, and with the authorities responsible for road research, construction and maintenance in other territories.

In order that research on road problems in overseas territories could be more actively pursued, an Advisory Committee of the Colonial Research Council has been set up under the chairmanship of Dr. W. H. Glanville, Director of Road Research, with the following terms of reference:-

"To advise the Secretary of State for the Colonies on matters of road research for the benefit of the Colonies."

A Colonial Section has now been set up at the Laboratory and the former work of the Colonial Liaison Officer has been taken over by the Section. Advice on the conduct of the work is given by the Advisory Committee. To facilitate the interchange of technical information on road matters, members of the staff of the Colonial Section visit colonial territories to study their road problems, and officers have been nominated by Colonial Governments to correspond directly with the Head of the Section.

The present series of Overseas Bulletins replaces and continues the series of Colonial Road Notes, numbers 1 and 2 being reserved for the re-issue of Colonial Road Note No. 1 and No. 2.

The bulletins are intended to draw attention to matters likely to be of particular interest to overseas road engineers, and to enable overseas engineers to describe work which they have carried out themselves on particular subjects. They are prepared in the first place for the official departments who are concerned with roads in the British overseas territories. A limited number of copies of the bulletins is also made available without charge to other organizations and individuals who are concerned with roads in tropical and sub-tropical areas. Any suggestions regarding problems requiring attention, or papers describing aspects of road research, or the solution of problems in overseas territories which may be suitable for this series, should be addressed to the Director of Road Research at the address below.

ROAD RESEARCH LABORATORY
HARMONDSWORTH, MIDDLESEX, ENGLAND.
Tel: Colnbrook 116 (four lines).

NYASALAND LATERITES AND THEIR INDICATIONS ON AERIAL PHOTOGRAPHS

By A. N. Schofield

THIS IS THE THIRD of three bulletins which have been prepared by the author in co-operation with the Colonial Section of the Road Research Laboratory. It describes work carried out while the author was on the staff of Messrs. Scott and Wilson, Kirkpatrick and Partners, Consulting Civil Engineers to the Government of Nyasaland.

A special study of about thirty laterite deposits in Nyasaland was made and, because they are an important source of pavement material, an account of the nature and origin of the deposits is given. This may be considered controversial, but the ideas developed assisted in the location of a large laterite deposit by interpretation of aerial photographs and systematic field work.

It is emphasized that the work recorded relates only to conditions in Nyasaland. Conditions in other territories will probably differ; the Laboratory would be interested to have similar reports of work done by engineers in other territories.

NYASALAND LATERITES

The laterites were the subject of a special study, for they were a valuable source of pavement material both in the high rainfall area around Mlanje and in the lower rainfall area in the Central Province. The formation of these laterites is discussed in some detail, and it is shown how in certain cases laterite deposits can be located from aerial photographs. It must be emphasized that this analysis refers only to laterite in Nyasaland and that the writer has not had the opportunity of making a study of the greater laterite deposits, such as those in India and other parts of Africa.

LATERITE: A DEFINITION

Laterite is a tropical soil which contains an accumulation of iron and hardens irreversibly on exposure to air, a property from which it derives its name ("later" is Latin for brick).(1) This hardening is accompanied by a yellow/red/blue/black colour change as ferrous compounds in the soft incipient laterite are oxidized to ferric compounds in the hard exposed laterite. A laterite formation that is exposed develops a hard dark surface, like slag, but the lighter hues of yellow and red can be seen among the variegated colours of a freshly exposed face of laterite. Laterite formations are sometimes honey-combed with voids. Around these more massive laterite formations the soil always contains a gravel of pea-like nodules, about ¼ in. in diameter: pea-laterite deposits often occur where there is no massive laterite formation. The nodules of pea-laterite can be broken open between the fingers or under the heel and they have a hard dark skin (that can be polished by rubbing) and a softer and more lightly coloured centre.

In this article the word laterite will be used to describe material with a hardness that could reasonably be compared with that of a brick. Soft or clayey material that appeared capable of developing into hard laterite, because it had the same colour and structure and occurred in the same deposits as hard laterite, will be described as "incipient" laterite. This distinction is necessary to distinguish between the sort of material that would be called laterite by materials engineers throughout Africa, and the tropical red earths that are sometimes[2] called "lateritic soils" or laterite just because they are red, although they are incapable of hardening on exposure to air.

ORIGIN OF LATERITE

Rainwater that has soaked through the leaves and vegetation of temperate forests[3] acquires the property of being able to transport iron in a soluble ferrous state. Bloomfield[4] shows that the litter from Scots pine, New Zealand kauri, or Norway spruce, is capable of mobilizing iron in a ferrous state, but that when the solution is subjected to a change of acidity (pH value), or an exposure to air, the iron is liable to be precipitated. Under temperate forests the iron moves downwards through the soil until it encounters a change of acidity, and at this depth deposition of iron occurs (forming a hard iron pan).

The writer considers that it is reasonable to assume that some similar mobilization of iron must occur in tropical areas where laterite is formed. It also seems reasonable to infer that where sheet deposits of laterite are found they may be the product of downward leaching of iron and of its precipitation at a depth where a change of acidity occurred. It seems equally possible that water seeping into the ground on a ridge top might transport iron out of contact with air as it seeped colluvially down to the valley, and that the iron would be deposited at springs on the slope of the ridge where the water containing ferrous compounds is forced out into contact with air. In both cases an accumulation of iron compounds, which would harden subsequently on exposure to air, would be formed in the soil.

Whereas the sheet laterite deposits would be expected to continue over a large area in an approximately horizontal plane, the deposits which were formed at springs could only be limited in extent. In the description of laterite deposits in Nyasaland, which follows, it is suggested that they are of the latter isolated type, which are formed at springs.

Two alternative theories to account for the formation of laterite have been considered but neither seems to apply to Nyasaland's laterite. One theory is that the laterites are residual soils in which there is an excess of iron because silica has been leached away, but for this to apply there should be a correlation between the occurrence of laterite deposits and of iron parent rocks, which does not seem to be the case. The other theory was the ground-water laterization theory which suggests that the iron is lifted up from a depth (and not washed down from a source at a higher level as suggested in the previous paragraph). According to this theory the rise in level of ground-water in the wet season would involve lifting iron compounds from a depth; then a film of water containing this iron would dry on each stone as the ground-water falls, so that iron would accumulate slowly in the layer in which cyclic variations of ground-water level occurs. This implies that ground-water comes flooding upwards during the rainy season, whereas in fact the ground-water level rises because rain arrives from the top. Small quantities of water which have soaked into the ground later rise as water vapour, but they could not lift iron compounds, and only under certain special conditions, which cannot generally occur, would it be possible for there to be a major rise of ground-water through capillary movements. Most of the water which soaks into the ground seeps away, always flowing vertically downwards and horizontally towards an outfall, with seepage velocities that increase with the head of water. It is difficult to see how iron compounds can be lifted from a depth against this general downward flow of ground-water.

CONCRETIONARY LATERITE DEPOSITS[5-7]

About thirty laterite deposits were examined in Nyasaland. They were small isolated deposits, and only half of them contained workable quantities of pavement material. Each workable deposit covered one or two acres and contained between five and fifteen thousand cubic yards of laterite. The formation of a deposit seemed to depend on accidental features of the topography. First the rain soaking into the ridge top had picked up ferrous compounds, then the shape of the ground was such that as the ground-water seeped down to the valley it converged into a concentrated flow through the area of laterization. At this point the concentrated flow had been forced to drain through the top soil,

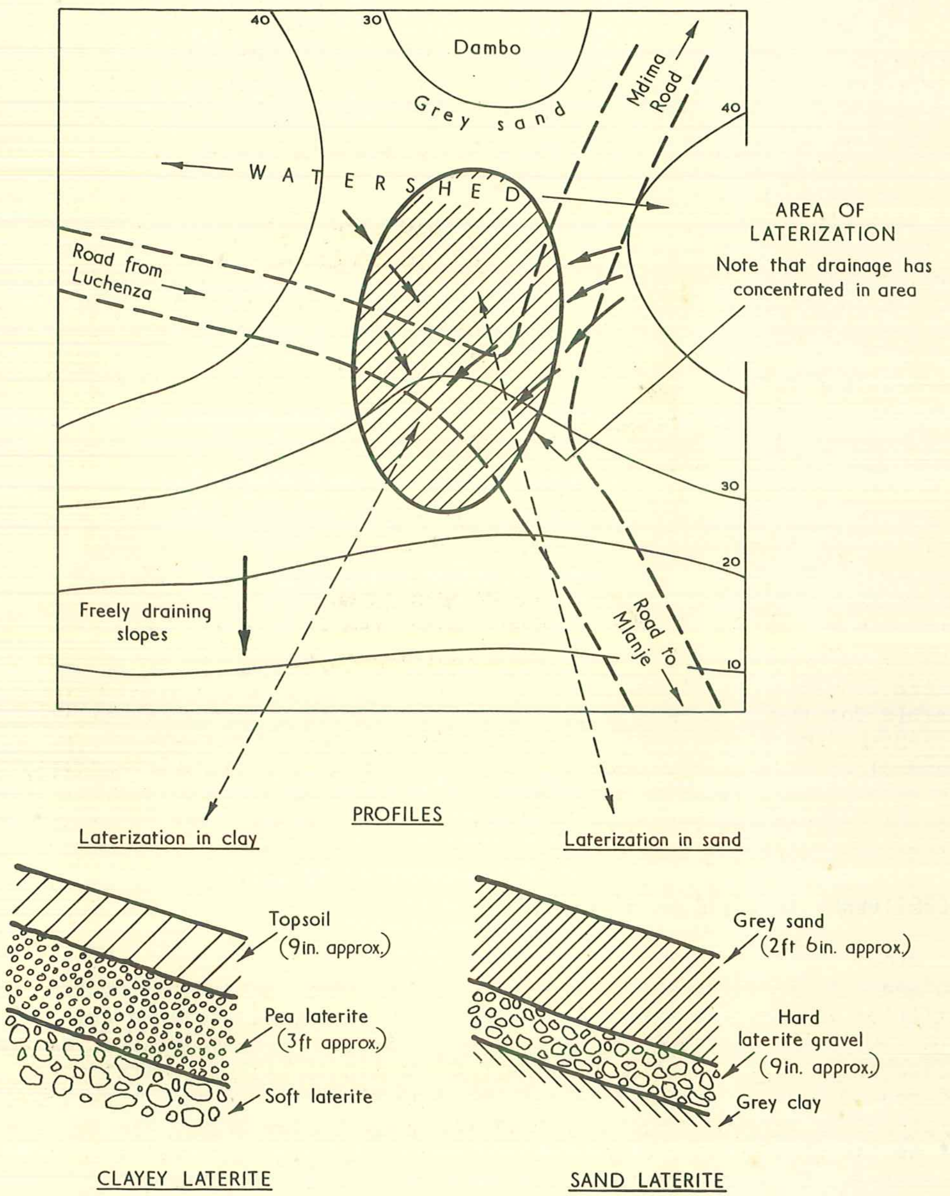
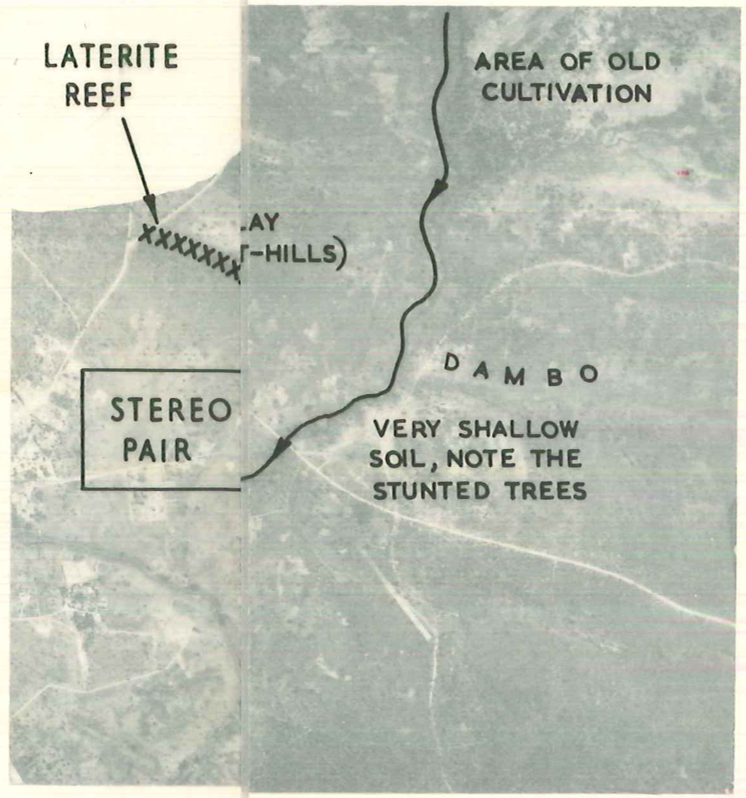


Fig. 1. SKETCH MAP SHOWING TOPOGRAPHY OF MDIMA CORNER PIT



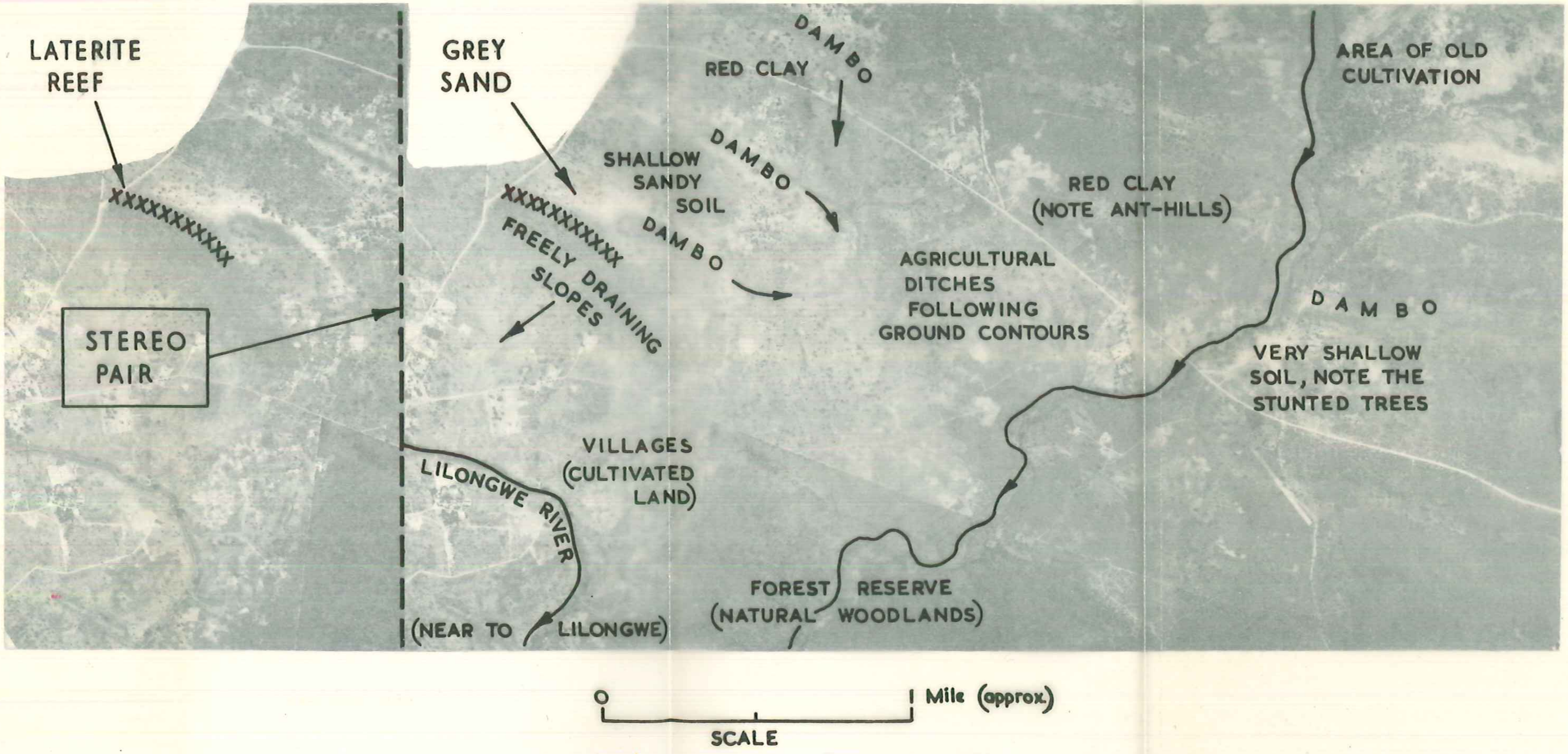


Plate 1. LILONGWE PENEPLAIN

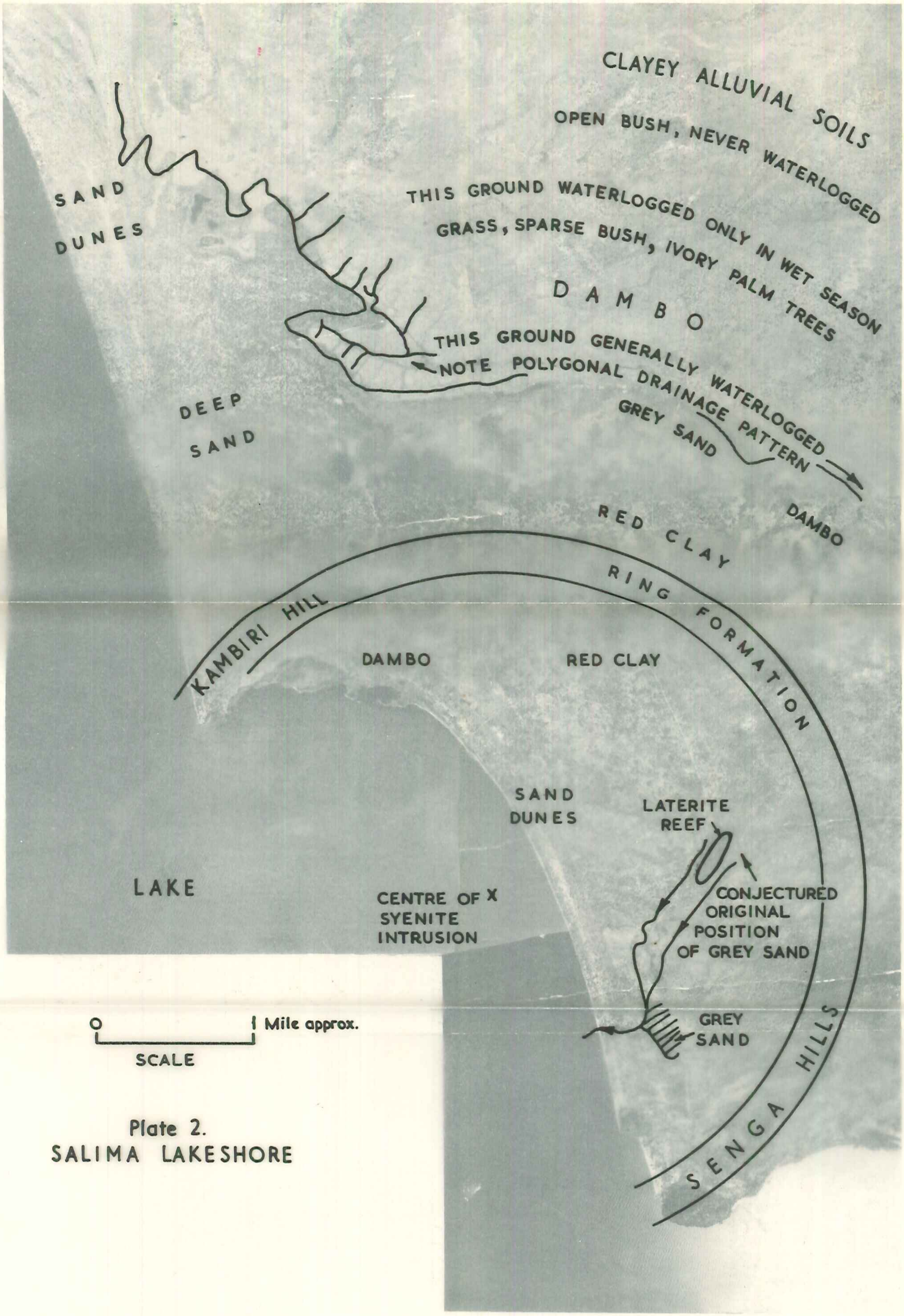


Plate 2.
SALIMA LAKESHORE

where it was in contact with air, because there was an impermeable layer of clay underneath. The ferrous compounds had set in this top soil, and the nature of the laterite depended on the degree to which air could penetrate into the soil.

A sketch map of one deposit (Fig. 1) shows that it lies to one side of a slight saddle, so that ground-water converged into the area of laterization. At one end of the deposit there was grey sand overlying a grey dambo clay. The water had flowed across this patch in the bottom six inches of the grey sand, and had formed a 6-in. layer of concretionary laterite. This sand laterite was a hard sharp gravel, blue or black in colour because there had been plenty of air circulating in the sand.

Over the rest of the area of laterization there was a brown clayey soil in which clayey pea-laterite had been formed. With each shower of rain, water would come seeping across this area, but between the showers the top few feet of soil would dry in the sun, and air would penetrate afresh into the ground. This resulted in the top two feet of the layer containing hard pea-laterite concretions; below them there is soft incipient laterite, yellow and clayey, with irregular streaks in it, but with no distinct concretions.

The clayey pea-laterite from this area was actually used for the construction of the lime-stabilized experimental length referred to in Overseas Bulletin No. 3. The 3-ft layer was all easily worked and only a few boulders of cemented concretions were left. The sand-laterite in this deposit was not workable, but in the deposit that was located for the Mlanje-Portuguese East Africa border road there was a workable thickness of 2 or 3 ft of laterite in the bottom of the layer of grey sand. This sand-laterite was a naturally stable gravel and proved to be excellent pavement material.

LATERITE REEFS

Ordinary concretionary laterite deposits are not visible on the aerial photographs because they were too small to be distinctive and they were too recent to be significant in the landform. However, as they develop they tend to resist erosion, and this can sometimes be observed on an aerial photograph. For example concretionary laterite occurring at a line of springs on the slope of a ridge can become more and more significant in the landform because it resists erosion while the rest of the ground is eroded away (Fig. 2).

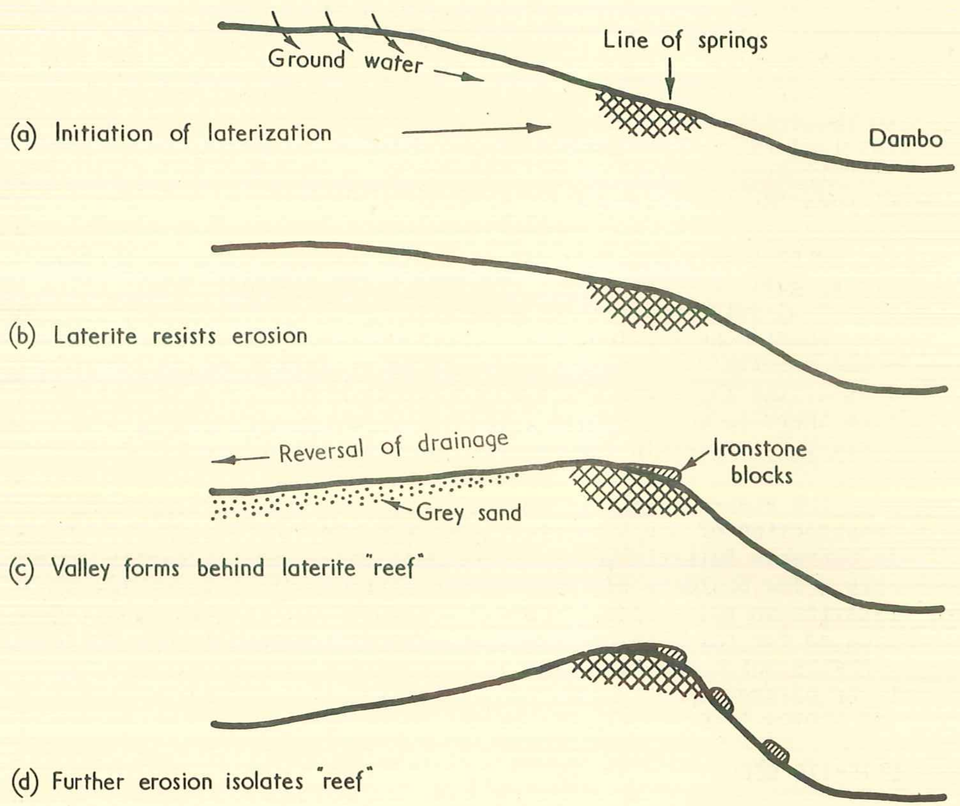


Fig. 2. LATERITE REEF DEVELOPMENT

A reef deposit of laterite is formed with a length much greater than its breadth. As long as ground-water seeps out through the springs it will form concretionary laterite in the clay beneath the reef (the soft red mottling of incipient laterite is always found in the clay under the reef), and the reef will grow thicker. The top of the reef is exposed by erosion, a hard black "crust" develops on the "cake" of yellow and red laterite, and when lumps of the crust are broken away they harden further as black honeycombed blocks.

From aerial photographs one such reef was observed near Lilongwe. It lay on a ridge which it was protecting from erosion. The steep slope up to the reef makes the ridge appear in the stereo photograph (Plate 1) as a sharp edge. The grey sand on the back slopes of this ridge results from the impeded drainage on the gentle back slopes, and also indicates the existence of some impediment to the drainage of the area. This reef was about 6 ft thick, 15 yd wide and more than 100 yd long. Along its length the top soil contained pea-laterite nodules (the surest indication of a laterite deposit in the field) and there were occasional exposed blocks of laterite.

Grey sand deposits were found to indicate the presence of laterite reefs in two other cases where the reef was in the stage of development shown in Fig. 2c. Another reef which had developed into the stage shown in Fig. 2d was located by a combination of direct interpretation of the aerial photograph and evidence from related soils and systematic field work which provides a good example of these methods.

LOCATION OF THE SENGA HILL LATERITE REEF (Plate 2)

There is an unsurfaced air strip near the Senga hills (constructed after the date of the photograph shown in Plate 2). When the construction of a paved runway was proposed attention was turned to a better site in the flat land towards Salima (off the top of the photograph). A thorough ground survey showed that the only pavement material within a 6-mile radius (an area of 100 square miles) of this new site was a moderately good sub-base sand. A study of the aerial photographs then revealed that the deep alluvial (or colluvial) soils around the new site had a distinct vegetation pattern, and that the only place in the vicinity with a different vegetation pattern was the area round the Senga hills. The hills were then observed to be in a circle and, since the rock in the hills was syenite, this suggested that the Senga hill area was a syenite intrusion on a rift fault. The soils on this intrusive rock included residual red clay, traces of colluvial grey sand and pea-laterite, and were different from the alluvial soils in all the surrounding area.

The Senga hill area was re-examined when a large deposit of grey sand was found because, on a previous occasion, grey sand had indicated a laterite reef. The sand lay at the end of two small valleys, and it was conjectured that the sand had once lain higher up on the ridge between these valleys. A search of this area was made on foot and was rewarded by the location of a large laterite reef containing slightly less than ten thousand cubic yards of pavement material.

The laterite formed a 9-ft capping to a mound, 200 yd long and 30 yd wide, on the ridge between these two small valleys. The valley to one side had gentle slopes from which grey sand had been eroded. The reef was evidently in the last stage of development (Fig. 2d) for the valley on the other side was undercutting the mound and there was a steep slope, down which boulders of laterite had rolled into this valley, 30 ft below.

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