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THE SURFACE FEATURES AND SOIL PATTERN OF THE HAMILTON BASIN

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ABSTRACT

The Holocene history of the Hamilton basin and devolopment of the soil pattern are closely related. The basin was partly filled by the large alluvial fan of the Waikato River which partly buried a hilly, ash-covered landscape. The normal depositional pattern of fans is recognisable (apex of coarse sediments; middle part with ridges of coarse sediments and swales with fine sediments; toe of fine sediments) but has been modified by changing river courses during fan building. Each of these courses was flanked by levees which dammed valleys and embayments and blocked drainage to form lakes. The lakes were the sources of the present day peat bogs. The properties of the soils developed on the wide range of parent materials and landforms in the basin are summarised.

INTRODUCTION

The Hamilton Basin is a good example of a region where a detailed soil survey has helped to clarify late Quaternary history (Grange **et al**, 1939). More recent studies have brought to light additional information and some of this is discussed in this report. It must be emphasised that, with field work still in progress, this paper must be regarded as a preliminary report and some of the hypotheses put forward may require later amendment.

The Hamilton Basin (or Middle Waikato Basin) is a roughly oval shaped depression more than 50 miles long in a north to south direction, and more than 25 miles wide. The city of Hamilton lies almost in the centre of the basin. The basin, except in the south, is almost completely surrounded by ranges up to 3,000 ft. high broken in only a few places by narrow gaps. In the south the basin floor rises gradually and merges with the dissected plateaus of the King Country.

South of Te Awamutu the floor of the basin consists of rounded hills rising 100 to 200 ft. above the narrow flood plains of the numerous small streams that drain the region. Northwards relief is lower and the topography consists of isolated hills and ridges rising from an alluvial plain. The Waikato River enters through a gap in the eastern ranges (the Maungatautari Gorge), flows across the basin in an entrenched course, and leaves by way of the Taupiri Gorge cut through the north-western ranges. The main tributary, the Waipa River, drains the southern part of the basin and joins the Waikato River at Ngaruawahia. Both rivers are flanked by low terraces.

This report deals mainly with the topographic features and soils of the floor of the northern part of the Hamilton Basin. Three broad topographic units are recognised: (a) low hills; (b) the plains; (c) river terraces.

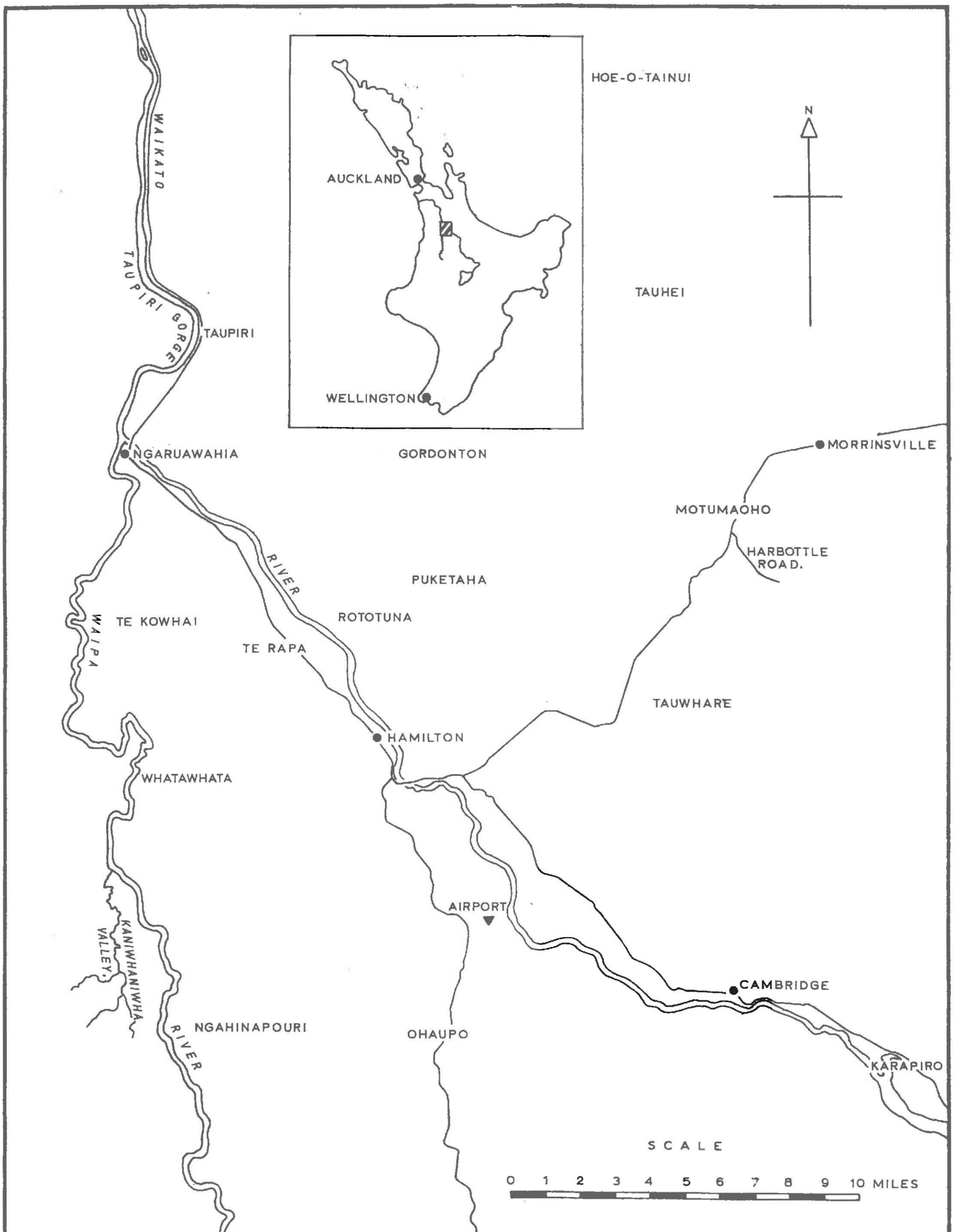

Figure 1: Locality Map, Hamilton Basin.

(a) LOW HILLS

The long, low ridges in the southern and western parts of the basin and the isolated hills in the eastern and northern parts are the eroded remnants of a system of terraces formed in Pleistocene deposits. The earliest deposits were pumice gravels and soft, unconsolidated ignimbrite-like materials (Puketoka Formation) and were followed by alluvium (Karapiro Formation) consisting of clays, sands and gravels which include fragments of volcanic rocks and greywacke (Kear and Schofield, in press). Red colours in the upper few feet indicate that these old sediments were "red weathered" during a warmer period.

Overlying these sediments is a mantle of volcanic ash. Three groups of ash can be recognised:

(a) Kauroa ash (Ward, in press): Discontinuous remnants of an old ash mantle, much weathered and dark brown in colour lie on the Karapiro and Puketoka sediments. The original thickness of the ash is unknown as at most sites in the basin only a few feet remain but Ward records a thickness of 28 ft. near Raglan. Where it is preserved the surface of the Kauroa ash is marked by a very prominent fossil soil, dark reddish brown in colour with a strongly developed blocky or prismatic structure. Neither the source or the composition of the Kauroa ash is known.

(b) Hamilton ash: After a period of erosion which stripped away most of the Kauroa ash and some of the underlying red weathered sediments the hills were again smothered with a thick mantle of ash. This time 10-15 ft. of ash, made up of 8 or 9 separate beds, were deposited. This deposit, the Hamilton Ash Formation, is described in detail by Ward in a forthcoming paper. The name does not imply that the source is near Hamilton (the source is still unknown) but merely that the ash was first described from a site near the city. The reported occurrence of ash beds similar in appearance to Hamilton ash from points as far afield as Henderson and Wellington, Gisborne and Raglan suggests a series of eruptions much larger than the Taupo eruptions of 130 A.D.

North of Hamilton the ash cover becomes progressively thinner and more patchy until, on the hills east of Taupiri, it covers much less than 50 per cent of the surface. It is presumed that erosion has stripped the ash but the reasons why this should be more severe in the northern part of the basin is not yet clear. One possibility is that the ash was removed by slumping caused by wave action along the foot of the hills when extensive lakes occupied the floor of this part of the basin.

(c) Mairoa ash: The mantle of light, friable ash which covers the King Country to a depth of several feet, and known as Mairoa ash, extends northwards into the Hamilton Basin and covers the older Hamilton ash. At Ohaupo it is still four feet deep but then thins rapidly until, at Hamilton, it disappears. This sudden thinning and disappearance is attributed to erosion. Pullar has shown (this issue) that Mairoa ash is largely comprised of thin beds of already identified ashes with sources in the Rotorua-Taupo region.

In the northern part of the basin a thin layer of yellowish grey silt covers the hills. It is thickest near Taupiri where there are patches, generally in slight hollows, up to 3 ft. thick but elsewhere it occurs as a discontinuous layer of variable thickness lying over the Hamilton ash or Pleistocene sediments. It seems to thin out towards Hamilton but at Te Rapa is still recognisable as a 2 in. to 4 in. thick mantle over Hamilton ash locally increasing, in small pockets, to 12 in. in thickness.

The silt is thought to be loess and though its source is, as yet, unknown it is likely to be of local origin possibly as dust blown from the surface of the aggrading Waikato fan or from the beds of former rivers. The silt apparently fell on to an uneven surface because its boundary with the underlying ash or sediments, although sharp, is uneven with many small hollows and pockets which may mark former tree sites.

A gently sloping, narrow apron of detritus consisting largely of redeposited Hamilton ash but containing also debris from the underlying sediments, flanks most of the hills in the basin. It is particularly well developed along the sides of the gullies that run back into the hills and some are partly infilled with the washed material.

The few steep slopes on the hills were probably formed by river trimming during the infilling of the basin. A discontinuous terrace 6-8 ft. high has been cut around the foot of many hills in the northern part of the basin. It is particularly well developed at the foot of spurs and is thought to have been cut by the wave action of former lakes. The tread of the terrace is, in many places, thinly covered with sands sorted from the Pleistocene sediments.

Soils of the Low Hills

Soils of the hills may be divided into four groups: yellow-brown earths; brown granular loams; yellow-brown loams and gley soils.

Yellow-brown earths are formed on the Pleistocene sediments and on debris derived from them. They have pale yellowish-brown subsoils with weakly developed blocky structures but appear massive in roadside cuttings. They are less friable than brown granular loams, firm when dry and sticky when wet owing to the prevalence of kaolin clays. Yellow-brown earths are also developed from loess and these are more friable than the soils derived from the Pleistocene sediments. Yellow-brown earths are common on the hills east and south of Taupiri where they form a complex pattern with soils derived from Hamilton ash.

Brown granular loams are developed from Hamilton ash and from Kauroa ash but soils forming exposures of the latter are very rare. They are distinguished from the yellow-brown earths by their reddish-brown subsoils which have a strongly developed blocky structure and are very friable. Commonly the soils will break up and stream away from a dry face when struck with a spade. Brown granular loams are most extensive on the hills near Hamilton (Hamilton clay loam is a well-known soil type) and are less common in the northern part of the basin. Many brown granular loams have silty topsoils developed from a thin mantle of loess or Mairoa ash.

Yellow-brown loams are developed on Mairoa ash. They are distinguished from other soils by their very friable, finely structured subsoils which stream through the fingers when handled. Ohaupo and Otorohanga silt loams are widespread soils of this group and cover the hills south of Hamilton. The high content of the amorphous clay mineral allophane in the yellow-brown loams gives rise to the characteristic greasy feel of these soils which contrasts with the stickiness of the yellow-brown earths and brown granular loams.

The apron of colluvium and washed detritus skirting the hills has poor internal drainage and is subject to seepage from the slopes above. Soils developed on this material are gleyed and marked by grey subsoil colours with many rusty mottles and by well developed prismatic structure. Most of these hillside gley soils are grouped as Rotokauri soils and, although restricted in area, are widespread throughout the basin.

(b) THE PLAINS

The greater part of the floor of the northern Hamilton Basin is a plain formed mainly by the fan of the Waikato River but including also an alluvial plain laid down by the Waipa River as well as several small fans and flood plains formed by local streams.

The Waikato Fan

When the Waikato River abandoned its course through the Hinuera Valley and Hauraki Depression and broke into the Hamilton Basin at Karapiro it began to fill the basin with alluvium. The alluvium (Hinuera Formation) consisted mainly of current bedded gravels and sands derived from ignimbrite, andesite, greywacke and pumice together with large quantities of quartz sand. It was probably mainly debris from the severe erosion that affected the uplands of the North Island during a cold period that coincided with the last advance of the ice in the South Island. From evidence deduced from ash shower cover this erosion seems to have slowed down greatly about 10,000 to 12,000 years ago.

The alluvium was deposited in the form of a large, low-angled fan which partly buried the ash-covered, hilly topography of the basin. The common three-part fan pattern is recognisable: (a) the apex sediments which stretch from Karapiro to beyond Cambridge and consist mainly of gravels; (b) the middle part which lies between Cambridge and Hamilton and consists of low gravel ridges separated by shallow depressions partly filled with fine sediments; (c) the toe which stretches far out into the basin beyond Hamilton and is comprised of fine sediments consisting mainly of pumice silts and sands. This simple pattern is complicated by the numerous courses followed by the river during the fan building. When deposition finally ceased and the river became established in its present course several of the old courses were preserved and six or seven can be recognised today (Fig. 2).

Old River Courses. The old courses can be readily indentified by the levees of coarse sediments which can be followed across the fan without difficulty. Generally they stand about 10 ft. above the general level of the fan. In some places, for example between Hamilton and Te Kowhai, the levees are the only evidence of former distributaries but in other places, for example along the old courses that run from Cambridge through Tauwhare to Morrinsville and from Puketaha through Gordonton to Taupiri, the former river bed is still clearly defined. Some of these well defined channels, for example the one that lies just south of and parallel to the main Hamilton to Cambridge highway, are occupied by and have been much deepened by, modern streams.

The levees of the old river courses have played an important part in the recent history of the basin and in establishing the soil pattern. As levees formed along each course they acted as dams, cutting off and ponding local drainage to form numerous lakes in a somewhat similar way that lakes have formed in the "back bottoms" behind the levees of the present river course near Huntly. Temporary damming of the Taupiri outlet of the basin by alluvium caused extensive lakes to form and there is evidence from the prevalent wave-cut platforms (which could only form on the shores of fairly large bodies of water) round many of the hills in the northern part of the basin that much of the basin floor north of Hamilton was covered by shallow water. The clearing of the obstruction in the gorge lowered the water level but a number of small lakes remained and it was around the shores of these that peat began to form and eventually gave rise to large peat bogs.

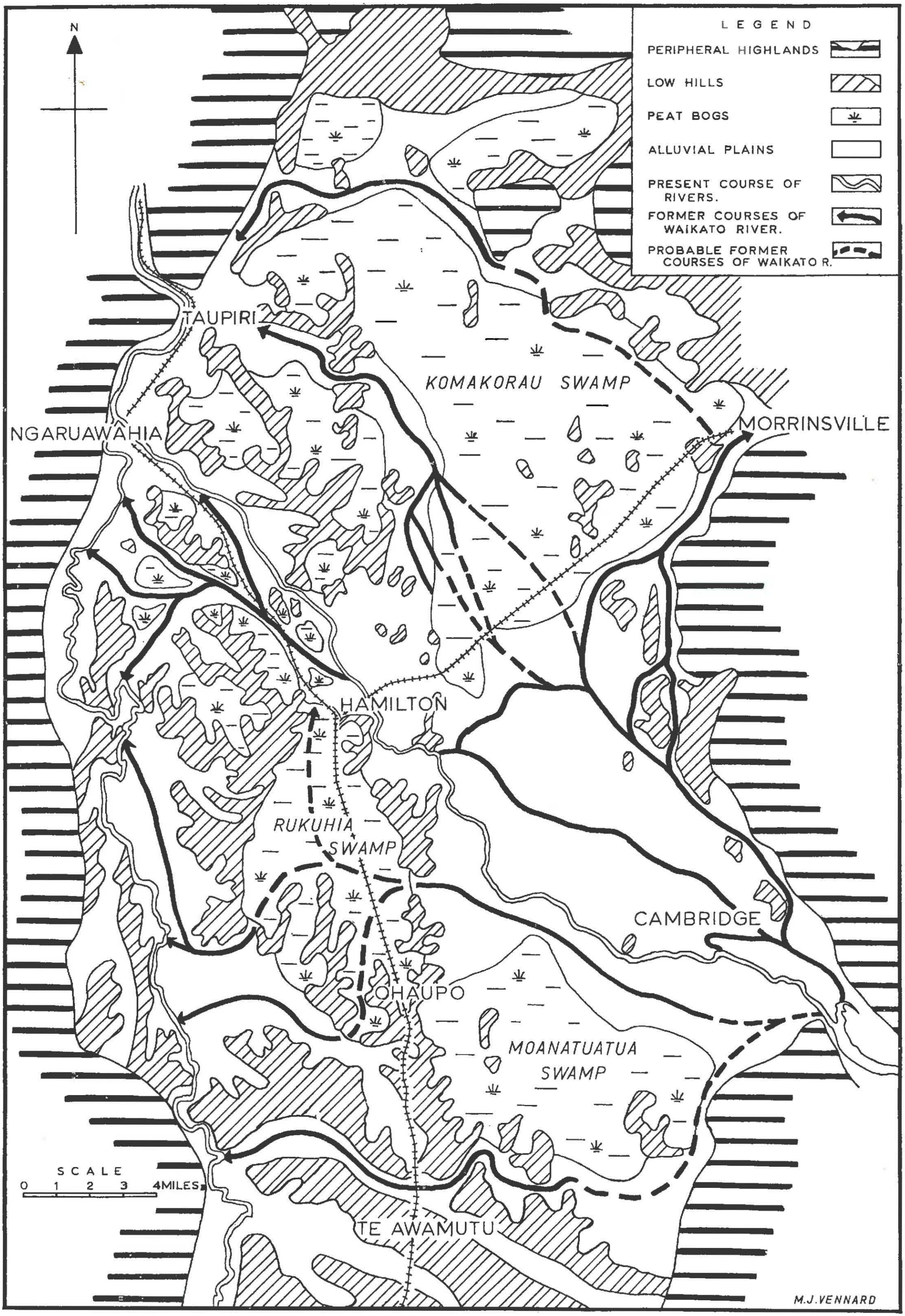

Figure 2: Map of Hamilton Basin showing generalised topography and old courses of the Waikato River.

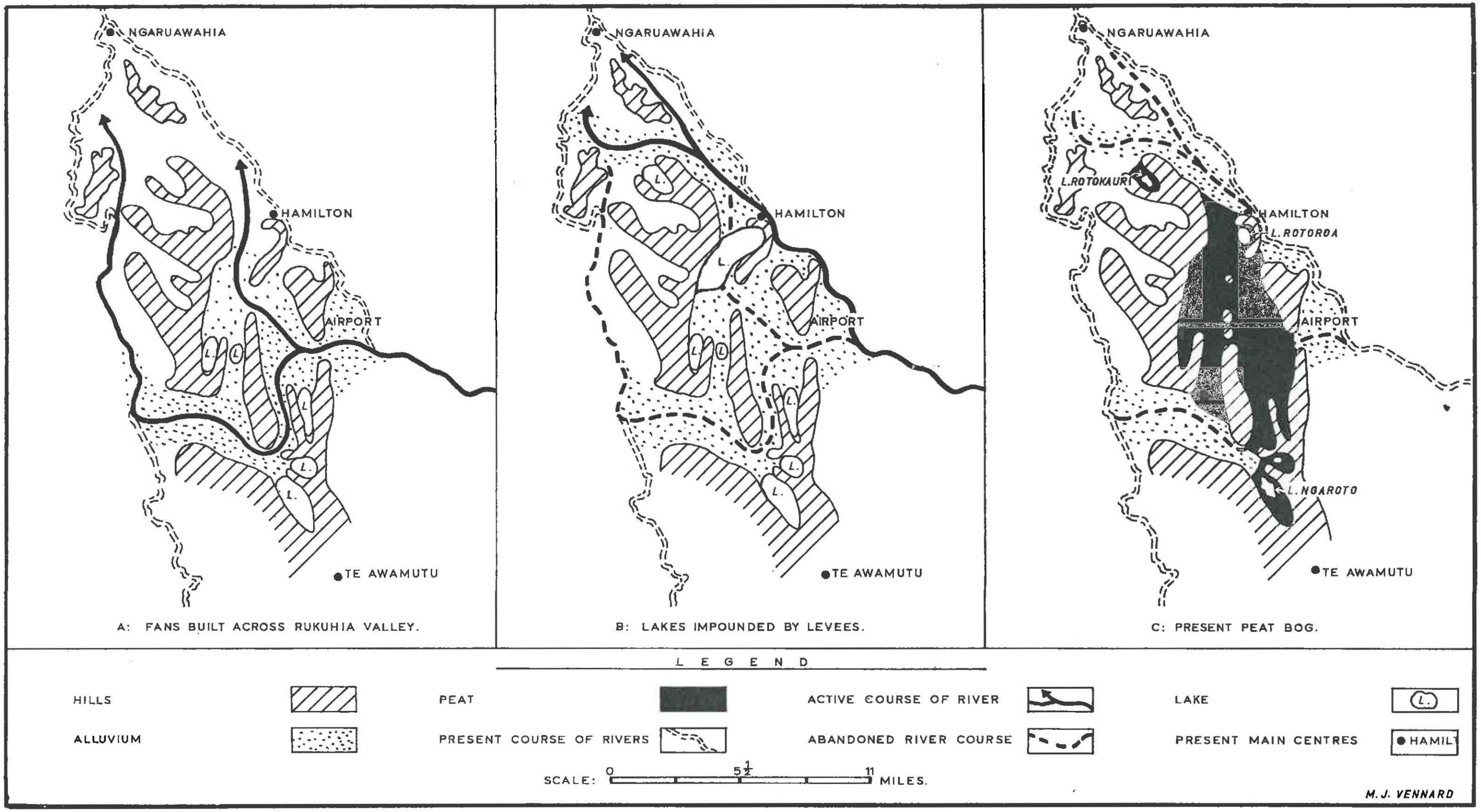

Figure 3: Possible stages in Development of Rukuhia Peat Bog.

Lakes and Peat Bogs. The lakes which gave rise to the peat bogs were formed by levee dams in two ways: (a) by damming embayments in the hills; (b) by trapping water against an older levee. Examples of the first type are the Hoe-o-Tainui bog which has developed in a lake formed in an embayment dammed by the levee of the Tauhei-Taupiri course, and the large Moana Tua Tua bog dammed by the Cambridge-Hamilton Airport course. An example of the second type is the Komakorau bog formed from a lake trapped between the Puketaha-Gordonton-Taupiri and the Tauhei-Taupiri courses. A second example is the Rukuhia bog which was initiated from a small lake formed between the levee of the course that flowed through what is now Hamilton Airport and went on to dam Lake Ngaroto and to join the present course of the Waipa River at Ngahinepouri, and the levee of the Hamilton-Te Kowhai course (Fig. 3).

The lakes in which peat started to form were probably small and shallow and as the peat filled them it grew out onto the surrounding country, sometimes spreading for a mile or more beyond the shore of the lake. Borings have shown that much of the shallow peat in the basin lies over a pattern of sediments similar to that of inter-distributary streams or in some places over old soils whereas the deep peats almost invariably lie over thin pumice silts of almost uniform thickness. It is suggested that these silts are lake floor deposits.

Dammed Valleys. Other features involving alluvial dams are widespread in the basin. Many of the small tributary valleys entering the basin from the surrounding ranges have been dammed by alluvium deposited by an old course of the Waikato River. A good example is the valley (through which runs Harbottle Rd.) south of Motumaoho (Fig. 4). The valley is about 3 miles long and half a mile wide and just inside the mouth is a sudden descent of about 20 ft. from the level of the Waikato fan to the floor of the valley. The valley floor is covered with a thin layer of fine alluvium which is partly from the Waikato River and partly of local origin. A small stream drains the valley by way of a gorge cut through the alluvial dam.

Other examples are plentiful but perhaps the most striking is the high dam blocking the mouth of the Kaniwhaniwha valley—the valley of a small stream entering the Waipa River (at this point occupying an old course of the Waikato River) between Pirongia and Whatawhata. The floor of the valley is about 30 ft. below the level of the Waipa River and is regularly flooded. Similar dams lie across the mouths of many of the valleys in the partly buried hills and ridges rising from the basin floor. Behind the dams are peat bogs or small lakes.

An interpretation of events giving rise to the dammed valleys is: during floods in the adjacent river course water backed up into the valley and, acting as a buffer to the river current, prevented all but suspended sediment from entering the valley. Coarse alluvium was deposited near the mouth of the valley where the swiftly flowing river met the relatively still water in the valley. As the alluvium at the valley mouth rose higher with successive floods a permanent lake formed in the valley and was left when the river changed course away from the valley. If the valley had sufficient catchment to support a stream the lake overflowed and a channel was cut through the dam and the lake drained leaving thin lake-floor sediments. If there were no stream, as with the hills in the centre of the basin, the lake remained (for example Lake Rotokauri) or was infilled with peat (particularly Whatawhata Road bog and many examples between Rototuna and Ngaruawahia).

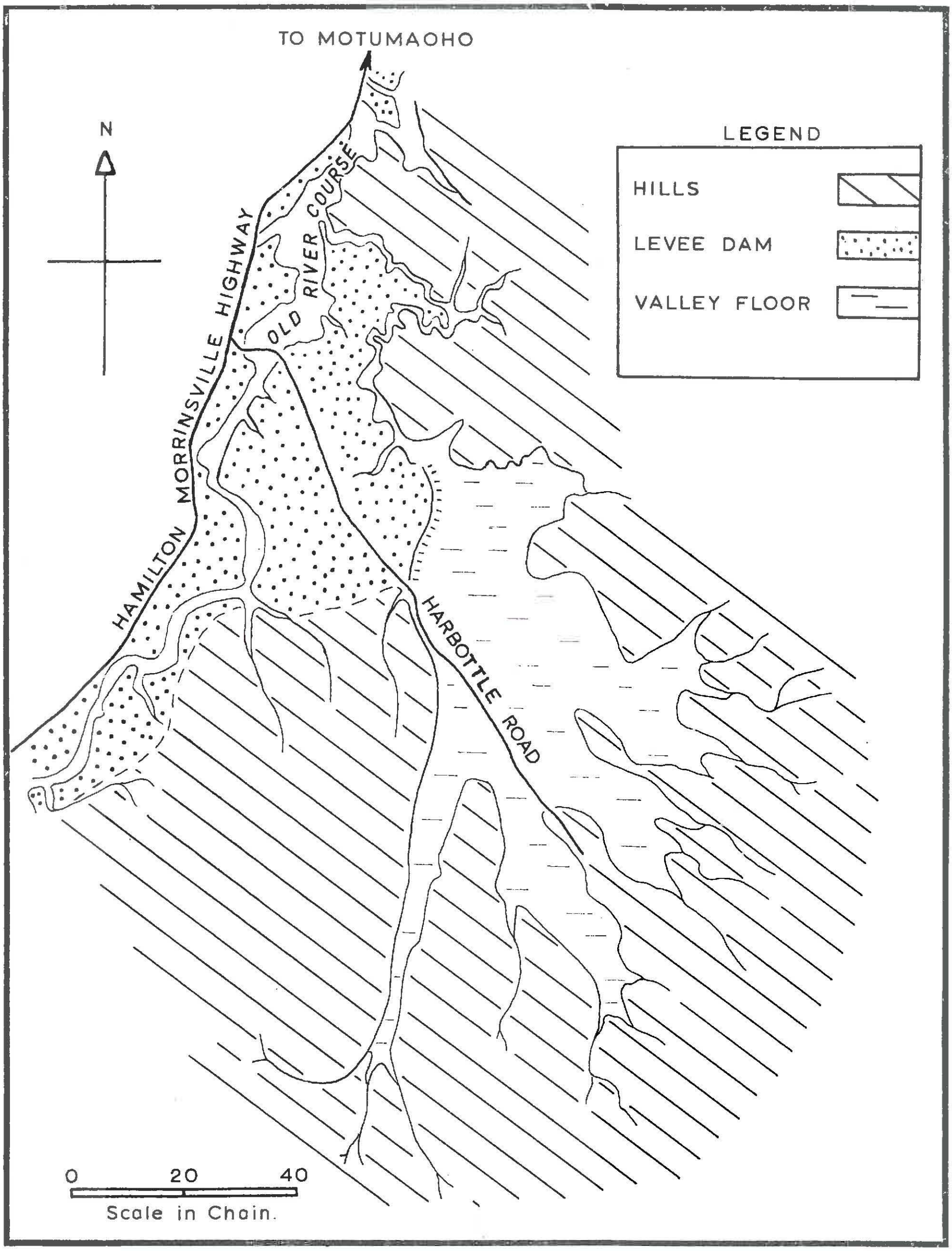

Figure 4: A dammed Valley south of Motumaoho.

The Interdistributary Stream Pattern. On the gentle, outer slopes of the levees, especially on the middle part of the fan, is a complex pattern of braided, closely spaced stream channels presumably formed when the river overtopped or broke through the levees in times of flood. These minor interdistributary stream channels are sometimes only a few feet wide and separated from each other by narrow, low ridges of gravel and sand. They are partly filled with white silts and fine sands derived from the breakdown of pumice, and assumed to be the last sediments to settle from retreating flood waters. The pumice sediments were, no doubt, re-sorted from the fan alluvium. This pattern of low ridges and swales is characteristic of the surface of the middle part of the Waikato fan and gives a "switchback" effect to many of the roads in the district.

When the Waikato River entrenched itself into its present course many insequent tributaries began to back rapidly into the fan forming narrow, steep-sided gullies. Most of these headed towards the peat bogs by a process of spring erosion. Evidence that many followed old stream channels is provided by the occurrence of wedge-shaped remnants of the pumice silts that floored the channels left on either side of the gullies (Fig. 5).

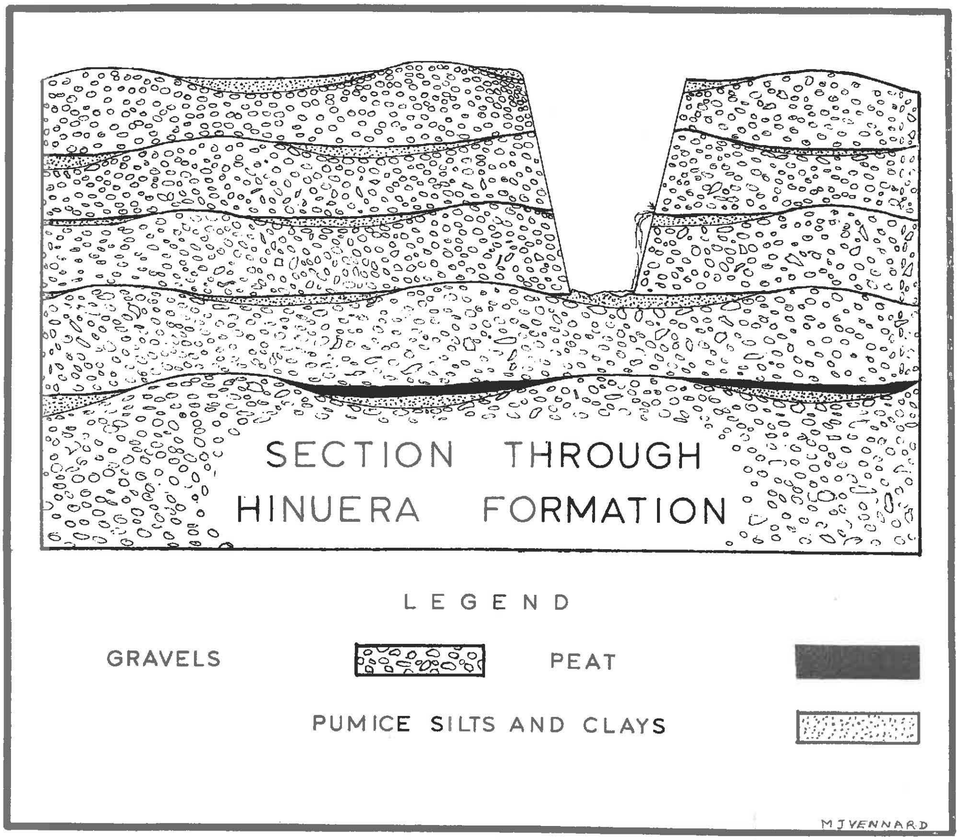

Figure 5 : Generalised cross-section through a stream channel that has been invaded by a more recent gully to show wedges of original channel bottom sediments, buried stream channels and peat.

Deep sections provided by these gullies in the middle part of the fan generally show several lenses of pumice silts, each a few feet thick, separated by layers of coarse sediments. These are stream channels that have been buried during the building of the fan. Sometimes a thin layer of peat above a buried lens shows that an appreciable time elapsed between the forming of the channel and its burial by a later flood. These buried peat layers occur at many places in the basin and at different depths. Whereas they may mark a major break in the fan building (Schofield, 1965) they could also mark much shorter breaks caused by changes in river courses.

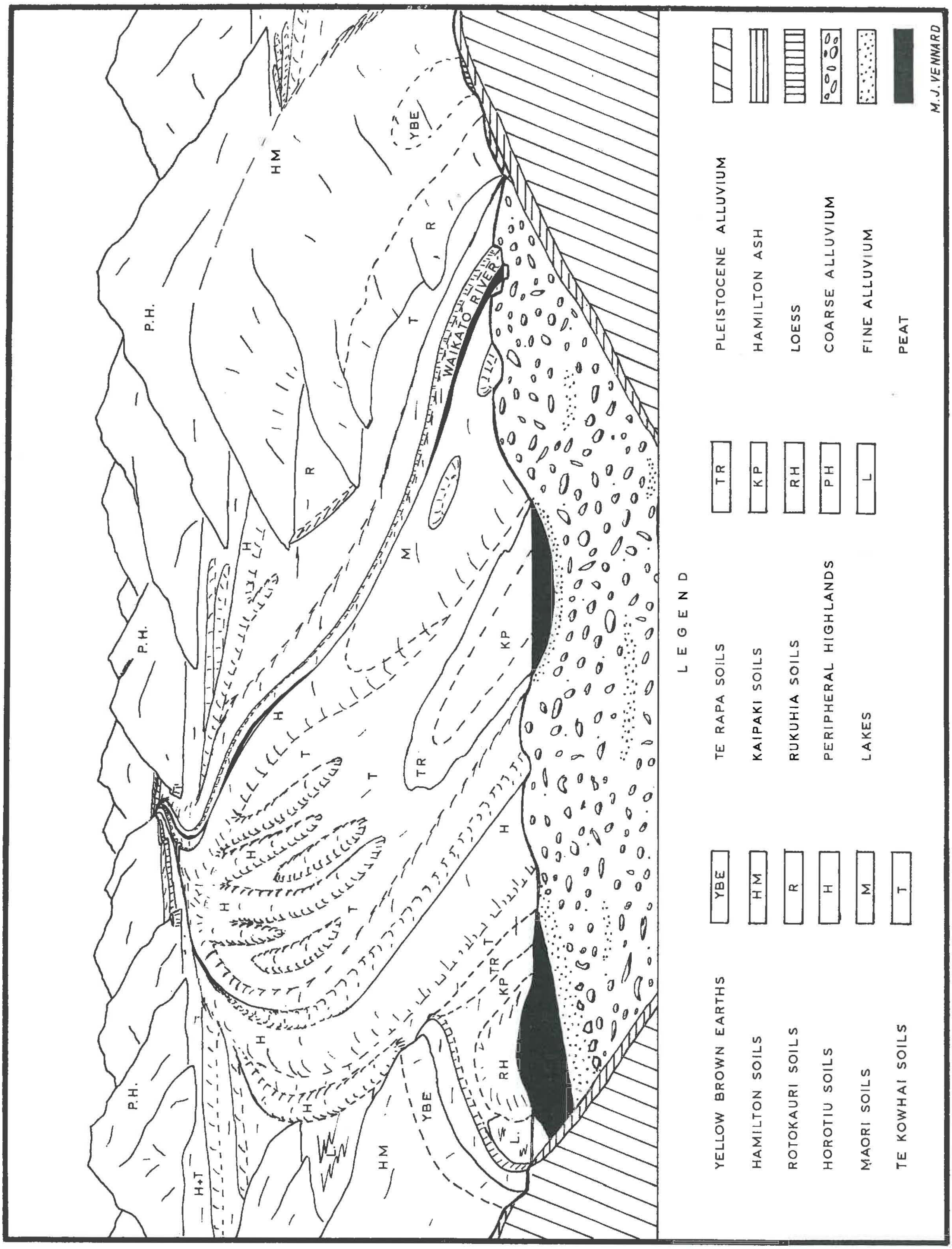

Figure 6 : Idealised sketch of part of Hamilton Basin to show relationship of topography, parent materials and soils.

The Waipa Alluvial Plain

The Waipa River, a less vigorous stream than the Waikato River, was dammed several times by alluvium deposited by changing courses of the latter river. Each time the Waipa River was ponded and sediment was deposited on the floor of the temporary lake. These tracts of lake sediments overlapped to form a more or less continuous alluvial plain stretching southwards from Ngaruawahia to beyond Whatawhata.

Perhaps the most spectacular damming took place at Te Kowhai where the Waikato River, after breaking through a gap in the low hills to the east built a large fan across the valley of the Waipa River. This created a lake in the Waipa River about 6 miles long and 2 miles wide. When the lake waters rose high enough they overflowed through a low saddle in the hills west of Whatawhata and into a tributary of the Waipa River. This has become the permanent course of the river.

The levees of the present course of the Waikato River dammed the Waipa River again at Ngaruawahia and sediment deposited in the resulting lake partly buried the fan formed by the earlier course.

The sediments deposited by the Waipa River in the lakes consist of silts and fine sands, several feet in thickness, derived from the erosion of the wide variety of rocks, including greywacke, volcanic rocks and Tertiary sediments, that occur in the catchment of the river.

Soils of the Plains

The soil pattern of the Waikato fan follows closely the parent material pattern. On the well drained low ridges separating the small stream channels, soils with brown, friable topsoils and very friable, weakly structured, yellow-brown subsoils with the characteristic greasy feel of high allophane content, predominate. These are the well-known Horotiu soils and are classed as yellow-brown loams, although as far as is known, there is no air fall ash in the parent material but there is undoubtly a content of alluvial ash. Horotiu soils range in texture from gravelly sands (on the highest parts of the levees) to silt loams.

Closely associated with Horotiu soils are Te Kowhai soils. These are developed on the fine textured pumice sediments of the fan toe and the swales. They have dark grey topsoils with well developed nutty structure and distinctive pale grey or almost white subsoils. It is now known that the very pale colours in the subsoils are not caused by the gley process but are the natural colours of the pumice parent material. Although the pumice sediments are of about the same age as the parent materials of the Horotiu soils it is evident that Te Kowhai soils are much less weathered. One possibility is that waterlogging has delayed weathering of the pumice. Accordingly the soils are classed as weakly developed gleyed yellow-brown pumice soils.

In some places where gullies, heading back from the Waikato River, have lowered water tables weathering of the pumice has speeded up and a range of soils intermediate between Horotiu and Te Kowhai soils is recognised.

Because of the complexity of the pattern of ridges and swales on the middle part of the Waikato fan it is only on the most detailed soil maps that the soils on these features can be separated.

On the levees of the present course of the Waikato River and on a few other well drained sites within a mile of the river are the soils used by the Maoris for kumara growing. From pits the Maoris excavated gravels and spread them in a thin layer over Horotiu soils. Manuka and other scrub was brought in and burnt and after cultivation with digging sticks a soil of suitable texture and fertility for kumara was obtained. The sites of these gardens are easily recognised by the presence of the conical holes about 15 ft. deep, these are particularly conspicuous on aerial photographs. The soil can be identified by the 9-10 in. layer of blackish gravelly sand, often containing fragments of charcoal, overlying an old topsoil. Most Maori soils overlie Horotiu soils as these provide good subsoil drainage and lie above gravels suitable for incorporating into the soils.

Three broad groups of organic soils are recognised:

(i) Te Rapa soils developed from shallow peats, probably originally high in inorganic matter, that had grown out over the land surrounding the large bogs. All of the peat has been humified and the soils have a high content of inorganic matter. They generally have less than 18 in. of peaty loam lying over old soils.

(ii) Kaipaki soils are developed on deeper low-moor peats generally in what was the shallow portions of the old lakes that gave rise to the peat bogs. Blackish loamy peat with well developed blocky structure up to 2-3 ft. deep may overlie peat. Logs and stumps of trees are not uncommon.

(iii) Rukuhia peat occurs on domed peat bogs and is mainly raw peat with little soil formation. It is extensive over the greater part of the large peat bogs.

One of the main difficulties in mapping peat soils is that their properties change rapidly under land development. Draining, burning and compaction cause peat to shrink and break down—organic matter disappears and inorganic matter becomes concentrated. Hence the depth of soil development, texture and other properties depend largely on how long the peatland has been under development and on the kind of treatment it has received. Thus a soil map of peatland based on the normal criteria used for separating soils is likely to become out of date through land development.

The soils formed on the lake deposited sediments of the Waipa River plain (Whatawhata soils) have heavy textures and slow internal drainage. They are subject to periodic waterlogging not from floods but from rain and seepage water and are classed as gley soils.

(c) THE RIVER TERRACES

A discontinuous terrace about 20 ft. above river level and up to 200 yards wide flanks the entrenched course of the Waikato River. The tread of the terrace is veneered with sediments of two kinds:

(a) Generally the part farthest from the river is covered with coarse pumice to a depth of about 6 ft. but in places where old meanders and stream channels have been filled it may reach a thickness of 30 ft. or more. The pumice blocked the mouths of the valleys of the numerous small tributary streams but all were able to cut through the dams except at Cambridge where a small lake is still impounded in a gully. The pumice was debris from the Taupo eruption of 130 A.D.

(b) Generally deposited nearer the river are current bedded sands and gravels derived from erosion of the Waikato fan alluvium.

The terrace is now above flood level.

SUMMARY OF INFORMATION ABOUT THE MOST EXTENSIVE SOILS OF HAMILTON BASIN

Name	Classification	Profile Characteristics	Parent Material and Topography
SOILS OF THE LOW HILLS			
Churchill soils	yellow-brown earth	yellowish-brown, massive, moderately friable subsoils	Pleistocene fine alluvium, red weathered in places, colluvium and wash from this alluvium; small patches on hills mainly in northern part of basin
Unnamed	yellow-brown earth	yellowish-brown, massive, friable subsoils	Silt more than 9 in. deep, probably loess; small patches on hills mainly in northern part of basin
Hamilton soils	brown granular loam	reddish-brown, strongly structured, friable subsoils	Hamilton ash, in places with thin mantle of loess or Mairoa ash; most extensive on hills near Hamilton, small patches on hills in northern part of basin
Rotokauri soils	gley soil	grey subsoils with rusty mottling and well developed prismatic structure	gently sloping apron of colluvium and wash from Hamilton ash and small amounts from Pleistocene alluvium
Ohaupo and Otorohanga soils	yellow-brown loams	topsoil: greyish-brown, weakly structured and very friable subsoil: yellowish-brown, weak structure; very friable, greasy feel	Mairoa ash on hills mainly south of Hamilton
SOILS OF THE PLAINS			
Horotiu soils	yellow-brown loam	topsoil: very friable, weak structure, brown subsoil: very friable, weak structure, yellowish-brown, greasy feel	alluvium (Hinuera Formation) containing ignimbrite, greywacke, andesite and ash; on apex of Waikato fan and on low ridges separating stream channels on middle part of fan
Unnamed	yellow-brown loam	topsoil: brown or brownish-grey, moderate structure, friable subsoil: yellowish-brown at top but grading down to white or very pale brown	pumice silts and sands; on middle and toe of Waikato fan on very low ridges intermediate in position between Horotiu and Te Kowhai soils

Te Kowhai soil	weakly developed gleyed yellow-brown pumice	topsoil: grey, moderate nutty structure, firm subsoil: white or pale grey, massive, mottling or concretions in upper part	pumice clays and silts, rarely sands; widespread on middle and toe of Waikato fan in stream channels and low lying sites
Te Rapa soil	peaty gley	6-18 in. peaty loam over pumice silts or sands or over Hinuera gravels, sometimes with buried soil	thin peat with large amounts of inwashed inorganic material; surface often hummocky; widespread around margins of large peat bogs
Kaipaki soil	organic soil	2-3 ft. of black loamy peat with well developed blocky structure over peat or loamy peat	low-moor peat with inwashed inorganic material; widespread on toe of fan and around domes on large peat bogs
Rukuhia peat	organic soil	up to 4 in. loamy peat over brown undecomposed peat	high-moor peat; on domes of large peat bogs
Whatawhata soil	gley soil	pale yellowish-grey subsoil with abundant mottles and concretions; moderately developed blocky structure	fine alluvium deposited in lakes by Waipa River, mainly detritus from volcanic rocks and Tertiary sediments; surface flat
Maori soil	man-made soil	blackish gravelly, loamy sand with charcoal over Horotiu soils, some over Waikato soils, rarely over Te Kowhai soils	topsoil of Horotiu soils plus added gravel and burnt vegetation; surface broken by scattered large pits; on levees of present river and on low ridges close to river
SOILS OF THE RIVER TERRACES			
Waikato soils	weakly developed yellow-brown pumice soil	2-3 in. dark-grey loamy sand over slightly stained, coarse pumice	Taupo pumice alluvium; on terrace of Waikato River, surface much broken by old stream channels
Waipa soils	recent soils	2-3 in. slightly humus stained sand on raw sand	Waipa River alluvium; 10 ft. terrace with frontal levee and swampy back bottom

Soils of the Terraces

Soils on the alluvial pumice have weaker soil development than those on air-fall pumice of the same age probably owing to the removal of fine material by water sorting. Nevertheless these soils (Waikato soils) are classed as weakly developed yellow-brown pumice soils. Soils on the sands and gravels are weakly developed yellow-brown loams.

A terrace about 10 ft. high flanks the lower reaches of the Waipa River and is covered with water in times of high flood. The alluvium contains little pumice but a large amount of detritus from the extensive deposits of Tertiary sediments in the catchment of the river. A narrow levee of sand fronts the river whereas the poorly drained "back bottom" is covered with clays and silts. Soils (Waipa soils) have very little profile development and are classed as recent soils.

ACKNOWLEDGMENTS

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