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THE GEOLOGY OF THE KIRK RANGE–LISUNGWE VALLEY AREA

by

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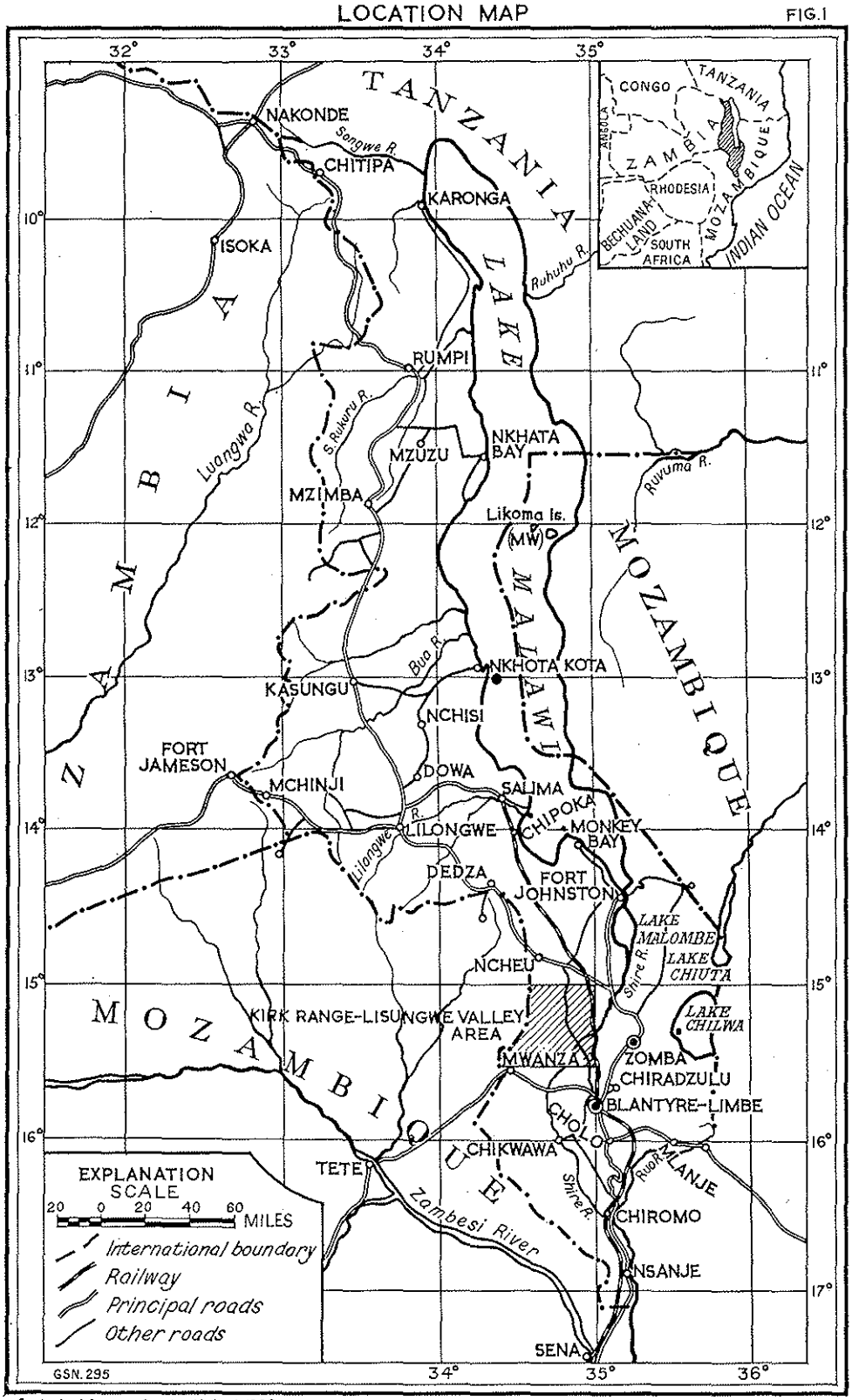
LOCATION MAP FIG.1



Geological Survey Dept. Malawi 1965

JRM.

II. PHYSIOGRAPHY

(a) Relief

The area varies in altitude from 1,240 to just over 6,000 feet above sea level and may be divided into five more or less distinct physiographic units. In descending order these comprise the Kirk Plateau, the Border uplands, the Neno step, the foothills zone and the Shire Valley plain. The last may be further subdivided. The units, which are transitional to each other in many places are shown on Plate II and will be described in turn.

(i) *The Kirk Plateau*

This is the southern extension of the Angoni Highlands of the Lilongwe–Dedza area and the Angonia Province of Mozambique. It consists of gently rolling, grass-covered uplands which slope gradually eastwards from about 5,500 feet on the Mozambique border to 4,500 feet around the edges of the plateau. To the north-east, east and south-east the plateau becomes strongly dissected and the ground falls rapidly through a foothills zone of very broken country to about 3,000 feet.

Rising 750 feet or so above the surface of the plateau near the Mozambique border is a series of residual inselbergs. These include such fine examples as Tsangano (6,073 feet) (*see* Plates I and III) and Nkweza Hill (5,919 feet) on both of which border beacons are situated. Twin-peaked Dzonze Mountain (6,956 feet) just off the northern edge of the map-sheet is a high NW.-trending ridge of hard leucocratic pyroxene-gneiss. Most of the other hills are also strike ridges and the 40 degree dip-slope on Nkhokwe Hill (5,284 feet) for example, is a very clearly defined feature.

Numerous parallel and curving strike-ridges of gneiss and schist are particularly evident in the foot-hills zone to the east and south-east of the plateau. Individual ridges composed of a particular rock type such as biotite-muscovite-schist are often as little as 2,000 feet or so in width. These features are all particularly noticeable on the aerial photographs and provide useful mapping aids.

Basic and ultrabasic rocks give rise to low hills such as Masinjere and Chimwadzulu and there is usually a marked difference between the weathering effects produced by these types and by the paragneisses that form the country rocks. The latter form smooth whale-backs whereas the former have a much more blocky type of weathering.

Unlike the western side of the Rift Valley in southern Malawi, there is no main fault-scarp. Although the ground falls rapidly from the plateau area, it does so in a series of sub-parallel steps produced by a number of associated faults. Similar step-faulting is noticeable to the north-west in Mozambique where the country appears to descend gradually in a series of wide, fairly flat terraces having a gentle easterly or south-easterly tilt. The physiographic effects of the north-trending faults are noticeable in several places and they form cliffs on the eastern faces of both Nkweza and Tsangano. There is also an abrupt NW.-trending fault-scarp to the north-east of Dzonze Mountain.

(ii) *The Border uplands*

This dissected area lies between the Wamkurumadzi River and the Mozambique border and rises gradually northwards where it is separated from the Kirk Plateau by a 750 feet-high escarpment particularly evident on the Neno-Ncheu road above Kweneza Village. Here the border is about 5,000 feet above sea-level, gradually

falling to the south to about 4,000 feet near Kapisi Village. Hills such as Mwala-wa-kuda (5,322 feet), Mwanjeli (5,409 feet), Dola (4,044 feet), Tasi (4,253 feet), Kasache (4,037 feet) and Kandema (4,193 feet) rise above the general level, usually forming marked inselbergs. North-west of Neno, the uplands form a rather dissected but plateau-like area and, from the border, the ground falls gently for about four miles before reaching a steep fault-scarp some 500 feet in height overlooking the Wamkurumadzi River and the Neno step. Nsamba Hill lies near the edge of this narrow plateau. To the south, the junction between the uplands and the Neno step is less marked and the ground descends gradually to the east in a series of step-faults.

Southwards the uplands gradually merge into what Dixey (1941, p. 100) termed the Mwanza step, a slightly more uniform surface sloping gently eastwards from the watershed to a NW.-trending fault-scarp along the western side of the Dwali Stream. This is an average of about 3,000 feet above sea level, covers that part of the area on map-sheet 1534A4 and extends on to the south-western corner of sheet 1534B3. In places it is very deeply dissected by such strike streams as the Mwanza and the Dwalibamba.

Since the Mwanza step is gradational into the higher ground to the north it is not demarcated as a separate unit on Plate II.

On the southern part of the uplands are some of the finest examples of inselbergs to be seen in this area of Malawi, typified by such hills as Nsunje, Mphingwe and Aphakala which rise steeply out of thinly bush-covered grassland.

All stages in the formation of these inselbergs can be made out. First a hard, probably migmatized, band of biotite-hornblende-gneiss weathers to give a marked whale-back ridge. Differential weathering then takes place along joints which trend across the ridge at right angles to the strike giving it a castellated appearance. Further strong erosion forms large isolated rectilinear blocks which subsequently become rounded into the characteristic inselbergs by exfoliation. When the cross-joints are not vertical, undercutting occurs and the resulting inselbergs appear to lean over markedly in one direction. Part of Nsunje Hill has this appearance.

The first stage is represented by the ridges of Kandema and Banda Hills and the last by such a perfect example of an inselberg as Mphingwe.

Nine separate and distinct inselbergs, contained in a 1,000 feet-wide band and aligned exactly along the strike of the gneisses, occur within three miles at one locality between the Dwali and Dwalibamba Rivers. Included in this line are the prominent hills Kausiusi, Gobeke and Mbinje.

(iii) *Neno step*

This is well dissected and of moderate relief, with an altitude of between 3,000 and 4,000 feet above sea level. In general the country rises gradually eastwards from the Wamkurumadzi and Dwali Rivers, at the foot of two steep fault scarps, to the edge of the main Rift Valley scarp overlooking the Lisungwe and Shire Valleys. There is also a gradual increase in height from south to north. Residual hills such as Nanzanga, Nkanya and Sanjika rise 500 feet or so above the general level.

At its northern edge, around Chinchembere and Chimbalanga Villages, the Neno step becomes increasingly dissected and is separated from the Kirk Plateau by an ENE.-trending scarp. The transition zone is, however, quite wide.

In the south of the area the Neno step includes the Mlindi Ring Structure whose topographic expression is that of a saucer-shaped depression, about four miles across, bounded by a low oval ridge of hard granulite. It is, however, comparatively low-lying rather than flat, for its surface is sharply curved.

Neno itself lies at about 3,000 feet roughly in the middle of the Neno step and the few estates are also at this general level.

(iv) *Foothills zone*

The Neno step is separated from the Shire and Lisungwe Valleys by a marked escarpment just under 1,000 feet in height which follows the line of a major Rift Valley fault. Further north, however, this fracture is represented by a number of parallel step-faults and a seven to five-mile wide zone of foothills separates the Kirk Plateau from the plain. Near Ntonda a small area of undulating country at about 3,000 feet stands 500 feet above the valley-floor zone of the Rivi Rivi. Here Songwe Hill is a prominent strike ridge of garnetiferous hornblende-gneiss.

Broken country extends from the edge of the Kirk Plateau to near the Blantyre-Ncheu road, i.e. down to about 2,350 feet above sea-level and a low but prominent escarpment stretches north-south from Sikulumowa Village to the Senzani-Ntonda road. This scarp is delineated by a large scale rift-valley type fault which splits into several similar faults to the south.

A minor hill feature composed of resistant pyroxene-granulite and hornblende-gneiss is Chaumbwi Hill, 1½ miles south-west of Matale Village. The steep-sided Mbuche Ridge stretching north-east from the Lisungwe River consists of a thick hard dolomitic marble and the high ridges adjacent to the Nyanga Stream are composed of mica-schist with resistant epidote-rich intercalations.

(v) *The Shire Valley plain*

East of the Kirk Range foothills lies a planed-off area of gneisses of low to moderate relief lying at about 1,500–2,000 feet above sea-level. Within this area the Lisungwe River has carved out a deep valley and the Likudzi, Lipangwe and Nyuzudzi Streams are also deeply incised. These streams closely follow the strike of the gneisses, diverted southwards in many sections along approximately north-south fractures.

The lower Lisungwe River flows through a three mile-wide valley which is either almost completely featureless or comprises low hummocky country made up of sandy colluvium.

Harder bands of gneiss and marble form marked strike-ridges, often stretching for many miles across country. Good examples are found north of the track to Manondo Village, where a ridge of calc-silicate granulite can be followed north-east for about four miles, and east of the Mbinjewanada Rapids where a similar rock forms a long curving ridge feature. Prominent bands of marble make up Kapiri Hill (1,900 feet) north-west of Kanono Village, the marked ridge stretching south-west from Matope Bridge, and a seven mile-long feature north of Manondo. Hard amphibolitic bands form low but conspicuous strike-ridges in the neighbourhood of the Senzani Stream and Palula Village.

A swarm of sölvsbergite dykes stands out in sharp relief above the surrounding gneisses. Individual dykes form wall-like ridges about 25 feet in height and have been traced laterally for as much as eight miles.

South of the Shire River, which flows from north-east to south-west across the south-eastern corner of the area, two hills, Chipilanje (2,535 feet) and Little Michiru (about 2,616 feet) stand out above the plain. The former is composed of hard pyroxene-perthosite whilst the latter is a NNE.-trending ridge of meta-pyroxenite. West of Chipilanje and Little Michiru there is a great difference in topography between the gneiss and the perthosite country. The gneisses form a fairly flat-lying area bordering the Shire River whilst the perthosites make up a very broken hummocky country composed of numerous small whaleback ridges. The difference between the two types of country is very marked both on aerial photographs and on the ground. East of Chimbalame Rapids, for example, there is a sharp 120 feet step up from the area of the gneiss to that of perthosite. To the east of Chipilanje and Little Michiru, however, the difference in topography is not so well-marked presumably because a thicker blanket of colluvium and residual soils overlies the rocks.

The metapyroxenites stand out as being even more resistant to erosion than the perthosites. The western side of Little Michiru ridge is a prominent feature and marks the contact between the two rock types.

North of the Shire River and east of the Blantyre–Ncheu road, there is a very flat-lying area where the dissected country made up of gneisses gives place to a featureless region composed of black sandy clay supporting *tsanya** forest. This has an altitude of about 1,700 feet south-west of Utale Station and the only prominent residual is the volcanic Kangankunde Hill which rises about 600 feet above the plain.

The lines of demarcation between black clay and dissected gneiss are easterly-facing terrace-features of which several have been recognized (*see* figure 16).

The most westerly feature, which is in places up to 30 feet high, can be traced from just south of the old Rivi Rivi Farm, past the eastern foot of Kangankunde Hill, to within two miles of the Shire River—a distance of some 20 miles. It falls from about 1,950 to 1,700 feet above sea-level. Its northern extension is obscured by sandy colluvium which extends a short distance south of the Rivi Rivi Stream.

Immediately to the east of this terrace-feature there is a lower lying area of *tsanya*-covered black clay through which flows the Mtsimukwe Stream and its tributaries. Eastwards the ground rises slightly and there are a few exposures of gneiss, mainly in gullies, before the next terrace is reached.

Between the two roughly north-south terraces, stretches of shingle and gravel form gently rounded features rising above the clays. Around the headwaters of the Mtsimukwe, stream erosion has removed part of this gravel cover revealing yellow to black cotton soils. East of Kangankunde Hill a parallel series of low rubble-covered ridges, trending roughly ENE is the surface expression of a swarm of thin phonolitic dykes.

The second terrace can be traced northwards from the Shire River at Matope Mission (Chigaru) and is a rather more marked feature than the first. About seven miles from the river it splits into three parallel steps but again becomes a single unit near the upper Mlunguzi Stream. It is flanked on the east by the usual black clays with, at its southern end, a few narrow gravel ridges and, further north, isolated outcrops of gneiss and dykes. There is a southward slope of about 20 feet per mile. A third north-east-facing terrace passes north-west through Mitoche Village and is in places up to 25 feet high.

Along the eastern edge of the map there is a low terrace scarp facing to the west, not far from the railway line.

The Rivi Rivi Stream has carved a fairly deep valley in the colluvium north-east of the railway line and two changes in base-level are evident from the two associated riverine terraces.

South of the Shire River only one terrace can be discerned. This stretches south for about five miles from Chigaru and appears to be a continuation of the second terrace described above. It too separates gneisses on the west from black sandy clay on the east but gradually becomes obscured by sandy residual soils away from the River. It slopes northwards at about 40 feet per mile.

(vi) *Erosion surfaces*

The geomorphic development of this part of Malawi has been described in detail by Dixey (1941) who divided the area into the Shire Valley, the Neno, Mwanza and Chileka steps and the Kirk Plateau. The steps and the plateau were regarded as fault-splintered sections of the mid-Tertiary peneplain with easterly or westerly tilts, separated from the early Cretaceous Shire Valley floor by early Cretaceous and Late Tertiary faults. The residuals were thought to be remnants of the late Jurassic peneplain. Although there is no evidence of bevelling in these

**Copaifera mopane.*

residuals, there are signs of an accordance of summit levels at about 6,000 feet on Dzonze, Nkweza and Tsangano Hills. It should be noted that in the present area there is no evidence for the existence of the Chileka step which is described as running along the eastern bank of the Shire River to Matope and thence to Ncheu. Indeed, north of Matope, the only scarp-features are the terraces described in the previous section which are east-facing and not, as the Chileka step, west-facing.

The development of the Shire Valley floor has also been described in detail (Dixey, 1939B, pp. 91–96) and was regarded as similar in form and structure to the Nyasa trough. The valley-floor peneplain of early Cretaceous age marked the inland extension of a coastal surface. The trough was later infilled with Cretaceous sediments, peneplained in early and middle Tertiary and then resurrected as a result of continued uplift and erosion.

King (1951, pp. 245–6) contests the idea of a mid-Tertiary surface and refers Angoniland—of which the Kirk Plateau is a southern extension—to the late " Gondwana " cycle. The Shire Valley is regarded as part of the " Victoria Falls " cycle, initiated in the Miocene (*loc. cit.* pp. 326–7).

The evidence of the sediments and later lacustrine type sands and clays, together with successive terrace-slopes points to the local formation of a small lake within the Shire trough, and this lake probably degenerated into a swamp which finally dried up in comparatively recent times.

In a recent publication Dixey (1960, pp. 263) refers the Chileka surface to the mid-Tertiary and the valley-floor to the end-Tertiary.

(b) Drainage

Apart from the Shire River, which maintains a steady flow throughout the year and crosses the south-eastern corner of the area, the principal river is the Lisungwe. This rises in a broad *dambo* on the Mozambique border near Tsangano Hill and flows eastwards across the Kirk Plateau descending through the foothills in steep-sided gorges. Five miles north-west of Palula Village it is joined by the Likudzi Stream and lower down by the Mwendangombe whose confluence lies just below Manondo Village. It joins the Shire River just off the southern edge of the map.

Other perennial streams draining the uplands are the Nyanga, Nyuzudzi, Fumfuli, Nkombe, Ntembwe and Ntungamoa all of which flow into the Lisungwe. In each case, after flowing down the escarpment these streams angle off abruptly southwards. To the north of the plateau the Kapeni flows eastwards into the Rivi-Rivi. All these streams carry good supplies of fast-running clear water.

In the Border uplands and the country west and north-west of Neno the main drainage is effected by the south-flowing Wamkurumadzi and Mwanza Rivers and their tributaries the Mfundazi, Dwali and Dwalibamba. It should be noted that on most published maps the Mfundazi is shown as the Dwali whilst the Dwali is called the Dwalibamba. The actual Dwalibamba lies to the west of the Dwali.

There are springs along the escarpments. Along the Neno escarpment they are perched 200 to 300 feet above the valley floor, whilst along the Wamkurumadzi/Border escarpment they occur only slightly below the highest land levels. Many of the springs flow perennially and may be related to sub-surface bands of marble.

In the Shire Valley plain, the region west of the Ncheu road is drained by numerous small sandy tributaries of the major streams and a few of these, including the Lipangwe, Kanje, Phasale, Ntura, Senzani and Nkhanvu flow for several months of the year. Most of the others are subject to flash floods in the rainy season but remain dry for the greater part of the year.

East of the main road the country is badly drained and the few larger streams such as the Mtsimukwe, Mlunguzi, Mvulanjobvu and Msisa only flow for about three to four months of the year. However, there is often water in shallow pools resting on impermeable black clay well into the dry season.

In 1953 the maximum average monthly flow of the Shire River, measured at Matope, was 13,000 cusecs (April) and the minimum just over 7,000 cusecs (November). (Halcrow, 1954, Vol. II, Plan 4). The estimated maximum normal and catastrophic floods at the same point are 73,000 and 166,000 cusecs respectively (*loc. cit.*, p. 20). In 1956–7 a temporary bund was built across the Shire River at Liwonde, about 35 miles upstream from Matope. This resulted in a greatly reduced flow and the level of the river at Matope Bridge fell by about 18 feet.*

In the plateau area the streams appear to have reached a fairly mature stage; lower down they are more youthful and cut deeply into narrow gorges. The drainage pattern is directly controlled by the structure of the underlying rocks and there appear to be no examples of superimposition. The upper courses of the streams on the plateau are roughly determined by the general strike of the gneisses and to a lesser extent by fractures. Good examples of strike streams are the upper Kapeni and the Thabva, a tributary of the Lisungwe. Near Nkweza Hill, the Nsete and Chisungulu occupy strong fault-lines and are approximately at right angles to each other. In places the plunge of the lineation also seems to have had an effect on the drainage pattern.

The rather meandering course of the upper Lisungwe Stream, particularly the section immediately below the drift, seems to require a special explanation. This area lies near the centre of the structural dome which makes up the Kirk Plateau (*see* p. 186) and both the plunge of the lineation and the dip of the foliation planes in the gneisses are low and approximately the same. The general course of the stream lies in the direction of the lineation i.e. ENE. but in many places it curves and bends to follow the N. to NNE. gneissosity. North-south fractures have also had an effect. In the foothills immediately below the plateau the effects of structure on the drainage pattern are much more evident. The lower Lisungwe, the Likudzi and possibly the Kapeni flow along marked W. to WNW.-trending fractures and one of the main Rift Valley faults in this area is followed in part by the Namiso (a tributary of the Likudzi), the Litindi (a tributary of the Lisungwe) and tributaries of the Nyuzudzi and Mwendangombe.

A well-developed pattern of subsequent streams follows the north-east strike of the schists and gneisses along the southern edge of the plateau.

Most of the south-flowing rivers in the Neno area follow either soft bands in the gneisses or are aligned along strike-faults, whilst the Nkombe, and similar streams flowing east to the edge of the Neno escarpment, follow E. and NE.-trending fractures and have remarkably straight courses. The Wamkurumadzi, although rather meandering, closely follows the foot of a major fault-scarp over much of the area. To the west of the Mlindi Ring Structure, however, this river and several minor streams have adjusted themselves to the corresponding arcuate strike of the paragneisses. In places there is a trellis-type drainage pattern due to joint control.

As noted above, the Shire River flows from north-east to south-west across the south-eastern corner of the area. For the first four miles or so it meanders through a flat alluvial area until it reaches Chigaru, where the first rock exposures appear on the riverbed. From this point, its course is controlled by the structure of the underlying gneisses. The river flows along a major ENE. fracture zone from Chigaru to the Thima Rapids and thence along a NE.-trending fault to just above Matope Bridge. From the Bridge to the southern edge of the map sheet the Shire follows the strike of the gneisses and flows either along particularly soft bands or along strike-faults. It is, however, offset half-a-mile or so in several places by NW.-trending cross-fractures and, where this happens, rapids are formed. The main rapids, from the Matope Bridge downstream are as follows:—Murchison Falls (Plate III, Fig. 2), Chasambia, Toni, Chimbalame, Nachimbeya, Chilembe and

*A recently constructed (1965) barrage at Liwonde is, at present, producing similar effects.

Mbinjewanada Rapids. At one point, about two miles below Matope, the course of the river is offset slightly by a major ENE.–trending sölvsbergite dyke.

Dr. A. Young* contributes the following additional note on the drainage and geomorphology of the Kirk Plateau:—

"The western part of the area consists of a dissected plateau, the majority of which lies between 4,500 and 5,500 feet. It has probably resulted from two stages of development, although the landforms resulting from each of these are not clearly separated from each other. The main ridge crests separating the larger rivers lie between 5,000 and 5,500 feet, rising gradually westwards towards the Shire–Zambesi watershed. This surface has been dissected by eastward-flowing rivers the upper sectors of which became graded to a base-level which now lies at approximately 4,500 feet. Within the main river basins, this cycle has reached the stage of mid-maturity; the valley-sides of adjacent tributary streams have intersected, lowering the height of the interfluve crest and thereby destroying much of the original plateau.

"Within each river basin the pattern of drainage is generally dendritic—in conjunction with the condition of mature dissection, this gives rise to a characteristic landform. The latter consists of an interfluve broadly convex in cross-section; the longitudinal profile along its crest slopes evenly downwards for the majority of its length, below which it is terminated by a convexity.

"In the valley floors a relatively narrow concavity occurs. This landform covers a greater area than do the remnants of the original plateau. It is particularly well developed in the (upper) Lisungwe Valley west of the road, where the interfluves slope inwards towards the valley-centre, producing a basin-like form. . . ."

(c) Climate

As might be expected, with an altitude variation of nearly 5,000 feet the climate in the area covers a wide range of conditions.

In the uplands the mean temperature is about 65°F to 70°F but there is a considerable range. In the winter months it becomes quite cold and frost is common at night on the plateau in June and July. Here the climate is very pleasant indeed. Around Neno the climate is fairly equable. The mean temperatures fall within the 70°–75°F range but, as in many similar parts of Malawi during the month or so immediately preceding the rains, afternoon temperatures are in the 90°s and it becomes rather hot. During the winter months cold misty *chiperoni* conditions are common.

In the Shire Valley area, apart from the three winter months, the weather is rather unpleasant. There is a wide temperature range from about 50° to 90°F but, between September and December, the afternoon temperatures in the vicinity of the Shire and Lisungwe Rivers often exceed 100°F.

The mean annual rainfall in the uplands is between 40 and 56 inches and in the higher parts of the Shire Valley 33 to 40 inches. Along the banks of the river and in the low-lying plains crossed by the Rivi Rivi and Mlunguzi Streams the mean annual rainfall is less than 33 inches.

(d) Vegetation†

The plateau region and the higher parts of the Border uplands NW. of Neno are at present covered by rolling grassland amid most of which only a few scattered short trees and bushes occur. The most extensive dominants are *Hyparrhenia filipendula* var. *pilosa* and *Themeda triandra*. Different species occur on recently abandoned cultivations, among which the following may be dominant or co-

*Formerly Soil Surveyor, Department of Agriculture, now Lecturer in Geography, University of Sussex.

†Based largely on an unpublished account by A. Young.

Much of the weathered biotitite and biotite-metapyroxenite of the Mlindi Ring Structure contains abundant mica, apparently hydrobiotite, which exfoliates to a marked degree on heating (about 10 times) after which it weighs about 16 lb./cu. ft. According to Goldstein (1946) no vermiculite product weighing more than 6 lb./cu. ft. is of any commercial value so the material seems to have limited application. It may nevertheless be suitable for mixing with ground apatite to make a natural fertilizer (*see* section (m), p. 220).

(w) Water supplies

(i) *Hot springs*

There are two hot springs near Manondo Village. One of these is in the banks of the Madziphisa Stream whilst the other is at the head of a small gully, between the Lisungwe River and the Village. The two springs are about a quarter of a mile apart and appear to be situated on the same ENE. fracture zone in biotite-gneiss. The temperature of the former is 38°C, and of the latter, 46°C, an analysis of which is give below in Table XXIX.

TABLE XXIX

CHEMICAL ANALYSIS OF WATER FROM MANONDO HOT SPRING

pH 7.8	Calcium	1.28 pp.	100,000
	Magnesium	0.67	,,
	Potassium	0.55	,,
	Sodium	11.05	,,
	Carbonate	1.20	,,
	Bicarbonate	9.76	,,
	Chloride	7.10	,,
	Sulphate	2.37	,,
Total soluble salts (direct determination)		68.2	,,
Equivalent hardness (as $CaCO_3$)		6.0	
Grains per gallon		3.5	

Analyst: C. V. Cutting

Dr. Cutting also reports as follows:—

" This water is moderately soft, since the salts present are chiefly sodium compounds and not those of calcium. The main salt component is sodium sulphate (Glauber's salts), so the water would have a certain therapeutic value. It is similar to but rather more saline than water from Kota Kota hot springs."

It should be noted that the Manondo spring water is used by the local Africans for washing purposes only. Drinking water is obtained from the Lisungwe River.

Other hot springs were found on the banks of the Lisungwe River a mile SE. of Mbuche Ridge and on a small hill about two miles to the north of this locality. Neither are apparently situated on major faults.

(ii) *Wells*

Numerous wells and several boreholes were sunk in the area by the Geologica Survey Department during the 1930's. The present policy is to replace wells by boreholes and many of these have been constructed in recent years.

Most wells are restricted to the areas of black sandy clay south of the Shire River and east of the main Blantyre-Ncheu road although there are a few to the south-west of Little Michiru Hill and near Chipilanje. Two wells were constructed near Kanono Village on the banks of the Mtsimukwe Stream and there are a number near stream courses to the north and north-east of Kangankunde Hill and also near the railway line. In this latter area several are in weathered gneisses.

Many of the wells are relatively shallow near the larger river courses but deeper in the intervening areas. It was found that where 20 feet or less of drift rests on weathered rock, there was little difficulty in obtaining an adequate supply of water.

Rock weathering is highly variable in this area and several deep trial shafts were often necessary before water-bearing patches could be found.

The eastern part of the area in which wells were sunk i.e. around the Chia and Malala Streams, was found to be underlain by alluvium to a depth locally of more than 120 feet. In some places alternating dark clays and lighter-coloured clayey sands were encountered whilst in others the arenaceous Matope Beds were met with, resting on gneiss. This latter formation was often found to be dry, although the underlying gneiss was water-bearing.

At several points the deep alluvium contains water under pressure. Some shallow wells in the area of thick alluvium draw their water from local perched aquifers. Depths of wells range from 14 to 118 feet.

The only noticeably mineralized water encountered was found in three wells about four miles ENE. of Chipilanje Hill, not far from the Chia Stream.

Analyses of water from these wells are given below (Dixey, 1936, Table IV):—

TABLE XXX

ANALYSES OF WELL WATER (p.p.m.)

Locality	*" Madzala B "*	*" Madzala C "*	*" Madzala D "*
Depth from which sample taken	26 ft. (sub-artesian, rising from 109 ft.)	106 ft.	20 ft.
Geological formation	Alluvium	Alluvium	Alluvium
Turbidity of filtered water	Clear, but slightly yellow	Cloudy	Slight
Suspended matter—parts per million	13	135	13
CO_3 ,,	243	1,135	140
Cl ,,	76	355	17
SO_4 ,,	62	2,249	7
Ca ,,	17	79	45
Mg ,,	11	92	35
Na ,,	164	1,394	35
K ,,	31	44	21
SiO_2 ,,	31	62	45
Al_2O_3, Fe_2O_3 ,,	5	4	8
TOTAL (excluding suspended matter)	640	5,414	523
Residue on evaporation (dried at 130°C)	543	4,978	424

(iii) *Boreholes*

Boreholes sunk in the area during recent years are fairly widely distributed and not restricted to one particular geological formation. They are shown in Table XXXI. Holes have been put down both in weathered gneiss and in sandy

TABLE XXXI

WATER BOREHOLES SUNK IN THE KIRK RANGE-LISUNGWE VALLEY AREA BETWEEN 1954 AND 1960

No.	Locality	Depth (ft.)	Yield (g.p.h.)	Rest level (ft.)	Rocks penetrated	Remarks	Year drilled
A. Neno Step area							
J30	Neno boma	134	1,000	27	Biotite-gneiss	N. A. Mlauli	1960
J31	Johnathon	172	480	108	Weathered gneiss	,,	,,
J32	Nangombe	190	800	118	,,	,,	,,
L239	Butao	86	800	9	Biotite-meta-pyroxenite	,,	1956
B. Lisungwe Valley area							
W242	Mpatamoyo	104	820 (hot water)	45	Dambo sands and clays	N. A. Simon	1960
W243	Nkase	174	800	110	Sands and gravel	,,	,,
W244	Nankudwe	175	800	95	,,	,,	,,
W245	Thamanda	126	850	78	,,	,,	,,
L140	Kangankunde Hill	201	360	160	Contact breccia	for diamond drilling operations	1959
L245	Palula	130	800	70	Gneiss		1956
L227	Lisungwe Court	95	700	30	Sandy clay and gravel	N. A. Simon	,,
L228	Kasamba	90	900	18	Gneiss	,,	,,
L229	Carvalho (Nguluwe)	108	600	46	Sandy clay and gravel	,,	,,
L248	Senzani	138	250	40	Gneiss	,,	,,
K187	Manyenje	120	300	70	,,	,,	1955
K189	Mpanje	120	500	70	,,	,,	,,
K190	Chimbwafu	80	600	27	,,	,,	,,
K191	Milombwa	130	121	90	,,	,,	,,
K192	Kalumbe	165	400	95	,,	,,	,,
L207	Kaphikamtama	130	900	60	,,	,,	,,
L208	Mbwana	128	300	75	,,	,,	,,
L209	Chapasuka	81	400	20	,,	,,	,,
L210	Chikande	110	800	45	,,	,,	,,
L211	Naminjale	137	400	55	,,	,,	,,
C. Shire Plain							
W206	Makata's Court	118	960	14	Weathered gneiss	N. A. Chigaru	1960
W178	Ngwaya	154	720	75	,,	,,	,,
W230	Chiwaya	154	652	85	,,	,,	,,
W180	Masulani	120	650	12	Dambo deposits over gneiss	,,	,,
W179	Monekera	178	720	85	Margin of dambo	,,	,,
W241	Morson	104	800	48	Weathered biotite-gneiss	,,	,,
E129	Malawi	80	720	18	Clay over gneiss	N. A. Lundu	1958
E162	Shakila/Matengo	142	1,440	20	Thick clay	,,	,,
L214	Makande	125	500	76	Sandy clay and gravel	N. A. Chigaru	1956
L213	Dwaleni	175	300	100	Gneiss	,,	,,
L225	Mangwanle	120	600	60	,,	,,	,,
L226	Lazaro	600	1,000	20	,,	,,	,,
K182	Ntsenjele	170	800	95	Sandy alluvium	,,	,,
K186	Lipuluwa	120	800	37	Biotite-gneiss	,,	1954
K183	Kanono	123	1,000	24	Eluvium on biotite-gneiss	,,	,,
K184	Njalanzati	120	1,200	20	Biotite-gneiss	,,	,,

colluvium as well as in thick (?) lacustrine alluvium with varying results. There are, however, only a few boreholes in the uplands, near Neno.

Eight boreholes sunk in weathered granulites in the vicinity of the main Blantyre road, near Dwaleni, gave yields ranging from 200 to 1,000 g.p.h. The deepest borehole reached 175 feet. Nevertheless although one borehole at Njalanzati gave 1,200 g.p.h., yields from Basement Complex gneisses in N. A. Simon's area were not high. Here run-off is very great and sheet erosion has reached an advanced stage in some places. Weathered rock is only found as shallow pockets in the gneiss and may be completely dry. One borehole sunk at Salima encountered hard rock and was abandoned, whilst the average yield of other holes in this area was less than 500 g.p.h. At Kasamba Market, however, horizontally sheared biotite-gneisses were penetrated and a borehole 90 feet in depth yielded 900 g.p.h., with a rest level 18 feet from the surface.

Of particular interest is the hole at Mpatamoyo between the Lisungwe River and the foot of the main Rift Valley escarpment. This struck hot water at depth which, however, rose only a few feet and is presumed to have approached a subsurface hot spring probably situated on a fracture zone.

Also of interest is the Butao borehole, the only one in the country sunk in biotite-metapyroxenite. Here the water-bearing zone is very narrow and it would seem that this rock does not yield to earth stresses along broad and well-defined zones of dislocation as do the more common rigid gneisses and syenites. The metapyroxenite was found to be weathered to about 60 feet at which depth the main aquifer was encountered.

Yields from holes sunk in sandy colluvium are generally fairly high e.g., 800 g.p.h. at Ntenjele and 700 g.p.h. at N. A. Simon's Court. The water presumably lies within bands of coarse sand and gravel.

Near Kanono Village a borehole sunk through black sandy clay into gneisses (depth 123 feet) gave 1,000 g.p.h.

In no case was the water from boreholes found to be noticeably brackish.

(iv) *Rivers and streams*

The Kirk Range is well-served by perennial streams and rivers although many of the villages are situated well above their sources of water. In the lower lying country, however, apart from the Shire, Likudzi, Rivi Rivi and Lisungwe Rivers most of the streams have sandy floors and are subject only to the occasional flash flood. It is in this area that most of the wells and boreholes are situated.

The following table, compiled from reports of the Water Development Department gives river flow information for three of the perennial rivers in the area. It should be noted, however, that the Rivi Rivi has 14 (mean) annual days of no flow.

TABLE XXXII

RIVER FLOW INFORMATION

River	Locality	Catchment area (sq. miles)	Mean annual no. days of no flow	Minimum flow (cusecs)	Maximum flow (cusecs)
Shire	Matope	—	nil	4,880	25,715
Lisungwe	Moffat Village	461	nil	4.5	20,400
Rivi Rivi	Rivi Rivi Farm	300	14	nil	9,000

(v) *The Shire Valley Project*

The three main aims of the Malawi Government's Shire Valley Project are as follows:—

(a) the construction of an integrated scheme for the control of Lake Malawi and the Shire River.

(b) the production of hydro-electric power.

(c) the reclamation and protection of the Lower Shire marshes between Chikwawa and the Zambesi.

This project was fully investigated by engineers and surveyors employed by Sir William Halcrow and Partners during the years 1951 to 1954 and a comprehensive report published (1954, Vols. I & II).

A detailed ground survey of the whole of the Shire Valley was made, and in the present area, three prospective dam sites were examined, i.e., at Chigaru, just below Matope Bridge and at the Nachimbeya Rapids.

The following reports on these three sites are taken from the 1954 Report:—

1. " *Chigaru.* This site is at the head of the rapids section of the Shire River and near the old Matope Mission of the Universities Missions to Central Africa. Conditions to the downstream are favourable from a hydraulic point of view as there is a sudden increase in the river gradient downstream of the site. There is rock in the river bed and on the left bank but it is not visible on the right bank.

A barrage at this site to impound the water to the level of the lake in 1937 (1,556.4 ft.) would be 2,800 feet long at top water level but the river at this point is exceptionally deep.

2. *Matope.* The site examined is a little below the road bridge across the Shire on the Blantyre-Lilongwe road. A little to the upstream of the bridge the river takes a sudden left-hand bend at the head of the rapids which extend for some 1,000 yards downstream. After passing under the bridge the river runs in a narrow channel on a steep gradient. Our surveys have shown that a dam approximately 80 feet high and 1,200 feet long would impound the water to the level of the lake in 1937 plus allowance for a rise following major floods in the tributaries. Embankments would be required on either flank for a total length of some 5,000 feet.

On the left flank there is much weathered rock.

In a distance of a little over two miles below the dam site the river falls some 190 feet in a series of rapids and cascades and this site thus provides the possibility of the development of hydro-electric power in combination with lake regulation.

We conclude from all these examinations that the site at Matope is the most favourable for the main regulating barrage because it is at least as effective as any of the others in controlling the lake; it is the most effective for controlling the unregulated catchment below the lake; it represents a possibility of developing hydro-electric power; finally it would make possible navigation from Lake Nyasa downstream to a land and water terminus within 36 miles of Blantyre.

. . . Below the Matope Bridge the river runs for some 400 yards at a fairly steep gradient and then by cascades for a further 40 feet into calm water. The total fall from the head of these rapids to the foot is 60 feet. Below this first series of rapids, there are several smaller ones ending about three miles below the bridge in the Toni Rapids where there is a fall of about 35 feet. Although the total fall between Matope Bridge and the foot of the Toni Rapids is 190 feet, if a barrage were constructed at Matope to regulate the lake, the total fall would then be of the order of 230 feet . . . it is not possible to present, at this stage, a detailed scheme for the development of the full head. We are confining ourselves for the present to an initial low head development in the barrage itself or an intermediate development of the main Matope Rapids. The first would appear to satisfy the demand for power in Malawi for some years, and it is proposed that four sets, including one spare set, each of 10,000 KW capacity should be installed. The machines would operate at a minimum head of 47 feet . . .

The full development of the rapids below Matope would allow the development of an average head of some 225 feet. With a regulated flow of 5,000 cusecs, some 75,000 KW of continuous power might be generated.

A lesser development of the main part of the Matope Rapids themselves would utilise a head of about 100 feet and might generate some 32,000 KW of continuous power. This compares with an output of 16,000 KW continuous for a power station in the barrage itself.

3. *Nachimbeya.* The Nachimbeya and Chimbalame Rapids are situated about two miles downstream of the Toni Rapids. The river, after flowing at a gentle gradient, turns sharply to the right and in a short rapid known as the Chimbalame, falls about 13 feet. It

continues at an easy gradient for about 5,000 feet and, taking a sharp turn to the left, passes down the main Nachimbeya Rapids with a fall of about 43 feet. The total fall from the head of the Chimbalame to the foot of the Nachimbeya is about 61 feet.

The development of this site is influenced by proposals for the development of the larger scheme at Matope, because the full development of Nachimbeya and Chimbalame would pond back the water above the tailrace level of the full Matope development. On the other hand, if the full Matope development did not prove worthwhile, some of the head might be recovered at Nachimbeya. Access to this site is limited to a track from the Simon's Cotton Market Road down to the village of Zalewa and thence north to the proposed site."

After the publication of the 1954 report a more detailed examination of the Matope dam site was carried out by the consulting engineers. This included a very detailed ground survey and much exploratory diamond drilling with grout tests, and several deep trial shafts were sunk along the centre line of the proposed dam wall. This work was finally completed early in 1957 and was aided by the construction of a bund across the Shire River at Liwonde. Subsequently, it was decided that the Matope scheme would be too costly and, indeed, a cheaper scheme at Nkula Falls ten miles downstream was proposed.

(x) Zircon

This was found at only one locality—near Butao Village, in the centre of the Mlindi Ring Structure—where it occurs in apatite-bearing feldspathic pegmatite. The crystals are short prisms and subprismatic forms and up to four inches in size.

A report by the Mineral Resources Division of Overseas Geological Surveys indicates that *some* of these zircons are *almost* gem quality and so the occurrence may be worth following up from this point of view.

Since a spectrographic analysis of the zircon showed between 0.5 and 1.0 per cent hafnium (*see* p. 129) which is about the usual amount found elsewhere (von Knorring and Hornung, 1961) they can not be regarded as a potential source of this metal.

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