# A STUDY OF CERTAIN GENETIC SOIL TYPES OF

# THE SWAN RIVER AREA OF MANITOBA

A THESIS

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By

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# A STUDY OF CERTAIN GENETIC SOIL TYPES OF THE SWAN RIVER AREA OF MANITOBA

## I. INTRODUCTION:

In conducting a soil survey of the Swan River Area of Manitoba in 1950 and 1951 it was found that many of the dominant soil types presented a complex classification problem. The main reason for this problem was that the soils in two of the main landscape areas appeared to be in a state of transition and were not climax types of soil. In one area the soils showed certain morphological characteristics normally found only in soils developed under prairie-grassland conditions but where the dominant native vegetation was trees. The soils in this area showed some blackearth characteristics and some grey-wooded characteristics. The soils in the other landscape area appeared to resemble blackearths and yet, on closer inspection it became apparent that such factors as drainage and parent material may have had a profound influence on the type of soils that had developed within this area.

As the reconnaissance survey of the soils in the Swan River Area progressed it became obvious that a more detailed study was necessary before these soils could be properly understood and classified. Therefore the study herein reported was undertaken. The results have clarified the concept of the soils and enabled the author to offer a classification of some of the soils in the Swan River Area of Manitoba.

## II. LITERATURE REVIEW:

There is very little published information about the Swan River Area of Manitoba pertaining to its physical features such as soils, climate, geology and vegetation. A few of the early explorers did pass through this area and wrote down their impressions. Dawson (5) in 1859 makes references to this area and says, "On June 10, the time at which we passed, the trees were in full foliage and the prairie openings presented a vast expansive green sward." This is proof that at least one hundred years ago the vegetation was a mixture of woodland and prairie. In another account, which as far as can be determined, refers to the Upper Valley Plain, Dawson (5) states: "We pass through a beautiful country presenting an equal extent of woodland and prairie. As we proceed (up the valley) the openings become larger and the woods less frequent."

Tyrell (26) in 1887 referred to the area, now designated as the Lower Valley Plain as the "Great Meadows". Of this area he says: "They are wide stretches of rich, flat land, covered with a thick growth of long grass, separated by narrow irregular belts covered with willow, and small, sometimes large, poplars." This observation is in agreement with the fact that today the soils and vegetation in the Lower Valley Plain area show definite signs of having developed under conditions of poor drainage or meadow-land conditions.

In 1938 Ellis (11) wrote briefly on the Swan River Area and reported that in some places it appeared that deep blackearth soils had been invaded by woodland and have given place to degrading blackearth soils. This author (11) explains the term "degrading blackearth" as follows: "The degrading blackearths (or grey-blacks) are soils which were developed as blackearths with blackearth characteristics, but with the invasion of woods, the soil climate became more humid and the soil-forming processes became modified. Greyish blotches now appear in the dark portion of the soil profile and a somewhat heavier "B" horizon has developed, due to the increase in the percolation of water, and to the different feeding habits of the trees. In the heavier horizon, which develops below the surface horizon in this soil type, the granular structure gives place to a nutty structure and the lime tends to leach deeper in the profile."

Mitchell (19) states: "The term "degraded black" is used to describe a former grassland (black) soil that under the influence of later forest cover has developed some of the features of the podsols (forest) type of profile." He goes on to state also that, "The nature of the degraded black soils is determined largely by the relative length of time it has been under a tree cover, and the degree to which it has leached." These transitional soils in Saskatchewan show considerable variation; on the one hand the organic matter in the slightly degraded black soils is similar in content and distribution in the profile to that found in the blackearth soil, while on the other hand strongly degraded black soils bear a close resemblance to the grey-wooded soils especially in their low organic matter content and the presence of a leached "$A_2$" horizon.

Mitchell (19) also states that, "Where true black soils are found to occur under wooded cover, it is assumed that the tree invasion is of too recent occurrence to have caused leaching, or degradation of the grassland profile." This concept of degrading blackearths is also supported by Joffe (14) who quotes Ruprecht as explaining the occurrence of chernozem soils under forest vegetation by advancing the theory that forest had invaded the prairie region after the chernozem had been formed.

In most of the heavily forested areas of the Swan River Area a podzolic type of profile has developed and these soils have been called grey-wooded. According to Ellis (11): "The virgin (grey-wooded) soils (of Manitoba) are characterized by a leaf mat of forest litter, and a grey platy structured ash-like "$A_2$" horizon varying in thickness from 4 to 7 inches. Between the leaf mat and the "$A_2$" horizon, a grey-black crumbly "$A_1$" horizon may be present where the organic matter from the leaves has been mixed with the upper few inches of soil by organisms. In some cases the grey-black crumbly "$A_1$" horizon is absent. Below the ash-like "$A_2$" horizon a well developed nutty structured "B" horizon occurs. This is the zone of accumulation of clay and humus materials leached from the "A" horizon. Below the tough "B" horizon, which varies in color from reddish-brown to grey-black, there is also a zone of lime carbonate accumulation. This grades into the underlying parent material. ........ These soil characteristics indicate a more moist condition than is found in the black earth regions of Manitoba and that there is sufficient moisture to cause leaching of the upper part of the profile but not enough to cause leaching of the lime carbonate completely out of the profile."

According to Mitchell (20) and Ellis (11) meadow soils are commonly associated with flat depressional topography where surface and profile drainage conditions are very poor. These soils have a mucky surface horizon very high in organic matter. Another characteristic of meadow soils is the iron-stained sub-soil. Free lime carbonate may occur at or near the surface in these soils. The native vegetation consists largely of swale grasses and, as these meadows dry up or are drained, willow and poplar tend to invade the area.

The transitional or intergrade soils referred to above usually have rather complex profile patterns because more than one soil-forming process has been responsible for their development. These soils require considerable study in order to comprehend the operative processes. Marbut (18) concluded that field examination cannot supply all the data needed to determine the character of a weathering process or the extent to which the process has gone. The degree of weathering is measured by the amount of loss or shifting of constituents, while the character of the process is indicated by the constituents that have been made mobile.

Mitchell (21) cautions that the value of laboratory studies depends upon how well the samples obtained represent the soils under discussion. In a study of soil genesis and classification he states that field observations are of paramount importance.

## III. INVESTIGATIONAL PROCEDURE:

### A. Outline of Field Studies:

The field investigations were made by the author while working with the Manitoba Soil Survey when it carried out a reconnaissance soil survey of the Swan River Area in 1950 and 1951. The procedure employed by this type of survey involves making a traverse around every section. The primary objective of these traverses is to observe, to classify and to map the soils as they exist in the field. The secondary objective of the traverses is to note any feature of the landscape which has a direct or indirect influence on the soils occurring in that location. It was while engaged in this survey that the author was able to make the necessary field investigations and with the aid of the information secured by the survey, to map the distribution and location of the problem soils.

The field investigations involved; (a) observations of the area as a whole and (b) investigation of the soils within the respective landscape areas. Observations were made of the Swan River Area as a whole with respect to such features as; location and extent, surface geological deposits, relief, drainage, climate and native vegetation. The area was divided into natural landscape areas, each of which was then studied in greater detail. Notations were made of all features that appeared to have a direct or indirect influence on the soils developed within each landscape area.

The investigation of the soils in the field showed that marked differences in soils occurred between the different landscape areas. The soils in the Mountain Landscape Area are all mature grey-wooded soils and are easily classified. Nevertheless, one of these mature soils was selected for this study to show the degree of weathering which has occurred in a grey-wooded soil under forest conditions, and to provide a basis for comparison with the other less severely weathered soils which present problems in classification.

The soil selected from the Mountain Landscape Area was the well-drained member of the Duck Mountain soil association[1/]. This is a mature grey-wooded soil developed on glacial till.

In the Valley Landscape Area the soils of the Upper and Lower Plains differ greatly. On the Upper Valley Plain the soils are in a state of transition and there is evidence that a tree invasion is occurring where once prairie-grassland conditions prevailed. The degree of tree invasion and its influence on the soil profile varies considerably. Here, two soil associations were selected for study. The Crestview soil was selected from a part of the Upland Plain where tree invasion was complete and the soil showed definite signs of degradation. The Kenville soil was selected from a part of the Upland Plain where the tree invasion was more recent and the soils still retained characteristics peculiar to Blackearths.

In the Lower Valley Plain the dominant soils appear to have been influenced by poor or imperfect drainage conditions. The Valley soil was selected to represent this condition.

Representative profiles were selected for each of the aforementioned soils and a complete morphological description was made of each soil profile in the field. (See Pages 19-28). Suitable monoliths of the profiles were secured for laboratory studies.

B. <u>Outline of Laboratory Studies:</u>

Determinations were made which were designed to give information on the chemical constitution of the horizons of the soil profiles and the pedological processes responsible for their development. The determinations selected were:

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1/ Soil association names established by the Manitoba Soil Survey.

(a) Reaction;

(b) Total Exchange Capacity, Exchangeable Cations;

(c) Nitrogen;

(d) Organic Carbon and Organic Matter;

(e) Calcium Carbonate;

(f) Ammonium Tartrate Extractable Iron.

## IV. FIELD INVESTIGATIONS:

### A. General Description of Swan River Area:

#### 1. Location and Extent:

The area designated in this thesis as the Swan River Area of Manitoba includes all the land lying within Townships 32-38, Ranges 24-29, W 1 inclusive, except that which is in the Porcupine and Duck Mountain Forest Reserves. (See accompanying maps.)

This area embodies approximately 579,840 acres.

#### 2. Surface Geological Deposits:

According to Tyrell (26) the Swan River Area consists largely of a preglacial valley cut through the Cretaceous plateau of the Duck and Porcupine Mountains. The exact age of the valley is uncertain but Tyrell considers it may be of Pliocene Age. He states (26) that, "During the glacial period the valley was ascended by a lobe of the great glacier of the Winnipeg basin, and after retirement of this glacier most of the lower portion of the valley was occupied by a wide bay of Lake Agassiz, and is now generally covered with lacustrine or alluvial sands and clays."

When the glacier withdrew it left a relatively thin deposit of glacial till on the valley plain. However, since glaciation, a great deal of the till has been buried under deltaic and shallow lacustrine deposits.

Presumably most of these deltaic and shallow lacustrine deposits were carried in from the west by a large flow of water down the Swan River channel. The deltaic and lacustrine nature of the deposits is due to the fact that the area where the deposits now occur was inundated by Lake Agassiz at the time of their deposition. Although most of these deltaic deposits were carried in from the west, some of them are products of erosion from the neighboring mountains.

The former inundation of this area by Lake Agassiz is evidenced by the occurrence of numerous old lake beaches. In some places these beaches are quite distinct although not continuous.

Since the recession of Lake Agassiz, the topography of the deltaic deposits has been changed by erosion. In the Upper Valley Plain the deltaic deposits have been eroded by many stream channels until now the area has the form of a much bisected plain. The surface geological deposits found in the mountain areas consist largely of glacial till and modified shale clay drift deposits.

In the Lowlands Landscape Area the surface geological deposits consist mainly of glacial till modified by wave action. Considerable tracts of peat cover the glacial till in this region. (See Map No. 2.)

3. <u>Relief:</u>

The general relief of the Swan River Area is shown by the Contour Map.(See Map No. 1.) The lowest elevation is in the northeast portion of the area where it is 900 feet A.S.L. The valley plain rises gradually toward the southwest and at the Manitoba-Saskatchewan border (Range 30, W 1 ) the elevation is between 1300 and 1400 feet A.S.L. This gradual rise is interrupted in some places by the occurrence of an escarpment. This escarpment is especially noticeable in Township 35, Range 27 and Township 35, Range 28 and here serves as the dividing line between the Upper and Lower Valley Plains. The whole valley plain is about three miles wide at the Manitoba-Saskatchewan border (Range 30, W 1 ) and gradually broadens out to about twenty miles in width as the eastern limit of the Swan River Area is approached.

To the northwest the relatively smooth valley plain landscape grades into the steep slopes of Porcupine Mountain. The Porcupine Mountain rises up to over 2200 feet A.S.L. To the west, in Township 36 and 35, Range 29, the valley plain is interrupted by Thunder Hill. (See Figure No. 1.) To the southeast the valley plain grades into the relatively steep northern slopes of the Duck Mountain. To the northeast the land surface of the valley plain continues to flatten out and gives place to, or merges with, the Manitoba Lowlands.

4. <u>Drainage:</u>

The drainage generally is towards the northeast conforming with the general slope of the area. (See Map No. 2.) The Swan River and the Woody River constitute the two main drainage systems of the area. These two systems are separated by a height of land which is, in many places, a deposit of till extending from Thunder Hill northeastward across the area between the two rivers. The Swan River drains the larger part of the area as well as the run-off from the north slopes of Duck Mountain. The Woody River drains the northwest portion of the area and collects the run-off from the southern slopes of Porcupine Mountain. For the most part the drainage can be considered as good. However, as the lower elevations (1000 and 900 feet A.S.L.) are approached, surface drainage into the river channels is somewhat impeded and poor drainage conditions are common in the Lower Valley Plain.

5. <u>Climate and Vegetation:</u>

The meteorological data for the Swan River Area is very meagre and incomplete. Some data have been recorded at the town of Swan River which is situated in a more or less central location in the valley. These data have been well summarized by W.A. Ehrlich (10) as follows: "The precipitation records for twenty-four years show a variation in summer rainfall (April - October) ranging from a low of 5.7 inches in 1926 to 20.5 inches in 1901. These variations indicate that the area is subject to periodic dry periods as well as periods in which excess moisture conditions prevail. Only five years data on winter precipitation are available and their range for the months of November to March was 2.7 to 5 inches. The information on total annual rainfall at Swan River is incomplete and too uncertain to be reliable."

"The temperature records at Swan River indicate an annual mean of 32.8°F and a seasonal mean temperature for the summer months of 51.1°F (i.e. 23 years average for April to October inclusive)."

Although these meteorological data are incomplete it is significant that it indicates a wide range in precipitation between wet and dry seasons. It can be readily understood that if there was a period of approximately five years or more when the rainfall was well above normal it would have a definite effect on the native vegetation. In these periods of above average rainfall the woods start to invade and grow on what was formerly a grassland area. Once the trees have established themselves they tend to create a more humid climate. The deep ravines in the area naturally have a moister climate than the upland and it is here that a mature type of woods, both coniferous and deciduous, are found. It is from these ravines that the woodland invasion has come when the climate on the upland became favourable. (See Figure No. 2 and Figure No. 3.) The mountain areas also may be a source of tree invasion.

B. <u>Landscape Areas:</u>

The Swan River Area as a whole forms a number of natural landscape areas which have been designated as follows:

1. Mountain Landscape Area;

2. Valley Landscape Area;

3. Lowlands Landscape Area.

1. Mountain Landscape Areas:

(a) Porcupine Mountain:

The Porcupine Mountain is the most northerly section of the Manitoba Escarpment in this province. The striking characteristic of this mountain is that the eastern and southeastern slopes are steep. To the east the slopes fall quickly to the Manitoba Lowlands and, to the southeast they drop quickly to the Swan River section of the Manitoba Lowlands. To the west there is little drop in elevation but rather the mountains level out and merge with the till area of Saskatchewan. Only a very small portion of the Porcupine Mountain occurs in the area under discussion. This portion is designated on Map No. 3 as 1 (a).

The surface geological deposits (see Map No. 2) in the portion of the mountain surveyed consist almost entirely of glacial till of limestone origin together with some gravelly outwash. The general topography is quite rough and hilly, and the area is well provided with fast running streams that flow along the bottom of deep ravines.

There are no meteorological data but the vegetation and soils indicate a more humid climate here than in the Valley Landscape Area. There is a heavy forest type of vegetation which, in the well-drained areas, is made up largely of white poplar, black poplar, and white spruce; while in the poorly-drained depressions, which are swampy, the dominant species are black spruce and tamarack with an underbrush of alder and willow. The well-drained soils occurring here are of the grey-wooded type commonly associated with forest vegetation and humid climatic conditions in Manitoba.

(b) Duck Mountain:

The Duck Mountain also forms a part of the Manitoba Escarpment. The northern and eastern slopes are quite steep and drop quickly to the Lowlands Region of Manitoba. The portion designated on Map No. 3 as area 1(b) lies partly on the mountain itself and partly in the northern mountain slopes. The lower line of division for this area is along a crest that constitutes the lower escarpment of the mountains. For the most part the topography is quite rough, characterized by hills with steep slopes and numerous deep ravines. In some parts, as in Townships 33 and 32, Range 29, the mountain area is relatively smooth and rolling. The surface geological deposits (see Map No. 2) consist largely of glacial till. The till here is largely of limestone origin intermixed with shale clay. In the areas where the topography is relatively smooth, the surface deposits consist generally of shale clay. The origin of this shale clay has not been definitely established but it is quite probable that the shale clay is derived from local Cretaceous shale, the surface contact of which roughly coincides with the occurrence of the shale clay deposits delineated on the map. These shale clay deposits have been modified by glaciation and by subsequent erosion.

The climate of this landscape area, as reflected by a well-established forest of both coniferous and deciduous trees and by the grey-wooded soils, is quite similar to that of the Porcupine Mountain referred to above.

(c) Thunder Hill:

Thunder Hill is an outlier of the Porcupine Mountain which it closely resembles with respect to vegetative cover and soils. It is a striking topographic feature of the western end of the Upper Valley Plain of the Swan River Area. It rises abruptly from the Upper Valley Plain to a height of over 1800 feet A.S.L. (See Figure No. 1.)

According to Wickenden (25), Thunder Hill consists partially of large masses of Cretaceous shale that were picked up by the glaciers and deposited over a hard shale core. During transportation the shales were crumpled and folded. Over the surface of these shale deposits there is a thin layer of glacial till deposits which constitute the soil parent material.

Figure No. 1: Thunder Hill (background) rises abruptly from the Upper Valley Plain.

(d) Minitonas Hill:

The Minitonas Hill may be considered to be an outlier of the Duck Mountain. The conditions of relief, drainage, and climate described for the Duck Mountain area agree fairly well with conditions on Minitonas Hill. It is quite a prominent topographic feature of Township 35, Range 26, W 1. The western, northern and eastern slopes are quite steep but the south slope is more gradual and falls only a small amount before it rises again and grades into the rising slope of the Duck Mountain.

2. Valley Landscape Areas:

The Valley Landscape Area includes all the land in the Swan River Area lying below the Mountain Landscape Area with the exception of a small area designated as the Lowlands Landscape Area (see Map No. 3). The Valley Landscape Area for the most part constitutes a broad valley plain between the two mountains. This plain has two natural sub-divisions, namely;

(a) The Upper Valley Plain,

(b) The Lower Valley Plain.

The sub-division is based largely on marked differences in drainage conditions between the two areas. The Upper Valley Plain on the one hand is well drained because of the relief and numerous drainage channels while, on the other hand, the Lower Valley Plain is relatively flat and poor drainage conditions exist. The line of sub-division is well-defined in many places by a definite escarpment. (This escarpment is especially well-expressed in Township 35, Range 28 and Township 35, Range 27.) Where the escarpment is non-existent the division is based on apparent differences in drainage revealed by the soil profile and vegetation.

(a) The Upper Valley Plain:

The Upper Valley Plain takes in a major portion of the Swan River Area (see Map No. 3). It includes the lower slopes of the mountains and the upper plain into which these slopes blend. In some areas the mountain slopes tend to be somewhat irregular and complex as in Townships 37 and 36, Range 29. Nevertheless, the terrain still has the same characteristic downward slope towards the Lower Valley Plain.

The surface geological deposits consist largely of deltaic and shallow lacustrine deposits (see Map No. 2). However, there are some areas where glacial till is found at the surface and constitutes the soil parent material. These till areas were apparently so situated that they did not receive a deposition of deltaic and lacustrine deposits.

The general relief of this area is revealed by the Contour Map (No. 1). At the higher elevations of this area the slopes are fairly steep but soon flatten out into a gently sloping plain. This plain is especially broad and relatively level in the following townships: Township 34, Range 29; Township 34, Range 28; Township 35, Range 29; Township 35, Range 28. However, this broad plain has been cut into by numerous drainage channels and in many places it has the appearance of a much bisected plain.

Good drainage conditions are characteristic of this area. This is due to the numerous rivers and intermittent streams which traverse this landscape area. Most of these waterways are contained within deep ravines. The deep ravine channels were eroded soon after the recession of Lake Agassiz because most of the slopes are well stabilized and mature woods are found on well developed soils. (See Figure No. 2 and Figure No. 3.) The overall drainage picture would indicate that, for the most part, this Upper Valley Plain has always had good drainage conditions.

There are no meteorological data which reveal the climatic dondi-tions that have existed in this area. However, in view of the fact that the climate of any area is always reflected in the vegetation and soil profile, a critical observation of these natural features will give some indication of the past and present climatic conditions. Two observations that were made indicate that prairie-grassland climate conditions had existed over most of the Upper Valley Plain. These observations were:-

(1) Small areas of virgin prairie are still found in some places.

(2) The type of soil profile found in many places here bears a close resemblance to soil profiles developed in the prairie-grassland region of Manitoba. However, at the present time the native vegetation found in many of the virgin areas of the Upper Valley Plain consists largely of a mature type of deciduous woods. This would indicate that the climate has become more humid and suitable for tree growth on the upland plain.

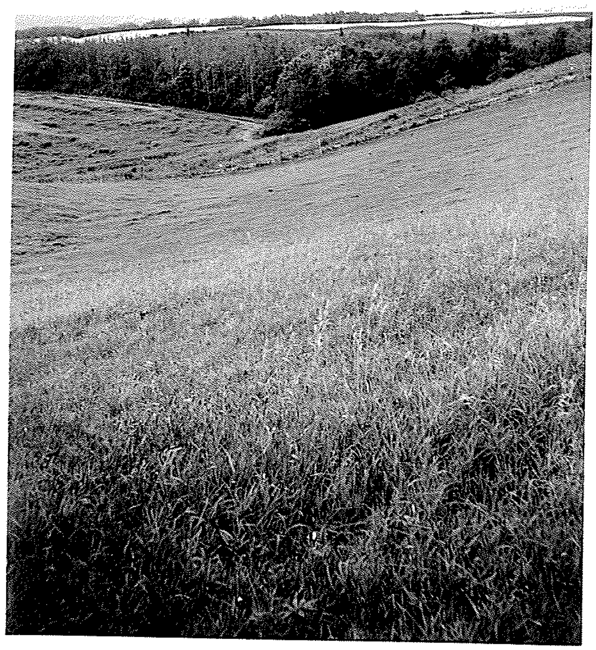


Figure No. 2: Showing the deep wooded ravines in the Upper Valley Plain.

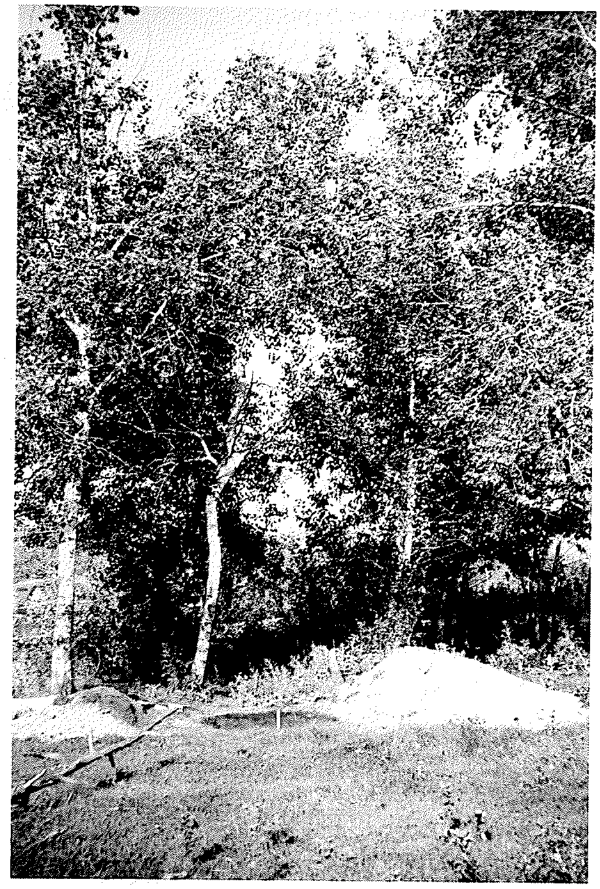


Figure No. 3: Showing the type of vegetation on the Upper Valley Plain where the Kenville No. 1 profile was secured.

(b) Lower Valley Plain:

This is the lower portion of the Swan River Valley Plain (see Map No. 3).

The surface geological deposits are made up largely of deltaic and shallow lacustrine deposits (see Map No. 2). There are a few areas of glacial till exposed and apparently these were of sufficient elevation, or in such a position, so as not to receive a deposition of deltaic and lacustrine material.

The contours, as drawn on Map No. 1, show plainly that this is an area which is relatively level with only a gentle slope towards the north-east. The surface drainage in general in this area has been impeded in spite of the fact that the main drainage channel of the Swan River Area, (namely, the Swan River itself) traverses this area. This condition of poor drainage has been due to the relatively flat land surface combined with the damming effect that the natural river levees have had on preventing water drainage into the river. These impeded drainage conditions existed prior to 1900, but since that time drainage has been altered somewhat as a result of artificial drainage and cultivation of the land. The drainage ditches have been cut through the river levees thereby reducing the damming effect.

In so far as the soil climate in this area is concerned, the present indications are that a humid condition has prevailed. The evidence of this is indicated by the following:

(1) In most places where virgin conditions still exist, a large amount of muck and partially decomposed peat occur in the smooth undrained areas.

(2) The soil in many places still effervesces with acid at the surface indicating free lime carbonate. The presence of free lime carbonate can be attributed to the capillary rise of ground water associated with poor drainage conditions.

Very little of the native vegetation now remains on the smooth plains between the rivers because of the extensive cultivation but, where it does exist it consists of white and black poplar together with an undergrowth of willow and hazel shrubs. Some of this tree vegetation has come into the area subsequent to the improvement in drainage because a poorly drained area, which may be swamped at times, is not the normal growth site for white poplar.

The fact that this area was poorly drained meadow land at one time agrees with the observations made by Tyrell (26) in 1887.

3. Lowlands Landscape Area:

The Lowlands Landscape Area is a small portion of the Lowlands Region of Manitoba. The surface geological deposits consist almost entirely of calcareous, lake-washed glacial till, on which a complex of rendzina, degraded rendzina, meadow and bog soils have developed. These are well recognized soil types and, from a classification standpoint, do not present the same problems as the soils of the Upper and Lower Valley Landscape Areas. Consequently, this thesis does not involve a detailed study of the soils in this area and is mentioned only because it is on the same map sheet.

C. Soils (Morphological Descriptions):

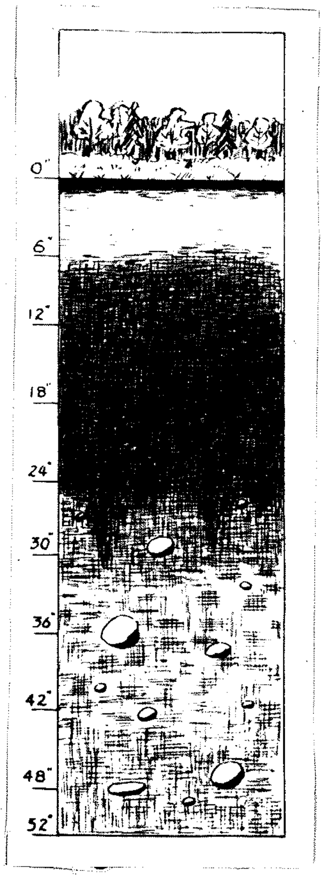
The representative soil profiles were described as they existed in the field. Each horizon was described as to color, texture, structure, consistence, intrusions, concretions, and reaction. In addition notations were made on the nature of the soil parent material, topography, stoniness, drainage, and vegetation.

Pen sketches of the respective soil profiles selected for the analytical studies, together with descriptive notations, are presented on Pages 20 to 28.

Duck Mountain Phytomorphic Associate:

Location: North centre of N.E. $\frac{1}{4}$ 11-33-29 W 1.

Condition: Moist.




| | | |
|---|---|---|
| $A_0$ | $0-1\frac{1}{2}$" | Leaf and sod mat fairly well decomposed; black to brown, 10 YR 2/1 - 10 YR 5/3* (10 YR 2/1 - 10 YR 5/3). Neutral in reaction. |
| $A_2$ | $1\frac{1}{2}-7$" | Fine sandy loam; greyish brown, 10 YR 5/2 (light grey, 10 YR 7/2). Well-Developed platy structure. Slightly acid in reaction. |
| $A_3$ | 7-12" | Clay loam; greyish brown, 10 YR 5/2 (light grey, 10 YR 7/2). Fine nuciform structure showing definite signs of degradation. Acid in reaction. |
| $B_1$ | 12-16" | Heavy clay loam to clay; greyish brown, 10 YR 4/2 (light grey (10 YR 7/2). Structure is fine nuciform, the aggregates are quite stable and do not adhere to one another. Plastic when moist. Acid in reaction. |
| $B_2$ | 16-23" | Clay; dark greyish brown, 10 YR 3/2 (greyish brown, 10 YR 4/2). Structure is medium to coarsely nuciform with columnar macro-structure. Firm,hard consistence when dry, and plastic when wet. Acid in reaction. |
| $B_3$ | 23-32" | Clay to heavy clay loam; brown 10 YR 4/3 (light brownish grey, 10 YR 6/2). Fine to medium nuciform structure, the aggregates are neutral on the outside but effervesce inside. |
| C | 32-52" | (Sampled by 4 inch depths). Clay loam to heavy clay loam glacial till; yellowish brown, 2.5 Y 5/4 (light brownish grey, 2.5 Y 6/2). Fine granular micro-structure and massive macro-structure. Effervesces strongly. |

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* Munsell color notation of moist soil; color of dry soil enclosed in brackets.

Duck Mountain Phytomorphic Associate (Continued):

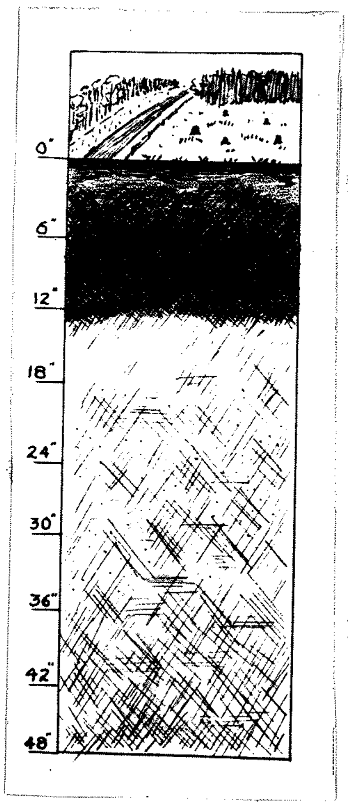
| | |
|---|---|
| Soil Parent Material: | Shale and limestone boulder till. |
| Stone: | Moderately stony. |
| Topography: | Complex, irregular gently sloping to irregular moderately sloping. |
| Vegetation: | White poplar, spruce, alder, willow, rosebush, chokecherry, vetch, strawberry, sow thistle, golden rod, etc. |

Crestview Phytomorphic Associate Profile No. 1:

Location: Centre east side, 29-36-29 W 1.

Condition: Moist.

$A_0$ 0-1" Well decomposed organic matter; black, 10 YR 2/1 (black, 10 YR 2/1). Alkaline in reaction.




$A_2$ 1-4½" Fine to very fine sandy loam; greyish brown, 10 YR 4/3 (light brown grey, 10 YR 6/2). Structure is weakly platy to single-grained. Slightly acid in reaction.

$B_1$ 4½-7" Clay loam; very dark brown, 10 YR 2/2 (very dark grey, 10 YR 3/1). Fine granular structure, plastic when moist and quite friable when dry. Acid in reaction.

$B_2$ 7-11½" Fine sandy clay loam; dark greyish brown, 10 YR 3/2 (brown, 10 YR 5/3). Columnar macro-structure breaks down readily into medium nuciform structure. Acid in reaction.

B3 11½-13" Clay loam to heavy clay loam; very dark brown, 10 YR 2/2 (dark greyish brown, 10 YR 3/2). Blocky structure breaks down readily into medium granular structure. Plastic when moist. Alkaline in reaction.

Ca 13-15" Fine sandy clay loam; dark yellowish brown 10 YR 4/4 (light yellowish brown, 10 YR 6/4). Weak fine granular structure. Effervesces strongly.

C 15-24" Silt loam to silty clay loam; yellowish brown, 10 YR 5/4 (light grey 10 YR 7/2). Crumb structure and quite friable when dry. Effervesces strongly.

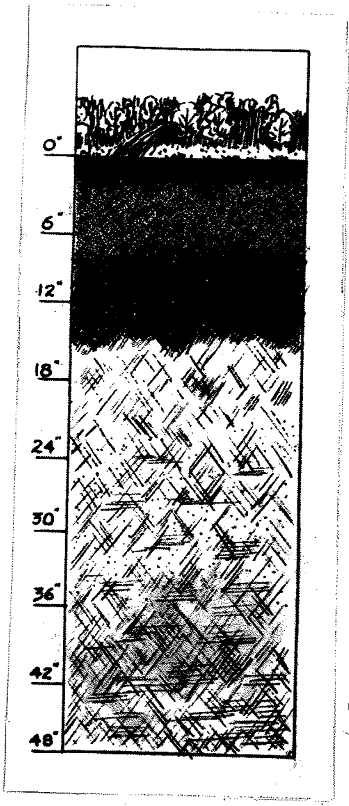
Crestview Phytomorphic Associate Profile No. 1 (Continued):

| | |
|---|---|
| Soil Parent Material: | Deltaic and shallow lacustrine deposit. |
| Stone: | None. |
| Drainage: | Well drained. |
| Topography: | Smooth very gently sloping. |
| Intrusions: | Rodent burrows. |
| Vegetation: | White poplar, black poplar, pincherry, saskatoon, high-bush cranberry, chokecherry. |

Crestview Phytomorphic Associate Profile No. 2:

Location: West centre of N.W. ¼ 28-36-29 W 1.

Condition: Moist.




$A_0$ 0-2½" Partially decomposed leaf mat; reddish brown to dark grey, 5 YR 4/4 - 5 YR 4/1 (reddish brown to dark grey, 5 YR 4/4 - 5 YR 4/1).

$A_2$ 2½-9" Mucky very fine sandy loam; dark grey, 10 YR 4/1 (grey, 10 YR 5/1). Finely granular structure. Friable when dry. Acid in reaction.

B 9-15" Heavy clay loam, dark greyish brown, 10 YR 3/2 (brown, 10 YR 4/2). Very weakly columnar macro-structure and medium nuciform micro-structure. Acid in reaction.

Ca 15-20" Very fine sandy loam to silty loam; light yellowish brown, 2.5 Y 6/4 (pale yellow, 2.5 Y 7/4). Quite friable. Effervesces strongly.

$C_1$ 20-24" Silty clay loam to very fine sandy loam, olive yellow, 2.5 Y 6/6 (pale yellow, 2.5 Y 7/4). Quite friable. Effervesces strongly.

$C_2$ 24-44" Sub-soil sampled at 4" depths from 24-44". Silty clay loam to very fine sandy loam, olive yellow, 2.5 Y 6/6 (pale yellow, 2.5 Y 7/4). Quite friable. Effervesces strongly.

Soil Parent Material: Deltaic deposit.

Topography: Smooth to very gently sloping.

Stone: None.

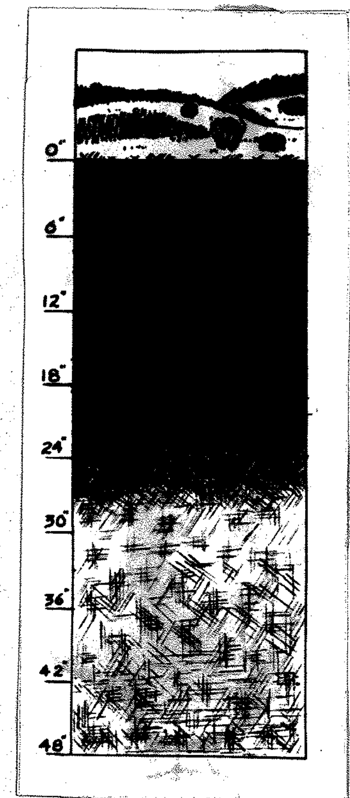
Drainage: Well drained.

Vegetation: White poplar, willow, dogwood, berry bushes, strawberry, vetch, etc.

Kenville Phytomorphic Associate Profile No. 1:

Location: North centre N.W. $\frac{1}{4}$ 23-36-26 W 1.

Condition: Dry to slightly moist.




| | | |
|---|---|---|
| $A_0$ | 0-1" | Leaf and sod mat; very dark brown, 10 YR 2/2 (very dark brown, 10 YR 2/2). Slightly alkaline in reaction. |
| $A_1$ | 1-2" | Mucky loam; black, 10 YR 2/1 (black, 10 YR 2/1). Slightly alkaline in reaction. |
| $A_2$ | 2-5½" | Clay loam; very dark grey, 10 YR 3/1 (dark grey, 10 YR 4/1). Structure is slightly platy to medium granular. Quite friable when dry. Acid in reaction. |
| $B_1$ | 5½-11" | Silty clay to silty clay loam; dark greyish brown, 10 YR 3/2 (greyish brown, 10 YR 5/2). Finely nuciform structure. Acid in reaction. |
| $B_2$ | 11-24" | Silty clay loam to heavy clay loam; (dark greyish brown, 10 YR 3/2). Columnar macro-structure. The columns break readily in the horizontal plane to form cubical structures and break down finally to a medium nuciform structure. The aggregates are a darker color on the outside than on the inside. Slightly acid in reaction. |
| $B_3$ | 24-27" | Silty clay loam; greyish brown, 2.5 Y 4/2 (light greyish brown, 2.5 Y 6/2). Weak nuciform structure. Effervesces. |
| Ca | 27-33" | Calcareous clay loam; brown 10 YR 5/3 (pale brown, 10 YR 6/2). Effervesces strongly. |
| $C_1$ | 33"+ | Silty clay loam to clay loam; light yellowish brown, 2.5 Y 6/4 (pale yellow, 2.5 Y 8/4). Laminated macro-structure, breaks down to single-grained structure when dry. Moderately plastic and sticky when moist. Effervesces strongly. |

Kenville Phytomorphic Associate Profile No. 1 (Continued):

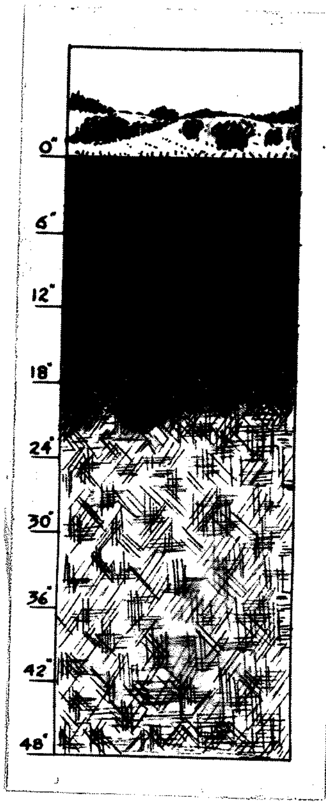
| | |
|---|---|
| Soil Parent Material: | Deltaic deposit. |
| Stone: | None. |
| Drainage: | Well drained. |
| Topography: | Gently sloping. |
| Vegetation: | White poplar, black poplar, few spruce, hawthorn, cherry bushes, blue grass, pigweed, etc. |

**Kenville Phytomorphic Associate Profile No. 2:**

Location: North centre 22-35-28 W 1 .

Condition: Moist.

$A_o$ 0-1" Partially decomposed leaves and roots; very dark brown, 10 YR 2/2 (very dark brown, 10 YR 2/2). Loose and mull-like. Alkaline in reaction.




A 1-8½" Clay loam; black, 10 YR 2/1 (black, 10 YR 2/1). Fine to medium granular structure. (This horizon varies from 4-26" in depth.) Acid in reaction.

$B_1$ 8½-11½" Heavy clay loam; black, 10 YR 2/1 (dark greyish brown, 10 YR 3/1). Finely nuciform structure, quite friable when dry and plastic when moist. Strongly acid in reaction.

$B_2$ 11½-16" Heavy clay loam; very dark brown, 10 YR 2/2 (very dark brown, 10 YR 2/2). Columnar macro-structure which breaks down readily into medium nuciform structure. Aggregates are coated on the outside. Acid in reaction.

$B_3$ 16-20" Clay loam; greyish brown, 10 YR 4/2 (light brownish grey, 10 YR 6/2). In this horizon the organic colloids have moved down into the calcareous parent material through cracks and root channels. The coating of organic colloids is neutral but the soil effervesces under the coating.

Ca 20-52" Clay loam to very fine sandy clay loam; yellowish brown, 10 YR 5/4 (very pale brown, 10 YR 7/3 to light grey, 10 YR 7/2). Quite friable when dry. Effervesces strongly. (The parent material was sampled by four-inch depth for analysis.)

Soil Parent Material: Deltaic and shallow lacustrine deposits.

Stone : None.

Topography: Irregular, very gently sloping.

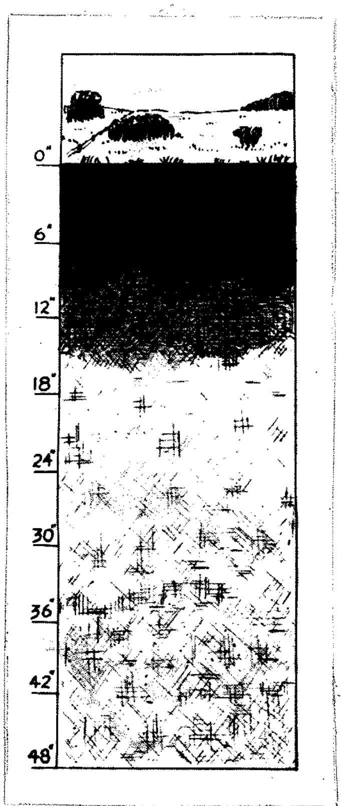
Drainage: Well drained.

Vegetation: White poplar, black poplar, willow, rosebush, hawthorn, blue grass, etc.

Valley Phyto-Phytohydromorphic Associate:

Location: 0.4 miles North of Southwest corner 13-37-27 W 1 .

Condition: Moist.




$A_{00}$ 0-1" Partially decomposed organic matter. Very dark brown, 10 YR 2/2 (very dark brown, 10 YR 2/2). Acid in reaction.

$A_0$ 1-3½" Decomposed organic matter. Black, 10 YR 2/1 (black, 10 YR 2/1). Acid in reaction.

$A_{1_1}$ 3½-6½" Clay loam. Black, 10 YR 2/1 (very dark grey, 10 YR 3/1). Cloddy macro-structure and medium granular micro-structure. Acid in reaction.

$A_{1_2}$ 6½-15" Clay loam. Very dark grey, 10 YR 3/1 (very dark grey to dark grey, 10 YR 3/1 - 10 YR 4/1). Medium to fine granular. Effervesces moderately.

$C_1$ 15-24" Clay loam. Yellowish brown, 2.5 Y 5/4 (light grey, 2.5 Y 7/2). Quite friable. Effervesces strongly.

$C_2$ 24-32" Clay loam. Greyish brown, 2.5 Y 5/2 (light grey 2.5 Y 7/2). Plastic when moist and quite friable when dry. Effervesces strongly.

Soil Parent Material: Deltaic and shallow lacustrine deposits.

Stone: None.

Drainage: Well to imperfectly drained.

Topography: Very gently sloping.

Vegetation: White poplar, black poplar, willow, raspberry, snowberry, sow thistle, aster, blue grass, etc.

# V. LABORATORY INVESTIGATIONS:

## A. Reaction:

### 1. Method:

The reaction or pH values were determined by the use of a Model 3 Electrometer (Coleman) equipped with glass electrodes after the procedure of Doughty (8).

### 2. Results:

The results are recorded in Table No. 1.

### 3. Discussion:

The data show marked differences in reaction in the soils studied. The reactions of the "$A_o$" horizons were all close to neutrality except in the Valley profile where the "$A_{oo}$" and "$A_o$" were definitely acid in reaction. The "$A_2$" horizons were all acid in reaction. Also the "$B_1$" and "$B_2$" horizons were acid in reaction in all cases. Where present, the "$B_3$" horizon was alkaline in reaction. The same was true of the "Ca" and "C" horizons.

On the basis of the thickness of acid soil and average pH, the Duck Mountain soil profile has been affected most by the processes of degradation and decalcification. (See Table No. 2.) The Crestview and Kenville profiles were intermediate in this respect; while the Valley soil has been the least affected by degradation.

TABLE NO. 1

REACTION (pH) OF SOIL HORIZONS STUDIED AS DETERMINED BY GLASS ELECTRODE METHOD.

| Duck Mountain Soil Profile | | | Crestview Soil Profile No. 1 | | | Crestview Soil Profile No. 2 | | | Kenville Soil Profile No. 1 | | | Kenville Soil Profile No. 2 | | | Valley Soil Profile | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Horizon | Depth | pH | Horizon | Depth | pH | Horizon | Depth | pH | Horizon | Depth | pH | Horizon | Depth | pH | Horizon | Depth | pH |
| $A_o$ | 0-1½" | 7.00 | $A_o$ | 0-1" | 7.35 | $A_o$ | 0-2½" | 6.80 | $A_o$ | 0-1" | 7.40 | $A_o$ | 0-1" | 7.50 | $A_{oo}$ | 0-1" | 6.50 |
| $A_2$ | 1½-7" | 6.05 | $A_2$ | 1-4½" | 6.50 | $A_2$ | 2½-9" | 6.20 | $A_1$ | 1-2" | 7.40 | A | 1-8½" | 6.35 | $A_o$ | 1-3½" | 5.78 |
| $A_3$ | 7-12" | 6.15 | $B_1$ | 4½-7" | 6.00 | B | 9-15" | 6.32 | $A_2$ | 2-5½" | 6.25 | $B_1$ | 8½-11½" | 5.65 | $A_{11}$ | 3½-6½" | 6.29 |
| $B_1$ | 12-16" | 5.85 | $B_2$ | 7-11½" | 6.00 | Ca | 15-20" | 7.90 | $B_1$ | 5½-11" | 6.50 | $B_2$ | 11½-16" | 6.10 | $A_{12}$ | 6½-15" | 7.73 |
| $B_2$ | 16-23" | 5.70 | $B_3$ | 11½-13" | 7.60 | C | 20-24" | 7.90 | $B_2$ | 11-24" | 6.70 | $B_3$ | 16-20" | 8.00 | $C_1$ | 15-24" | 8.15 |
| $B_3$ | 23-32" | 7.75 | Ca | 13-15" | 8.00 | | 24-28" | 8.00 | $B_3$ | 24-27" | 7.60 | C | 20-24" | 7.95 | $C_2$ | 24-32" | 8.15 |
| C | 32-36" | 7.70 | C | 15-24" | 8.00 | | 28-32" | 8.00 | Ca | 27-33" | 7.70 | | 24-28" | 8.00 | | | |
| | 36-40" | 7.80 | | | | | 32-36" | 8.00 | C | 33"+ | 7.70 | | 28-32" | 8.50 | | | |
| | 40-44" | 7.85 | | | | | 36-40" | 8.00 | | | | | 32-36" | 8.00 | | | |
| | 44-48" | 7.85 | | | | | | | | | | | | | | | |
| | | | | | | | 40-44" | 8.00 | | | | | 36-40" | 8.00 | | | |
| | 48-52" | 7.95 | | | | | | | | | | | | | | | |
| | | | | | | | | | | | | | 40-46" | 8.00 | | | |
| | | | | | | | | | | | | | 46-52" | 8.00 | | | |

TABLE NO. 2

The Thickness and Average pH of the Acid Soil Horizons.

| Soil | Total Thickness Of Acid Horizons | Average pH of Acid Horizons |
|---|---|---|
| Duck Mountain Soil Profile | 21.5" | 5.94 |
| Crestview Soil Profile No. 1 | 10.5" | 6.17 |
| Crestview Soil Profile No. 2 | 15.0" | 6.44 |
| Kenville Soil Profile No. 1 | 22.0" | 6.48 |
| Kenville Soil Profile No. 2 | 15.0" | 6.03 |
| Valley Soil Profile | 6.5" | 6.19 |

B. Total Exchange Capacity, Exchangeable Cations and Base Status:

The object of conducting exchangeable cation studies was to ascertain what cations were present in the exchange complexes and the proportion in which the various cations occurred in each of the respective soil horizons. These studies were carried out only on those horizons which were relatively free of calcium carbonate. The results and discussions on cation exchange studies by such investigators as Kelly (15), Barr (2), Caldwell (4), and Kelly (16), indicate that where soluble salts and / or free lime carbonate are present, it is difficult to differentiate between the cations which are adsorbed on the exchange complex and those which come from salts brought into solution during the leaching process. Hence, only those horizons that did not effervesce when treated with cold, 6 N hydrochloric acid were considered to be sufficiently low in free lime carbonate to warrant a study of their cation exchange properties.

1. Method:

The method used to determine the total cation exchange capacity was a modification of methods used by Barr (2) and Barshad (3). The soil was first leached with neutral N ammonium acetate and then leached with neutral ethyl alcohol (95%) to remove any occluded ammonia and leave only the ammonia adsorbed on the exchange complex. The soil sample was then placed in a 500 ml. Kjeldhal flask to which 450 ml. distilled water, a piece of paraffin wax (to reduce frothing), a piece of zinc, and 50 ml. N sodium hydroxide were added. The flask was then placed on the distillation rack and distilled slowly for three hours. The ammonia evolved was taken up in 0.1 N sulphuric acid. The excess sulphuric acid was titrated with 0.1 N sodium hydroxide, and the amount of ammonia evolved was calculated and expressed as milliequivalents of adsorbed ammonia per 100 grams of air-dry soil.

The ammonium acetate leachate of the soil sample was then analyzed for the exchangeable cations; i.e.; calcium, magnesium, sodium, and potassium. The calcium was precipitated as calcium oxalate and the quantity determined by titration using 0.05 N potassium permanganate. The magnesium was precipitated as magnesium ammonium phosphate which was then taken up in a known amount of 0.1 N sulphuric acid and the excess acid titrated with 0.1 N sodium hydroxide. The sodium was determined by the sodium uranyl magnesium acetate, method as outlined by Piper (23). The potassium was determined by the cobaltinitrite method as outlined by Jackson (13).

The exchangeable hydrogen was determined by using a modification of the method given by Parker (22). The soil (50 gms.) was shaken up in 200 ml. of 0.5 N barium acetate and allowed to stand overnight. The mixture was then filtered and leached with an additional 300 ml. of the barium acetate. The total amount of leachate was titrated to the phenolphthalein end point with 0.1 N sodium hydroxide. A blank determination was made by titrating a volume of the barium acetate equal to the volume of the leachate with 0.1 N sodium hydroxide. The difference between the two titration figures was used to calculate the amount of exchangeable hydrogen.

2. Results:

The results are recorded in Table No. 3 to Table No. 14 inclusive.

3. Discussion:

The results of the cation exchange studies show that all the soil profiles had a high degree of base saturation. Although determinations were not made on the calcareous horizons, it can be taken for granted that soil horizons containing appreciable quantities of free lime carbonate will not have undergone serious degradation.

In the various horizons of all the soil profiles, calcium was the dominant cation, followed in order by magnesium, hydrogen, sodium and potassium. The amount of exchangeable calcium tended to decrease, and the amount of exchangeable magnesium tended to increase in the lower horizons analysed. The amount of exchangeable sodium and potassium in the exchange complex of these soils was quite small, and there was no significant variation in these cations either between profiles or between horizons within the profiles. The data show that where the exchangeable hydrogen was high, the exchangeable magnesium was low. This indicates that the hydrogen replaces magnesium more readily than it replaces calcium. This agrees with the fact that the more highly hydrated ions are the more easily replaced and the magnesium ion is more highly hydrated than the calcium ion.

The average base saturation and the average percent of exchangeable hydrogen in the horizons of each respective soil profile is shown in Table No. 15.

## TABLE NO. 3

EXCHANGEABLE CATIONS AND TOTAL CATION EXCHANGE CAPACITY EXPRESSED AS MILLI-EQUIVALENTS PER 100 GRAMS OF AIR-DRY SOIL.

Duck Mountain Profile

| Horizon | Depth In: Inches | CATIONS | | | | | Total Cations | Total Exchange Capacity: By $NH_4$ Distillation |
|---|---|---|---|---|---|---|---|---|
| | | H | Ca | Mg | Na | K | | |
| $A_0$ | 0-1½" | --- | --- | --- | --- | --- | --- | --- |
| $A_2$ | 1½-7" | 1.68 | 5.65 | 0.88 | 0.09 | 0.04 | 8.34 | 7.70 |
| $A_3$ | 7-12" | 2.21 | 14.55 | 3.96 | 0.12 | 0.07 | 20.91 | 20.80 |
| $B_1$ | 12-16" | 3.08 | 20.44 | 6.63 | 0.10 | 0.08 | 30.33 | 29.55 |
| $B_2$ | 16-23" | 2.96 | 20.56 | 7.66 | 0.50 | 0.07 | 31.75 | 31.45 |

## TABLE NO. 4

EXCHANGEABLE CATIONS EXPRESSED AS PERCENT OF TOTAL AND PERCENT BASE SATURATION.

Duck Mountain Profile

| Horizon | Depth In: Inches | H | Ca | Mg | Na | K | Percent Base Saturation |
|---|---|---|---|---|---|---|---|
| $A_0$ | 0-1½" | ----- | ----- | ----- | ----- | ----- | ----- |
| $A_2$ | 1½-7" | 20.14 | 67.75 | 10.55 | 1.08 | 0.48 | 79.86 |
| $A_3$ | 7-12" | 10.57 | 69.58 | 18.94 | 0.57 | 0.33 | 89.42 |
| $B_1$ | 12-16" | 10.15 | 67.39 | 21.86 | 0.33 | 0.26 | 89.84 |
| $B_2$ | 16-23" | 9.32 | 64.76 | 24.13 | 1.57 | 0.22 | 90.68 |

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## TABLE NO. 5

EXCHANGEABLE CATIONS AND TOTAL CATION EXCHANGE CAPACITY EXPRESSED AS MILLI-EQUIVALENTS PER 100 GRAMS OF AIR-DRY SOIL.

Crestview Profile No. 1

| Horizon | Depth In Inches | CATIONS H | Ca | Mg | Na | K | Total Cations | Total Exchange Capacity By $NH_4$ Distillation |
|---|---|---|---|---|---|---|---|---|
| $A_o$ | 0-1" | ---- | ---- | ---- | ---- | ---- | ---- | ---- |
| $A_2$ | 1-4½" | 2.16 | 14.66 | 3.73 | 0.06 | 0.04 | 20.65 | 19.45 |
| $B_1$ | 4½-7" | 2.24 | 13.30 | 4.95 | 0.07 | 0.05 | 20.61 | 18.75 |
| $B_2$ | 7-11½" | 1.72 | 11.81 | 4.18 | 0.16 | 0.03 | 17.90 | 16.55 |

## TABLE NO. 6

EXCHANGEABLE CATIONS EXPRESSED AS PERCENT OF TOTAL AND PERCENT BASE SATURATION.

Crestview Profile No. 1

| Horizon | Depth | H | Ca | Mg | Na | K | Percent Base Saturation |
|---|---|---|---|---|---|---|---|
| $A_o$ | 0-1" | ---- | ---- | ---- | ---- | ---- | ---- |
| $A_2$ | 1-4½" | 10.46 | 70.99 | 18.06 | 0.29 | 0.19 | 89.53 |
| $B_1$ | 4½-7" | 10.87 | 64.53 | 24.02 | 0.34 | 0.24 | 89.13 |
| $B_2$ | 7-11½" | 9.61 | 65.98 | 23.35 | 0.89 | 0.17 | 90.39 |

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## TABLE NO. 7

EXCHANGEABLE CATIONS AND TOTAL CATION EXCHANGE CAPACITY EXPRESSED AS MILLI-EQUIVALENTS PER 100 GRAMS OF AIR-DRY SOIL.

Crestview Profile No. 2

| Horizon | Depth In: Inches | CATIONS H | Ca | Mg | Na | K | Total Cations | Total Exchange Capacity By $NH_4$ Distillation |
|---|---|---|---|---|---|---|---|---|
| $A_o$ | 0-2½" | ---- | ---- | ---- | ---- | ---- | ---- | ---- |
| $A_2$ | 2½-9" | 3.52 | 27.19 | 8.88 | 0.25 | 0.10 | 39.94 | 38.55 |
| B | 9-15" | 1.84 | 19.13 | 9.33 | 0.13 | 0.12 | 30.55 | 27.55 |

## TABLE NO. 8

EXCHANGEABLE CATIONS EXPRESSED AS PERCENT OF TOTAL AND PERCENT BASE SATURATION.

Crestview Profile No. 2

| Horizon | Depth | H | Ca | Mg | Na | K | Percent Base Saturation |
|---|---|---|---|---|---|---|---|
| $A_o$ | 0-2½" | ---- | ---- | ---- | ---- | ---- | ---- |
| $A_2$ | 2½-9" | 8.81 | 68.08 | 22.23 | 0.63 | 0.25 | 91.19 |
| B | 9-15" | 6.02 | 62.62 | 30.54 | 0.42 | 0.39 | 93.97 |

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## TABLE NO. 9

EXCHANGEABLE CATIONS AND TOTAL CATION EXCHANGE CAPACITY EXPRESSED AS MILLI-EQUIVALENTS PER 100 GRAMS OF AIR-DRY SOIL.

Kenville Profile No. 1

| Horizon | Depth In: Inches | CATIONS H | Ca | Mg | Na | K | Total Cations | Total Exchange Capacity By $NH_4$ Distillation |
|---|---|---|---|---|---|---|---|---|
| $A_o$ | 0-1" | ---- | ---- | ---- | ---- | ---- | ---- | ---- |
| $A_1$ | 1-2" | ---- | ---- | ---- | ---- | ---- | ---- | ---- |
| $A_2$ | 2-5½" | 1.28 | 30.13 | 8.75 | 0.64 | 0.16 | 40.96 | 41.70 |
| $B_1$ | 5½-11" | 1.12 | 23.00 | 10.75 | 0.70 | 0.07 | 35.64 | 34.80 |
| $B_2$ | 11-24" | 1.04 | 17.88 | 10.50 | 0.76 | 0.11 | 30.29 | 28.95 |

## TABLE NO. 10

EXCHANGEABLE CATIONS EXPRESSED AS PERCENT OF TOTAL AND PERCENT BASE SATURATION.

Kenville Profile No. 1

| Horizon | Depth | H | Ca | Mg | Na | K | Percent Base Saturation |
|---|---|---|---|---|---|---|---|
| $A_o$ | 0-1" | ---- | ---- | ---- | ---- | ---- | ---- |
| $A_1$ | 1-2" | ---- | ---- | ---- | ---- | ---- | ---- |
| $A_2$ | 2-5½" | 3.13 | 73.56 | 21.36 | 1.56 | 0.39 | 96.87 |
| $B_1$ | 5½-11" | 3.14 | 64.53 | 30.16 | 1.96 | 0.20 | 96.85 |
| $B_2$ | 11-24" | 3.43 | 59.02 | 34.66 | 2.51 | 0.36 | 96.55 |

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## TABLE NO. 11

EXCHANGEABLE CATIONS AND TOTAL CATION EXCHANGE CAPACITY
EXPRESSED AS MILLI-EQUIVALENTS PER 100 GRAMS OF AIR-DRY SOIL.

Kenville Profile No. 2

| Horizon | Depth In: Inches | CATIONS H | Ca | Mg | Na | K | Total Cations | Total Exchange Capacity By $NH_4$ Distillation |
|---|---|---|---|---|---|---|---|---|
| $A_o$ | 0-1" | ---- | ---- | ---- | ---- | ---- | ---- | ---- |
| A | 1-8½" | 5.12 | 40.38 | 13.00 | 0.00 | 0.12 | 58.62 | 63.47 |
| $B_1$ | 8½-11½" | 4.00 | 22.50 | 10.90 | 0.10 | 0.09 | 37.59 | 40.91 |
| $B_2$ | 11½-16" | 2.08 | 22.75 | 13.50 | 0.35 | 0.11 | 38.79 | 39.32 |

## TABLE NO. 12

EXCHANGEABLE CATIONS EXPRESSED AS PERCENT OF TOTAL AND PERCENT BASE SATURATION.

Kenville Profile No. 2

| Horizon | Depth | H | Ca | Mg | Na | K | Percent Base Saturation |
|---|---|---|---|---|---|---|---|
| $A_o$ | 0-1" | ---- | ---- | ---- | ---- | ---- | ---- |
| A | 1-8½" | 8.73 | 68.88 | 22.18 | 0.00 | 0.20 | 91.26 |
| $B_1$ | 8½-11½" | 10.64 | 59.86 | 29.00 | 0.27 | 0.24 | 89.37 |
| $B_2$ | 11½-16" | 5.36 | 58.65 | 34.80 | 0.90 | 0.28 | 94.63 |

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## TABLE NO. 13

EXCHANGEABLE CATIONS AND TOTAL CATION EXCHANGE CAPACITY
EXPRESSED AS MILLI-EQUIVALENTS PER 100 GRAMS OF AIR-DRY SOIL.

Valley Profile

| Horizon | Depth In Inches | CATIONS H | Ca | Mg | Na | K | Total Cations | Total Exchange Capacity By $NH_4$ Distillation |
|---|---|---|---|---|---|---|---|---|
| $A_{oo}$ | 0-1" | ---- | ---- | ---- | ---- | ---- | ---- | ---- |
| $A_o$ | 1-3½" | ---- | ---- | ---- | ---- | ---- | ---- | ---- |
| $A_{11}$ | 3½-6½" | 2.32 | 31.25 | 22.50 | 0.29 | 0.23 | 56.59 | 56.77 |

## TABLE NO. 14

EXCHANGEABLE CATIONS EXPRESSED AS PERCENT OF TOTAL AND PERCENT BASE SATURATION.

Valley Profile

| Horizon | Depth | H | Ca | Mg | Na | K | Percent Base Saturation |
|---|---|---|---|---|---|---|---|
| $A_{oo}$ | 0-1" | ---- | ---- | ---- | ---- | ---- | ---- |
| $A_o$ | 1-3½" | ---- | ---- | ---- | ---- | ---- | ---- |
| $A_{11}$ | 3½-6½" | 4.10 | 55.22 | 39.76 | 0.51 | 0.41 | 95.90 |

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TABLE NO. 15

The Average Percent Base Saturation and the Average Percent Exchangeable Hydrogen for Each Profile Studied.

| Soil | Total Thickness of Horizons Studied (Inches) | Average Base Saturation | Average % Exchangeable Hydrogen |
|---|---|---|---|
| Duck Mountain Soil Profile | 21.5 | 87.47 | 12.53 |
| Crestview Soil Profile No. 1 | 10.5 | 89.80 | 10.10 |
| Crestview Soil Profile No. 2 | 12.5 | 92.52 | 7.47 |
| Kenville Soil Profile No. 1 | 22.0 | 96.68 | 3.31 |
| Kenville Soil Profile No. 2 | 15.0 | 91.89 | 8.38 |
| Valley Soil Profile | 3.5 | 95.90 | 4.10 |

The Duck Mountain soil had a lower base saturation and contained more exchangeable hydrogen than any of the other soils when the depth of soil involved is considered. The eluvial horizons of the leached profiles contained the most hydrogen and were the least base saturated. The Crestview and Kenville soils were more highly base saturated and contained less exchangeable hydrogen than the Duck Mountain soils. One notable difference between the Crestview and Kenville soil is that the depth of profile containing exchangeable hydrogen was considerably less in the Crestview soil profiles than in the Kenville soil profiles. The Valley soil profile was significantly lower in exchangeable hydrogen and higher in base saturation than the other soils and only 3½ inches of the profile showed any degree of base unsaturation.

## C. Nitrogen:

The level of total nitrogen in soil provides the investigator with some evidence in respect of the decomposition of the organic matter.

### 1. Method :

The nitrogen was determined by the Gunning-Hibbard (7) method.

### 2. Results:

The results are recorded in Table No. 16 to Table No. 21 inclusive.

### 3. Discussion:

The total nitrogen determinations revealed a similar trend in all the profiles. The surface horizons were all high in nitrogen. The highest nitrogen levels were in the "$A_{OO}$" and "$A_O$" horizons of the Valley soil profile. These horizons were largely composed of forest litter. The nitrogen content of the leached "$A_2$" horizons was as high or higher than the nitrogen content of the "B" horizons in all the profiles. This would indicate that although the "$A_2$" horizons were leached, they contained some products of decomposition from the overlying "$A_O$" horizons. The data do not show any accumulation of nitrogen in the "B" horizons. This would indicate that the nitrogen that has been made mobile has passed through the profile or has been taken up by the plant roots. The "B" horizons of the Kenville soils contain considerably more nitrogen than any of the other "B" horizons studied.

## TABLE NO. 16

PERCENT ORGANIC CARBON, ORGANIC MATTER, NITROGEN; THE CARBON-NITROGEN RATIOS; AND THE INORGANIC CARBON EXPRESSED AS CALCIUM CARBONATE.

Duck Mountain Soil Profile

| Horizon | Depth In Inches | Organic Carbon (Percent) | Organic Matter (Organic Carbon x 1.742) | Nitrogen (Percent) | Carbon-Nitrogen Ratio | Inorganic Carbon as Calcium Carbonate (Percent) |
|---|---|---|---|---|---|---|
| $A_0$ | 0-1½" | 19.33 | 33.32 | 1.37 | 14.11:1 | 2.59 |
| $A_2$ | 1½-7" | 0.77 | 1.33 | 0.08 | 8.66:1 | 0.00 |
| $A_3$ | 7-12" | 0.68 | 1.17 | 0.08 | 8.50:1 | 1.75 |
| $B_1$ | 12-16" | 0.36 | 0.62 | 0.09 | 4.00:1 | 0.57 |
| $B_2$ | 16-23" | 0.54 | 0.93 | 0.08 | 6.75:1 | 0.66 |
| $B_3$ | 23-32" | 0.48 | 0.83 | 0.06 | ---- | 12.76 |
| C | 32-36" | 0.19 | 0.33 | 0.06 | ---- | 19.50 |
| | 36-40" | 0.46 | 0.79 | 0.06 | ---- | 21.00 |
| | 40-44" | 0.34 | 0.59 | 0.06 | ---- | 19.30 |
| | 44-48" | 0.22 | 0.38 | 0.04 | ---- | 18.27 |
| | 48-52" | 0.19 | 0.33 | 0.04 | ---- | 16.87 |

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TABLE NO. 17

PERCENT ORGANIC CARBON, ORGANIC MATTER, NITROGEN; THE CARBON-NITROGEN RATIOS; AND THE INORGANIC CARBON EXPRESSED AS CALCIUM CARBONATE.

Crestview Soil Profile No. 1

| Horizon | Depth In Inches | Organic Carbon (Percent) | Organic Matter (Organic Carbon x 1.742) | Nitrogen (Percent) | Carbon-Nitrogen Ratio | Inorganic Carbon as Calcium Carbonate (Percent) |
|---|---|---|---|---|---|---|
| $A_o$ | 0-1" | 21.31 | 36.74 | 1.43 | 14.90:1 | 1.14 |
| $A_2$ | 1-4½" | 1.50 | 2.59 | 0.15 | 10.00:1 | 1.86 |
| $B_1$ | 4½-7" | 0.88 | 1.52 | 0.11 | 8.00:1 | 0.00 |
| $B_2$ | 7-11½" | 0.77 | 1.33 | 0.07 | 11.00:1 | 0.43 |
| $B_3$ | 11½-13" | 0.57 | 0.98 | 0.08 | ---- | 10.65 |
| Ca | 13-15" | 0.43 | 0.74 | 0.07 | ---- | 37.14 |
| C | 15-24" | 0.44 | 0.76 | 0.05 | ----- | 36.59 |

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TABLE NO. 18

PERCENT ORGANIC CARBON, ORGANIC MATTER, NITROGEN; THE CARBON-NITROGEN RATIOS; AND THE INORGANIC CARBON EXPRESSED AS CALCIUM CARBONATE.

Crestview Soil Profile No. 2

| Horizon | Depth In Inches | Organic Carbon (Percent) | Organic Matter (Organic Carbon x 1.742) | Nitrogen (Percent) | Carbon-Nitrogen Ratio | Inorganic Carbon as Calcium Carbonate (Percent) |
|---|---|---|---|---|---|---|
| Ao | 0-2½" | 35.74 | 61.62 | 1.75 | 20.42:1 | 1.07 |
| $A_2$ | 2½-9" | 3.63 | 6.26 | 0.30 | 12.10:1 | 0.34 |
| B | 9-15" | 1.01 | 1.74 | 0.09 | 11.22:1 | 0.00 |
| Ca | 15-20" | 0.85 | 1.47 | 0.07 | ---- | 34.41 |
| C | 20-24" | 0.38 | 0.66 | 0.04 | ---- | 32.37 |
| | 24-28" | 0.33 | 0.57 | 0.04 | ---- | 27.19 |
| | 28-32" | 0.57 | 0.98 | 0.05 | ---- | 37.50 |
| | 32-36" | 0.56 | 0.97 | 0.05 | ---- | 37.59 |
| | 36-40" | 0.22 | 0.38 | 0.05 | ---- | 34.75 |
| | 40-44" | 0.33 | 0.56 | 0.04 | ---- | 32.76 |

## TABLE NO. 19

PERCENT ORGANIC CARBON, ORGANIC MATTER, NITROGEN; THE CARBON-NITROGEN RATIOS; AND THE INORGANIC CARBON EXPRESSED AS CALCIUM CARBONATE.

Kenville Soil Profile No. 1

| Horizon | Depth In Inches | Organic Carbon (Percent) | Organic Matter (Organic Carbon x 1.742) | Nitrogen (Percent) | Carbon-Nitrogen Ratio | Inorganic Carbon as Calcium Carbonate (Percent) |
|---|---|---|---|---|---|---|
| $A_0$ | 0-1" | 15.69 | 27.05 | 1.30 | 12.07:1 | 1.61 |
| $A_1$ | 1-2" | 13.74 | 23.69 | 1.22 | 11.26:1 | 0.45 |
| $A_2$ | 2-5½" | 3.54 | 6.10 | 0.37 | 9.57:1 | 0.00 |
| $B_1$ | 5½-11" | 1.64 | 2.83 | 0.20 | 8.20:1 | 0.68 |
| $B_2$ | 11-24" | 0.63 | 1.09 | 0.12 | ---- | 1.91 |
| $B_3$ | 24-27" | 0.73 | 1.30 | 0.10 | ---- | 17.43 |
| Ca | 27-33" | 0.64 | 1.10 | 0.07 | ---- | 23.43 |
| C | 33"+ | 0.28 | 0.48 | 0.07 | ---- | 21.04 |

## TABLE NO. 20

PERCENT ORGANIC CARBON, ORGANIC MATTER, NITROGEN; THE CARBON-NITROGEN RATIOS; AND THE INORGANIC CARBON EXPRESSED AS CALCIUM CARBONATE.

Kenville Soil Profile No. 2

| Horizon | Depth In Inches | Organic Carbon (Percent) | Organic Matter (Organic Carbon x 1.742) | Nitrogen (Percent) | Carbon-Nitrogen Ratio | Inorganic Carbon as Calcium Carbonate (Percent) |
|---|---|---|---|---|---|---|
| $A_o$ | 0-1" | 15.71 | 27.08 | 1.15 | 13.66:1 | 3.34 |
| A | 1-8½" | 7.89 | 13.60 | 0.77 | 10.25:1 | 0.00 |
| $B_1$ | 8½-11½" | 1.36 | 2.34 | 0.17 | 8.00:1 | 1.25 |
| $B_2$ | 11½-16" | 0.84 | 1.45 | 0.15 | 5.60:1 | 0.45 |
| $B_3$ | 16-20" | 0.46 | 0.79 | 0.11 | ---- | 17.43 |
| C | 20-24" | 0.54 | 0.93 | 0.10 | ---- | 19.61 |
| | 24-28" | 0.53 | 0.91 | 0.09 | ---- | 19.18 |
| | 28-32" | 0.18 | 0.31 | 0.07 | ---- | 20.84 |
| | 32-36" | 0.35 | 0.60 | 0.06 | ---- | 26.96 |
| | 36-40" | 0.49 | 0.84 | 0.07 | ---- | 20.41 |
| | 40-46" | 0.56 | 0.97 | 0.06 | ---- | 13.96 |
| | 46-52" | 0.35 | 0.60 | 0.06 | ---- | 19.05 |

TABLE NO. 21

PERCENT ORGANIC CARBON, ORGANIC MATTER, NITROGEN; THE CARBON-NITROGEN RATIOS; AND THE INORGANIC CARBON EXPRESSED AS CALCIUM CARBONATE.

Valley Soil Profile

| Horizon | Depth In Inches | Organic Carbon (Percent) | Organic Matter (Organic Carbon x 1.742) | Nitrogen (Percent) | Carbon-Nitrogen Ratio | Inorganic Carbon as Calcium Carbonate (Percent) |
|---|---|---|---|---|---|---|
| $A_{oo}$ | 0-1" | 23.89 | 41.19 | 2.07 | 11.54:1 | 1.52 |
| $A_o$ | 1-3½" | 25.83 | 44.53 | 2.06 | 12.54:1 | 1.02 |
| $A_{1_1}$ | 3½-6½" | 4.95 | 8.56 | 0.48 | 10.35:1 | 0.43 |
| $A_{1_2}$ | 6½-15" | 1.88 | 3.24 | 0.27 | 6.96:1 | 2.41 |
| $C_1$ | 15-24" | 0.49 | 0.84 | 0.14 | ---- | 15.69 |
| $C_2$ | 24-32" | 0.44 | 0.76 | 0.08 | ---- | 28.40 |

D. Organic Carbon and Organic Matter:

The organic matter content of a soil profile and the distribution of organic matter in the profile are important criteria in classifying soils. The distribution of the organic matter in a soil profile is determined largely by the type of vegetation that has been growing on the soil. The plant debris from grasses and other herbaceous plants is added to the soil both at the surface (aerial parts) and throughout the surface few feet of the soil (roots), while the debris from trees and other woody shrubs is added in large quantities only at the surface of the soil.

1. Method:

The inorganic carbon and the total carbon were determined by using a wet combustion method adopted from Adams (1) and Waynick (24). The organic carbon was obtained by subtracting the amount of inorganic carbon from the total carbon. The amount of organic matter was calculated by multiplying the amount of organic carbon by the factor 1.724 as suggested by Piper (23).

2. Results:

The results are recorded in Table No. 16 - Table No. 21 inclusive, and shown graphically in Figure No. 4 and Figure No. 5 .

3. Discussion:

The Valley profile has a fairly deep layer of organic matter in the form of "$A_{oo}$" and "$A_o$" horizons. The organic matter level than drops off sharply to the "$A_1$" horizon. From the $6\frac{1}{2}$ inch level downward the organic matter content tapers off sharply. In the Kenville soil profile No. 1, the two surface horizons have much less organic matter than the comparable horizons in the Valley profile. The organic matter content tapers off more gradually and extends farther down in the profile than in the Valley profile.

FIGURE NO. 4

ORGANIC MATTER CONTENT OF SOIL PROFILES STUDIED

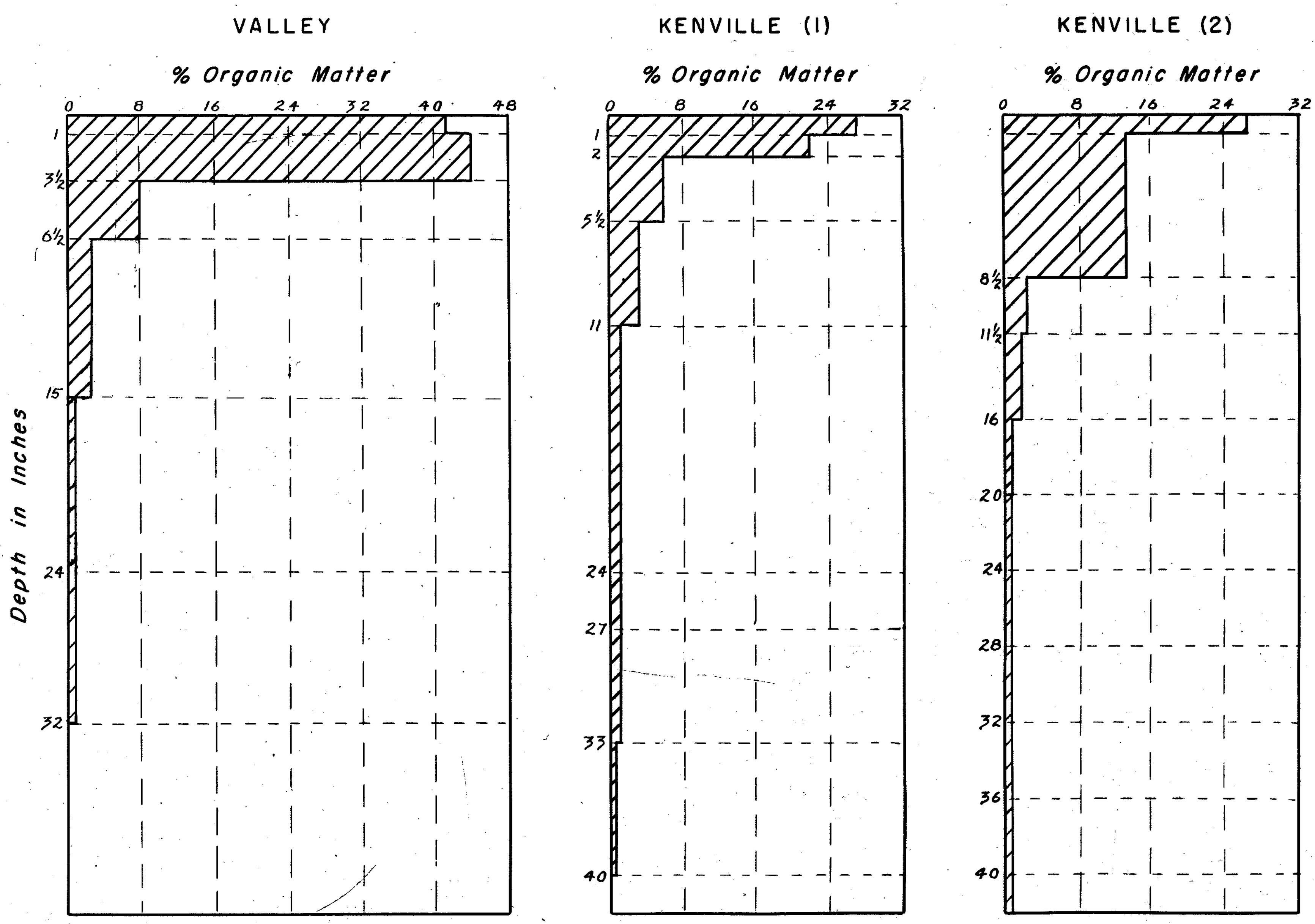
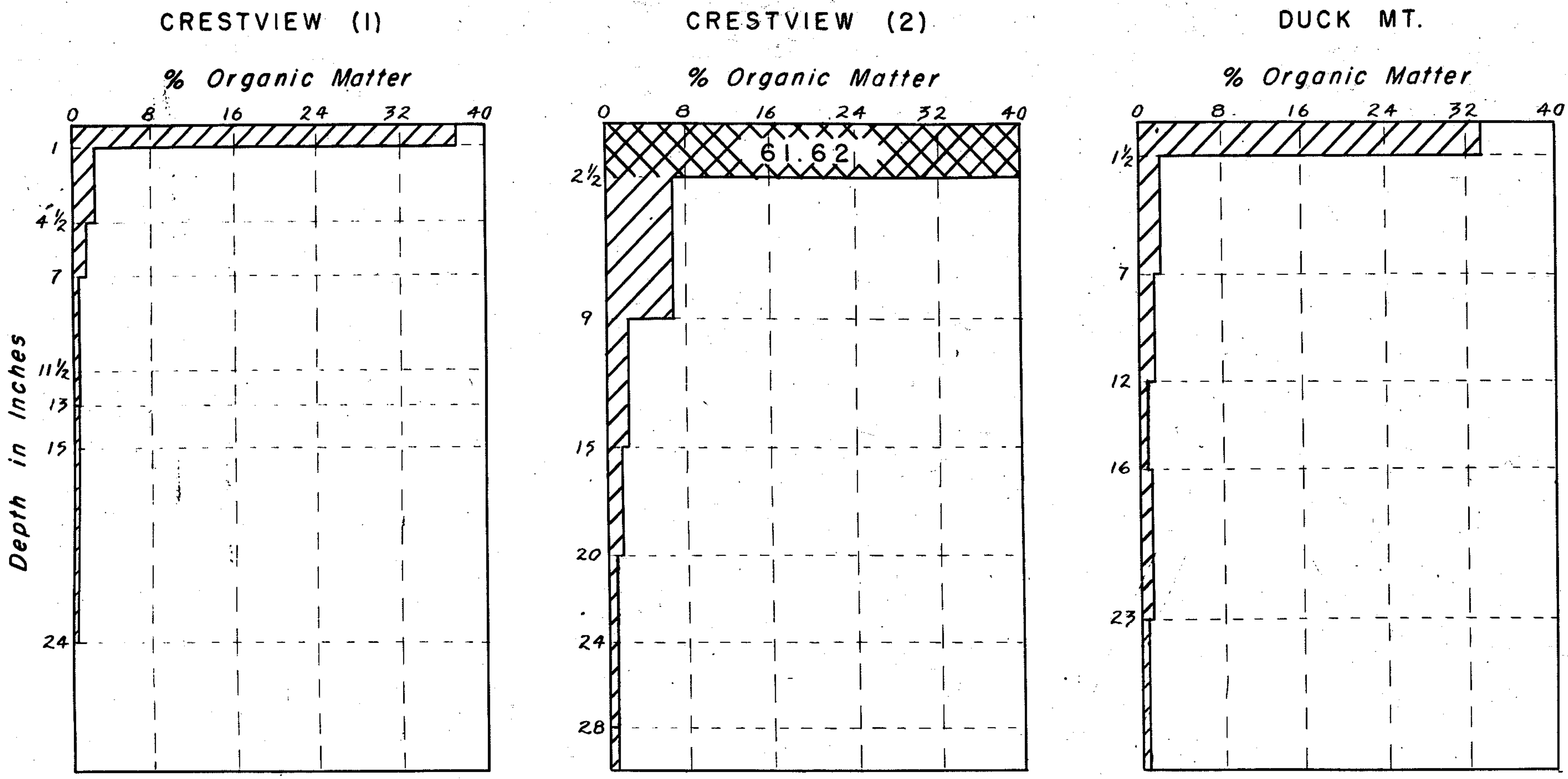


FIGURE NO.5

ORGANIC MATTER CONTENT OF SOIL PROFILES STUDIED



The pattern of the organic matter content is somewhat different in the Kenville soil profile No. 2. There is the same, fairly shallow, organic horizon at the surface but the deep "A" horizon has a high content of organic matter. The organic matter tapers off sharply in the "B" horizon of the Kenville soil profile No. 2. There is more organic matter within this profile than there is in the Valley profile and Kenville profile No. 1 where most of the organic matter is in the surface horizons. The content and distribution of the organic matter in the Kenville No. 2 profile is similar to that found in the blackearth soils of Manitoba studied by Barr (2) and Hobbs (12). The Crestview soil profile No. 1 has a very low content of organic matter. There is a thin organic horizon at the surface. The remainder of the profile contains less than 2.5 percent of organic matter. The Crestview soil profile No. 2 has a surface organic horizon, $2\frac{1}{2}$ inches in thickness, that is very high in organic matter. The organic matter content tapers off rapidly in the other horizons and extends to a depth of about 28 inches. The Duck Mountain profile has a thin surface horizon of organic matter but below that the profile contains only a relatively small amount of organic matter. The leached "$A_2$" horizons of some of these profiles contain as much organic matter as the corresponding "B" horizons.

E. <u>Carbon-Nitrogen Ratios:</u>

The carbon to nitrogen ratios show the relationship between the organic matter and nitrogen in the soil which helps to reveal the differences in the state of decomposition of the organic matter fraction of the soil horizons. The relationship of carbon to nitrogen in soils is discussed by Van Slyke (27). According to this authority, "when organic matter decomposes in soils, the carbon and nitrogen tend to accumulate in the residue, but the accumulation of nitrogen is greater than that of the carbon, compared with the amount in the original undecomposed material." He reports that the carbon-nitrogen ratio in fresh plants may be 20 or 40:1 while in a soil where decomposition of the organic matter has occurred the carbon-nitrogen ratios are 8:1 to 20:1.

Leighty and Shorey (17) found: (a) that wide carbon-nitrogen ratios such as 20:1, indicate the presence of an organic fraction which has not undergone extensive decomposition; (b) that during decomposition, the carbon-nitrogen ratio of the organic matter present in the soil becomes narrower; and (c) that a narrow carbon-nitrogen ratio (10:1) indicates an organic fraction which has fairly well decomposed. It was also noted by these investigators (17) that the carbon-nitrogen ratios in soil organic matter varied greatly from soil to soil.

1. <u>Method:</u>

The carbon-nitrogen ratios were calculated from the carbon and nitrogen data.

2. <u>Results:</u>

The results are recorded in Table No. 16 to Table No. 21 inclusive.

3. <u>Discussion:</u>

The carbon-nitrogen ratios are of value because these ratios give some indication of the state of decomposition of the organic matter. If the ratio is high (over 12:1) it indicates that most of the organic matter is in an undecomposed condition but, if the ratio is low, it indicates that the organic matter has decomposed to a large extent and nitrogenous compounds have formed as by-products. The data show that the "$A_0$" horizons of the Duck Mountain, Crestview and Kenville profiles all have wide carbon-nitrogen ratios and hence must be composed largely of undecomposed humus. In the

Valley profile the "$A_{oo}$" and "$A_o$" horizons are highly organic and yet their carbon-nitrogen ratios are relatively narrow which would indicate that in these organic horizons decomposition has proceeded farther than in the surface horizons of the other soils. In the "$A_2$" and "B" horizons of the various profiles, the carbon-nitrogen ratios are all narrow and this would indicate that here too, the organic matter is well-decomposed.

F. Calcium Carbonate:

A study of the calcium carbonate content and its distribution in a soil profile helps to indicate the soil-forming processes that are in operation. If there has been a removal of calcium carbonate from the upper part of the profile and an accumulation of it lower down, then it is an indication that the degradation process has been active.

1. Method:

The carbonate content of the soil was calculated from the inorganic carbon and expressed as calcium carbonate.

2. Results:

The results are recorded in Table No. 16 - Table No. 21 inclusive, and shown graphically in Figure No. 6 and Figure No. 7.

3. Discussion:

The pattern of the calcium carbonate content of the soil profiles is shown in Figure No. 6 and Figure No. 7. In the Valley profile there is a slight accumulation of calcium carbonate at the surface after which the content decreases to the 6½ inch level and then increases again to a high of 28.40 percent in the 24 to 32 inch depth. In the Kenville profile No. 1 there is a similar pattern except that the 2 to 5 inch horizon contains no calcium carbonate. Also the calcium carbonate is leached down to a much greater depth. This profile shows a zone of accumulation in the 27 to 33 inch level. The data for the Kenville soil profile No. 2 reveal a considerable depth ($6\frac{1}{2}$ inches) completely leached of calcium carbonate. The calcium carbonate begins to accumulate at a considerably higher level than in the Kenville profile No. 1. In the Crestview profile No. 1, the top $4\frac{1}{2}$ inches contain some calcium carbonate below which there is a depth of 3 inches without any calcium carbonate. The calcium carbonate content increases quickly at the $11\frac{1}{2}$ inch level and reaches a high of 37.14 percent in the 13 to 15 inch level and decreases slightly to the 24 inch level. The Crestview profile No. 2 shows a very similar pattern except that the horizon containing no calcium carbonate is at a lower depth in the profile. The Duck Mountain profile shows an accumulation at the surface, below which there is very little calcium carbonate until the 23 inch depth is reached. The calcium carbonate content reaches a peak of 21.0 percent at the 36 to 40 inch level and then decreases slightly to the lowest depth of sampling. This accumulation at the 36 to 40 inch level indicates a "Ca" horizon which could not be detected in the field investigations.

There is some significance to the fact that the profiles showing the highest calcium carbonate content at the lowest depth sampled (Crestview profile No. 1 and No. 2) also show a marked accumulation of calcium carbonate higher up in the profiles than in the other profiles studied. The following sequence in respect of calcium carbonate content of the parent material in each profile is noted; Crestview No. 1 is the highest followed by Crestview No. 2, Valley, Kenville No. 1, Kenville No. 2, and Duck Mountain.

FIGURE NO. 6

## CALCIUM CARBONATE CONTENT OF SOIL PROFILES STUDIED

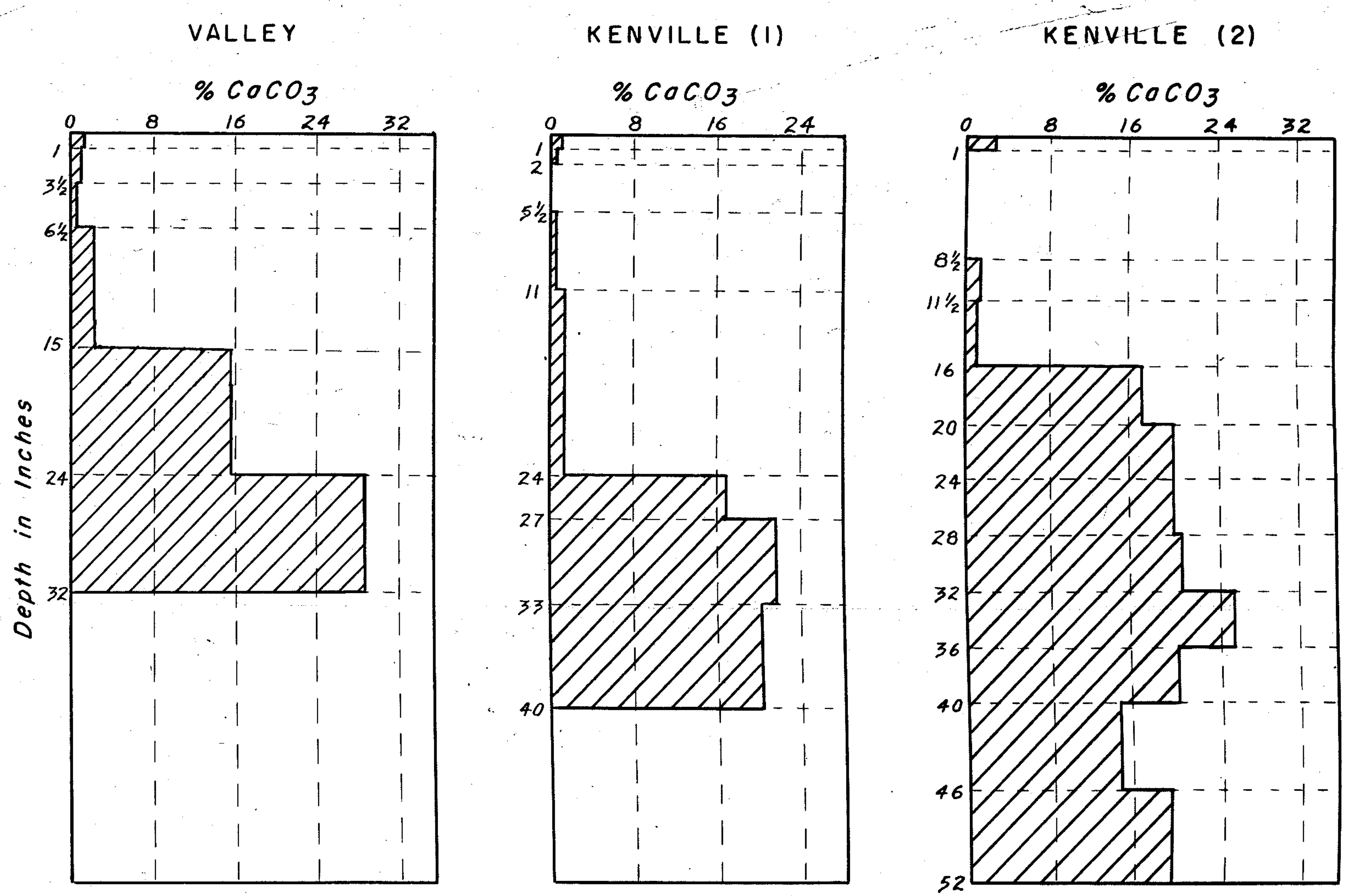
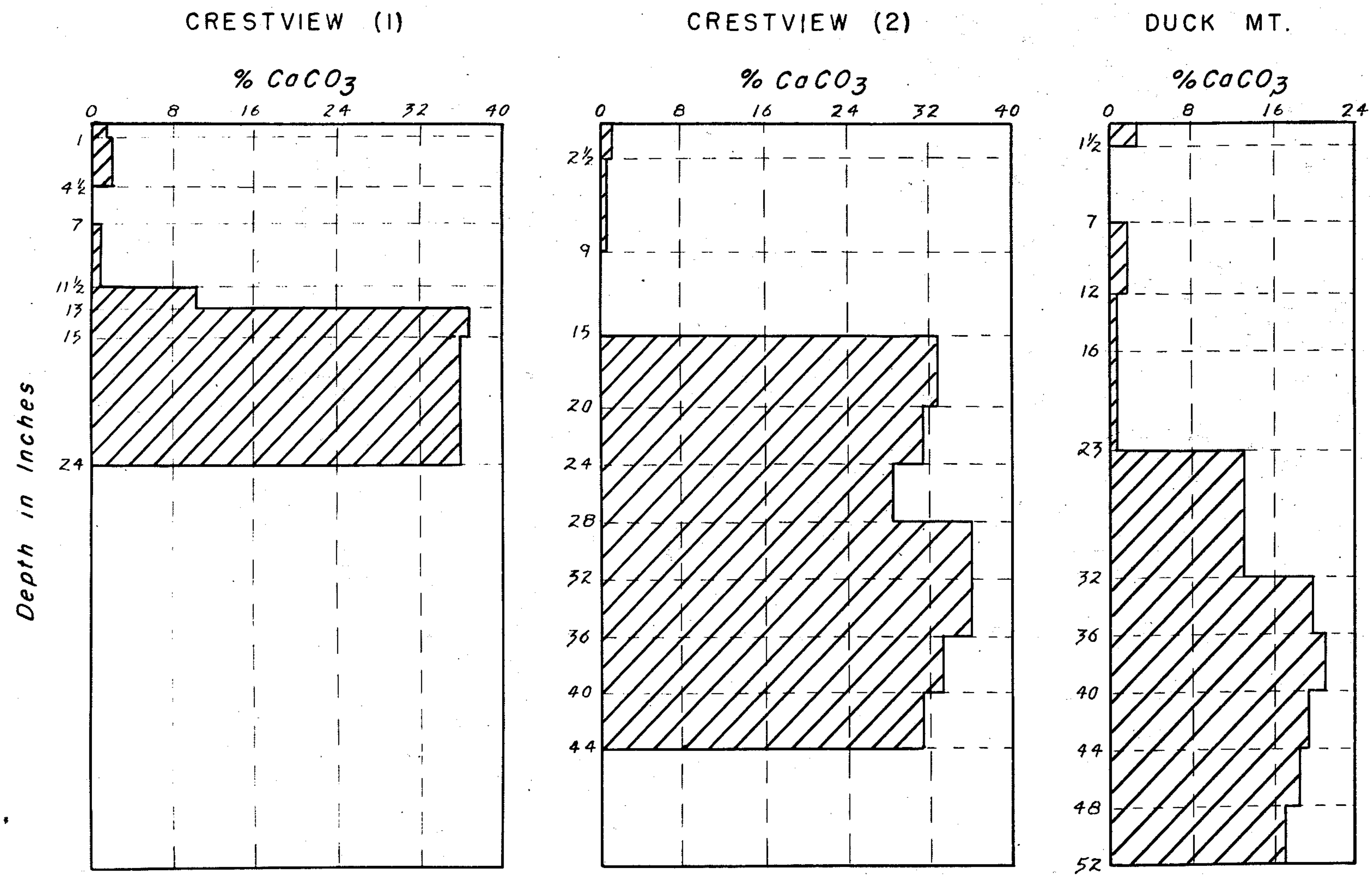


FIGURE NO. 7

CALCIUM CARBONATE CONTENT OF SOIL PROFILES STUDIED



G. Ammonium Tartrate Extractable Ion:

This determination was made in order to determine what effect the pedological processes have had on the decomposition of the minerals as measured by the amount of iron that can be extracted with a suitable reagent.

1. Method :

The extraction of the free iron from the soil was carried out by a modification of the aluminium-ammonium tartrate method developed by Dion (6). This procedure employs nascent hydrogen, which is produced by the reaction of ammonium tartrate and aluminium, for the reduction and solution of free iron oxides from soils. Ammonia is released by the combination of aluminium and the tartrate ions and removed by boiling. This action maintains the solution at a constant pH of 6.4, which is less destructive to the minerals containing iron than are more acid solutions.

A five-gram sample of soil (previously treated with hydrogen peroxide) was added to a 500 ml. aluminium beaker containing three closely-wound spirals of aluminium wire. Then 100 ml. of 10 percent ammonium tartrate were added to the beaker. The contents of the beaker were maintained at slow boiling for about one hour. Dion recommended a 10 gram sample of soil, but it was found that more accurate results were obtained if only 5 grams were used.

When the digestion was complete the suspension was poured into a beaker, and the aluminium beaker and spirals were washed three times with small amounts of N ammonium acetate (a total of 50 ml.) and finally once with 10 ml. of 0.05 N hydrochloric acid. The suspension was allowed to settle and supernatant liquid decanted and filtered through a Buechner funnel. The soil was transferred to the funnel and washed three times with a total of 15 ml. N sodium chloride (acidified to a pH of 3.0).

The determination of the iron was carried out according to Dyer's (19) method. An aliquot of the extract containing 0.01 - 0.10 mgms. of iron was placed in 100 ml. volumetric flasks. About 50 ml. of 10 N ammonium acetate solution (pH approximately 6.1) and 3 ml. of 0.005 M solution of $\alpha \alpha'$ dipyridyl was added. A trace of sodium hydrosulphite (iron free) was added to reduce all the iron. The flask was then filled with the acetate buffer. After the solutions were allowed to stand for about one half an hour, the color was measured in a Coleman Spectrophotometer. The ferrous dipyridyl was then determined by reference to calibration data previously prepared.

2. Results:

The results are recorded in Table No. 22.

3. Discussion:

The data show that there is some ammonium extractable iron or free iron in all of the horizons of the soil profiles studied. The Duck Mouhtain profile shows the greatest variation. The data for this profile strongly indicate the movement of iron from the "$A_2$" horizon and its accumulation in the "$B_2$" horizon. This movement of iron indicates that there has been considerable weathering of the soil minerals.

The data for the Crestview and Kenville profiles reveal the presence of extractable iron in all of the horizons but do not show any marked difference between the respective horizons. The data for the Valley profile reveal that the "A" horizons are relatively low in extractable iron. The "C" horizon of this profile contains about the same amount of extractable iron as the parent material of the other profiles. However, in relation to the "A" horizons there appears to be an accumulation of iron in the "C" horizon. The other investigations show that this profile has never undergone degradation serious enough to cause a downward movement of iron.

Therefore it may be concluded that some of the iron in the "C" horizon of this profile was deposited there by the ground water.

Table No. 22

The Ammonium Tartrate Extractable Iron
Expressed as Percent Ferrous Iron.

| Soil Profile | Horizon | Percent $Fe^{++}$ |
|---|---|---|
| Duck Mountain | $A_2$ | 0.59 |
| | $B_2$ | 1.07 |
| | C | 0.89 |
| Crestview No. 1 | $A_2$ | 0.67 |
| | $B_2$ | 0.70 |
| | C | 0.58 |
| Crestview No. 2 | $A_2$ | 0.82 |
| | B | 0.86 |
| | C | 0.74 |
| Kenville No. 1 | $A_2$ | 0.56 |
| | $B_2$ | 0.52 |
| | C | 0.72 |
| Kenville No. 2 | A | 0.64 |
| | $B_2$ | 0.60 |
| | C | 0.66 |
| Valley | $A_{11}$ | 0.24 |
| | $A_{12}$ | 0.29 |
| | C | 0.55 |

## VI. GENERAL DISCUSSION OF FIELD AND LABORATORY INVESTIGATIONS:

The laboratory investigations made of the soil horizons from a typical Duck Mountain phytomorphic associate confirmed the observations made in the field that this soil was formed under a process of degradation and decalcification and is a typical grey-wooded soil. On this basis the area in which these soils occur can be included in the Grey-Wooded Soil Zone.

The soil in the other landscape areas had a peculiar combination of morphological characteristics which made their classification difficult. However, with the supporting information secured through laboratory investigations the processes responsible for these characteristics have been clarified.

The field examination of the Crestview soil association showed that the phytomorphic associate had undergone partial degradation. The laboratory data for the Crestview soil profiles show the degree of degradation in relation to the degraded grey-wooded soils of the Mountain Landscape Area. The leached "$A_2$" horizon of the Crestview soil profile No. 1 is mottled and not as well developed as the "$A_2$" horizon of the Duck Mountain soil profile. The eluvial "B" horizon is not as deep or as well developed in the Crestview soil profile as in the Duck Mountain soil profile. The Crestview soil profile No. 2 is similar to the Crestview soil profile No. 1 except that the "$A_2$" horizon is deeper but this horizon is also mottled and not nearly as well developed as the "$A_2$" horizon of the Duck Mountain soil profile. The laboratory data show that there has been a removal of calcium carbonate from the upper horizons of these profiles. The calcium carbonate has moved farther down in the Duck Mountain soil profile than in either of the Crestview profiles. The "$A_2$" and "B" horizons of the Duck Mountain profile have a more acid reaction and a lower base saturation than the Crestview soil profiles. The content and distribution of the organic matter in the Crestview soil profile No. 1 and in the Duck Mountain profile is similar. The Crestview soil profile

No. 2 has considerably more organic matter in both the "$A_o$" and the poorly developed "$A_2$" horizon that was found in the Duck Mountain profile or in the Crestview profile No. 1. This higher organic matter content is a sign that degradation has been less severe. The fact that there has been movement of iron in the Duck Mountain soil and not in the Crestview soil indicates that a much more severe degradation has occurred in the former than in the latter. The total depth of the "A" and "B" horizons of each of the Crestview profiles is only one-half the depth of the corresponding horizons in the Duck Mountain soil profile. The investigations indicate that this difference may be due to two possible causes. First, the forest cover which has developed on the Crestview soil is more juvenile and not as heavy as the forest cover on the Duck Mountain soil and hence degradation processes have not been active for as long a time on the former soil as on the latter. Second, the parent material of the Crestview soil contains approximately twice as much calcium carbonate as the parent material of the Duck Mountain soil. The calcium carbonate content of the Crestview soil parent material is relatively high and has undoubtedly retarded degradation. However, this parent material is not sufficiently calcareous for the Crestview soils to be classed in the rendzina category.

In the final analysis, it would appear that the Crestview soils are developing into grey-wooded soils but at the present time they must be classed as grey - black intergrades or transitional soils.

The two Kenville soil profiles were selected from a part of the Upper Valley Landscape where the field observations indicated that there had been a tree invasion of a former prairie area. This being the case it would be expected that the soils in this area should reflect the influence of both these environments.

The Kenville soil profile No. 1 was selected as a representative profile from an area where the tree invasion was almost complete. The laboratory and field studies made on this profile show that some blackearth characteristics are still present. The organic matter content of the "A" horizon is higher than in either the Duck Mountain soil profile or the Crestview soil profile No. 1, but it is not as high as in the Crestview soil profile No. 2. The organic matter extends well down in the Kenville profile No. 1 and is of a sufficiently high content to give the soil a dark color. The eluvial "$A_2$" horizon is weakly developed in this profile and is not very noticeable under field conditions. The Kenville soil profile No. 1 is more highly base saturated than either the Duck Mountain or Crestview soils.

However, the process of degradation is active in the Kenville soil profile No. 1 as shown by the downward movement of the calcium carbonate, by the acid reaction of the "A" and "B" horizons, and by the well-developed, colloidally coated, nuciform aggregates in the "B" horizon. The investigations, both in the field and in the laboratory, indicate that the Kenville profile was originally developed under prairie but that the tree invasion has been active for a sufficient length of time to modify the morphological characteristics of the soil profile. This soil profile also is in a state of transition and may be classed a degrading blackearth.

The Kenville soil profile No. 2 definitely shows some blackearth characteristics. The deep "A" horizon of this profile is very dark brown in color and has a high content (over 13 percent) of organic matter. This is a characteristic peculiar to grassland soils where the organic matter is deposited in the soil and not on the surface as it is under a tree-type of vegetation. Under field conditions there is no sign of the eluvial "$A_2$" horizon found in the other wooded soils. Although this profile looks blackearth-like, some of the other findings show that it has certain characteristics not found in a blackearth profile. This dark "A" horizon contains no free calcium carbonate, it is acid in reaction, and is only 91.26 percent base saturated. The "$B_1$" and "$B_2$" horizons of this profile have a characteristic nutty structure and acid reaction. These conditions are signs of degradation and although the soil looks like a blackearth the laboratory investigations show that it is not. Hence, the pedological process which has been operative of recent years consists of degradation or decalcification under woods. The evidence presented here indicates that this soil should be classed as a degrading blackearth.

The field investigations of the Lower Valley Plain indicate that most of the soils in the area were very dark in color and showed little or no sign of degradation. A representative profile was chosen from the phyto-hydromorphic associate of the Valley soil association to study the nature of the soils in this area. The occurrence of relatively shallow and immature soil profiles in this area appears due either to the poor drainage conditions that had existed in the area, or to the calcareous nature of the soil parent material. A study of the Valley soil profile indicates that it must have been more poorly drained at one time. This is shown by the mucky surface horizons of this profile. The top $3\frac{1}{2}$ inches of this profile are composed of 41.19 to 44.53 percent organic matter. The relatively high iron content in the "C" horizon of the profile must have been derived from ground water and this also indicates that this soil has been poorly drained. The laboratory data show that the parent material of this soil is calcareous (28.40 percent calcium carbonate), but this is not sufficiently high in lime to place this soil in the rendzina category. It must be concluded that hydromorphism has been a dominant influence in the development of this profile.

The data for this soil profile also reveal that it has undergone improvement in drainage. This is evidenced by some leaching and degradation in the profile. With improvement in drainage, the organic matter has been decomposing as shown by the relatively narrow carbon-nitrogen ratios of 11.54:1 to 12.54:1 in the highly organic "$A_{OO}$" and "$A_O$" horizons. There has been some downward movement of calcium carbonate but not nearly so much as in the other profiles. The acid reaction of the top $6\frac{1}{2}$ inches of soil is another indication that slight degradation has occurred in this profile.

The field investigations of the Lower Valley Plain indicated that the dominant soil was a calcareous black-meadow soil. However, the analytical results from the profile selected to represent the soils in this area show that degradation is now taking place. The improvement in drainage accompanied by an invasion of trees has been responsible for degradation. It may be concluded from this, that the dominant soil of the Lower Valley Plain was a calcareous black-meadow soil but that with continued improvement in drainage the soils in this area have developed into black-meadow soils.

## VII. SUMMARY:

The investigations carried out on certain soils in the Swan River Area and herein reported were undertaken for the purpose of obtaining more detailed information in respect of the pedological processes responsible for the development of these soils. This detailed information was necessary before the respective soils could be classified satisfactorily.

The field investigations involved a study of the factors that determine soil development. These determining factors are climate, vegetation, parent material, topography and relief, drainage, age and culture or the influence of man.

To facilitate the presentation and discussion of the field investigations, a contour map, a map of the landscape areas, and a map showing the surface geological deposits were prepared and submitted.

Six representative soil profiles were selected from different parts of the Swan River Area. One profile was selected from the Duck Mountain phytomorphic associate of the Mountain Landscape Area. Two profiles were selected from the Crestview phytomorphic associate of the Upper Valley Plain. Two profiles were selected from the Kenville phytomorphic associate of the Upper Valley Plain. One profile was selected from the Valley phytohydromorphic associate of the Lower Valley Plain. Complete morphological descriptions were made of these profiles and then monoliths of these profiles were secured and transported to the laboratory for further investigation.

In the laboratory, determinations and calculations were made to secure information on total cation exchange capacity, exchangeable cations, base status, nitrogen, organic matter, carbon-nitrogen ratios, calcium carbonate, and ammonium tartrate extractable iron.

The investigations have shown that the Duck Mountain phytomorphic associate is a grey-wooded soil, the Crestview phytomorphic associate is a grey-black soil, the Kenville phytomorphic associate is a degrading blackearth soil, and the Valley phytohydromorphic associate is a black-meadow soil.

## VIII. CONCLUSIONS:

1. The Swan River Area in Manitoba is a complex of three distinct natural landscapes; (a) the Mountain Landscape areas, (b) the Upper and Lower Valley Landscape areas, and (c) the Lowlands Landscape area.

2. Field observations of the morphological features expressed in the profiles of the dominant soils in the Mountain Landscape areas indicate that they have been subjected to degradation and could be classed genetically as of the Grey-Wooded type or group. Detailed laboratory studies on the Duck Mountain soil profile, selected as representative of the dominant regional soil found in the Mountain Landscape, confirm the field observations and justify the classification of the Mountain Landscapes of the Swan River Area as lying within the Grey-Wooded soil zone.

3. Field observations of the morphological characteristics of the dominant soil associates in the Crestview, Kenville, and Valley soil associations, which occur in the Valley Landscape areas, indicate that laboratory studies were necessary before these soils could be classified correctly and placed in their respective genetic categories.

4. The laboratory studies undertaken have shown that the Crestview phytomorphic soils, occurring in the Upper Valley Plain, were blackearths that are now in the process of degradation but that at the present stage of development they are intergrades or transitional soils, which can be classed as Grey-Blacks.

5. The laboratory studies of the Kenville phytomorphic soils, which also occur in the Upper Valley Plain, show that these soils originally developed as blackearths under prairie conditions, but as a result of tree invasion of this former prairie area, the process of degradation has become more operative in the soils and has modified their morphology. At the present time these soils can be classed as Degrading Blackearths.

6. The soil forming processes of the Valley phytohydromorphic soils in the Lower Valley Plain have been greatly influenced by hydromorphism.

However, the indications are that the drainage conditions have improved to the extent that a slight degree of degradation has occurred in the representative soil profile studied. It is concluded that this soil was formerly a Calcic-Black-Meadow soil, but that at the present time it should be classified as a Black-Meadow soil.

7. As a result of the field and laboratory determinations made on the various representative soil profiles, the soils of the Swan River Area can be classed genetically as follows: (a) the soils of the Mountain Landscape areas can be placed in the Grey-Wooded soil zone; (b) the soils of the Upper Valley Plain are intergrades or transitional soil types consisting of both Grey-Black and Degrading Blackearths and the area in which they occur can be classed as a Grey-Black Degrading Blackearth sub-zone; and (c) the soils in the Lower Valley Plain are Black-Meadow soils and this area can be classed as a local area of intrazonal soils.

8. The two main limiting factors which have influenced the depth of soil profile development in the soils of the Swan River Area are the amount of calcium carbonate in the soil parent material and the drainage conditions of the soil.

9. In the degraded soils studied, the greyish eluvial "$A_2$" horizons contained as much organic matter as their corresponding dark-colored, illuvial "B" horizons. A study of the organic fractions, and the effect that the degradation processes have had on the soil organic matter, should be undertaken.

10. The results of the cation exchange studies herein reported indicate (a) that calcium and magnesium are the dominant cations in the exchange complex of the soils studied; (b) that exchangeable sodium and potassium in the soils studied hardly exceed the experimental error involved in the methods available for their determination; and (c)

that hydrogen has replaced magnesium from the exchange complex of these soils more than it has replaced calcium.

11. As a result of modifications made by the author in the methods used in the cation exchange determinations, very good agreement was obtained between the total cations extracted and the total cation exchange capacity.

12. The accumulation of a higher percentage of ammonium tartrate extractable iron in the "B" horizon of the Duck Mountain soil profile reflects a greater degree of mineral weathering than has taken place in the soils of the Valley Landscape areas. This accumulation of extractable iron is evidence not only of a greater degree of degradation but also of the fact that the degradation process has been in operation over a longer period of time.

13. Tree invasion in the Upper Valley Plain has been responsible for the degradation of the soils in this area. The source of this invasion was the forest vegetation in the deep ravines and in the surrounding mountain areas. The cause of this invasion was a change in the humidity climate which favored tree growth on the upland plain.

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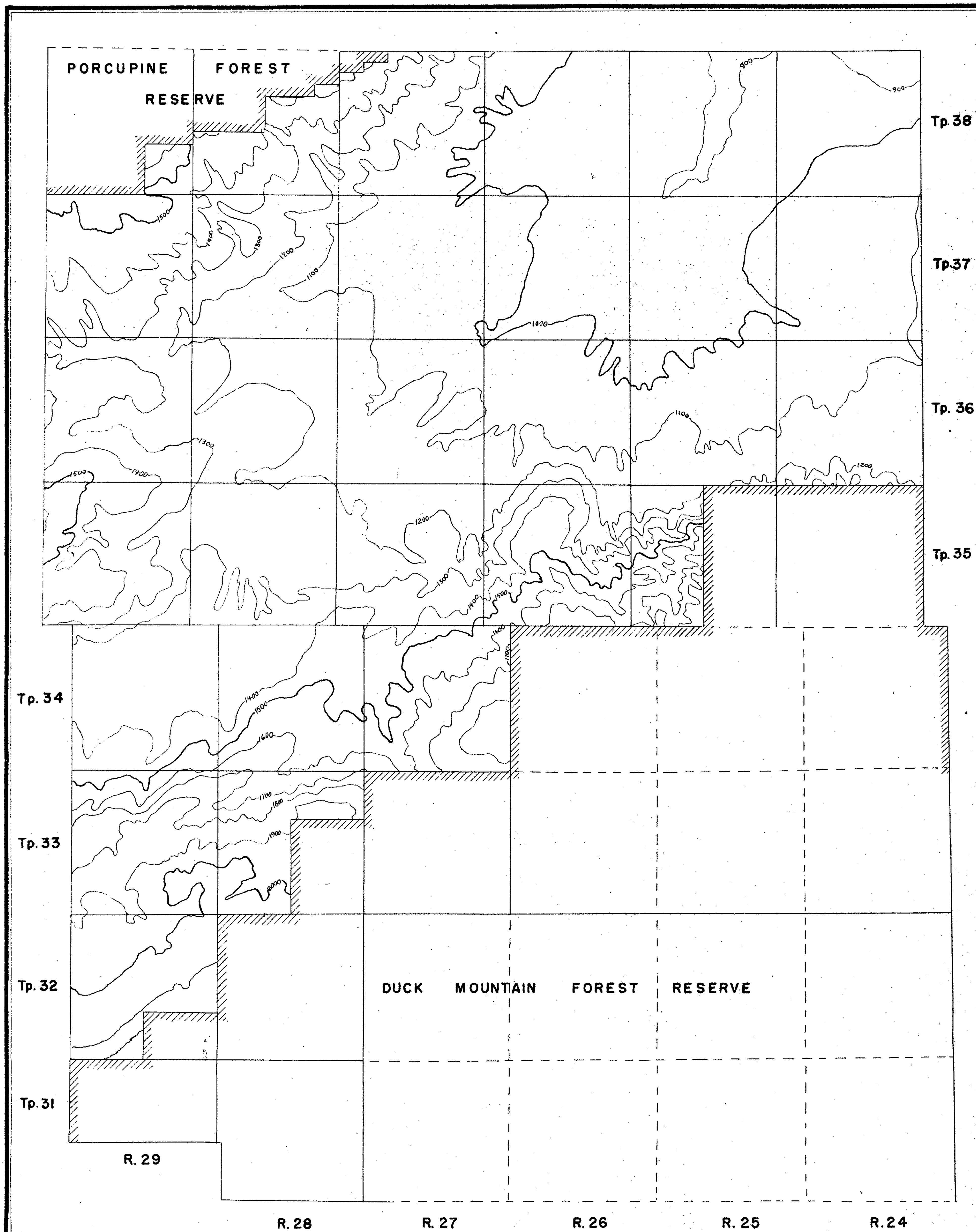
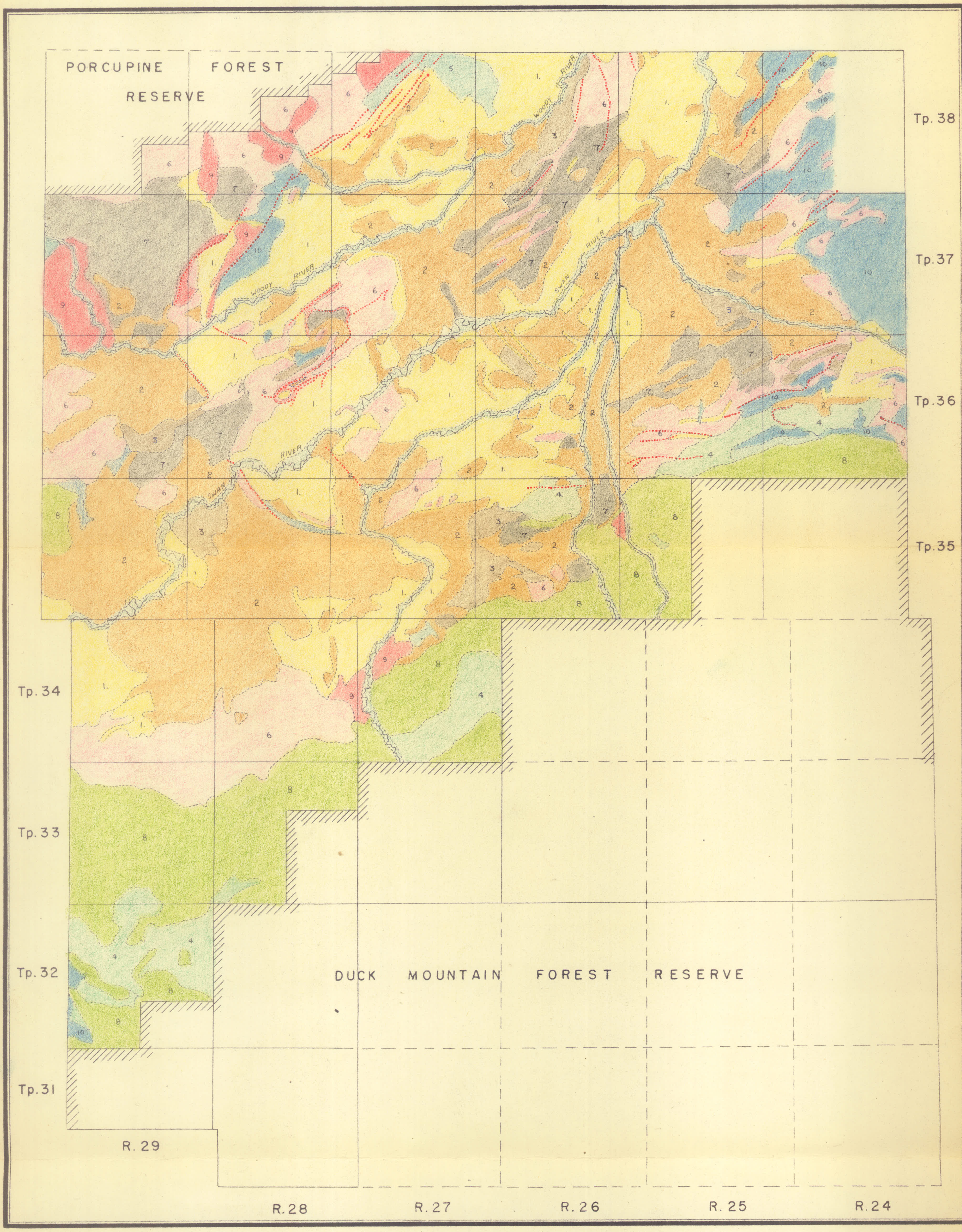
MAP NO. 1

# CONTOUR MAP
# SWAN RIVER AREA, MANITOBA




*Contour detail showing feet above sea level, from sectional maps No. 221, 171. Topographical Survey of Canada.*

# SURFACE DEPOSITS
# SWAN RIVER AREA, MANITOBA




Deltaic and Shallow Lacustrine Deposits

- 1 *fine sand to sandy loam*
- 2 *clay loam to silty clay loam*
- 3 *heavy clay loam to clay*

Shale Clay:

- 4

Boulder Till:

- 6 *calcareous clay loam boulder till*
- 7 *boulder clay*
- 8 *boulder till intermixed with shale clay*

Lake Beaches:

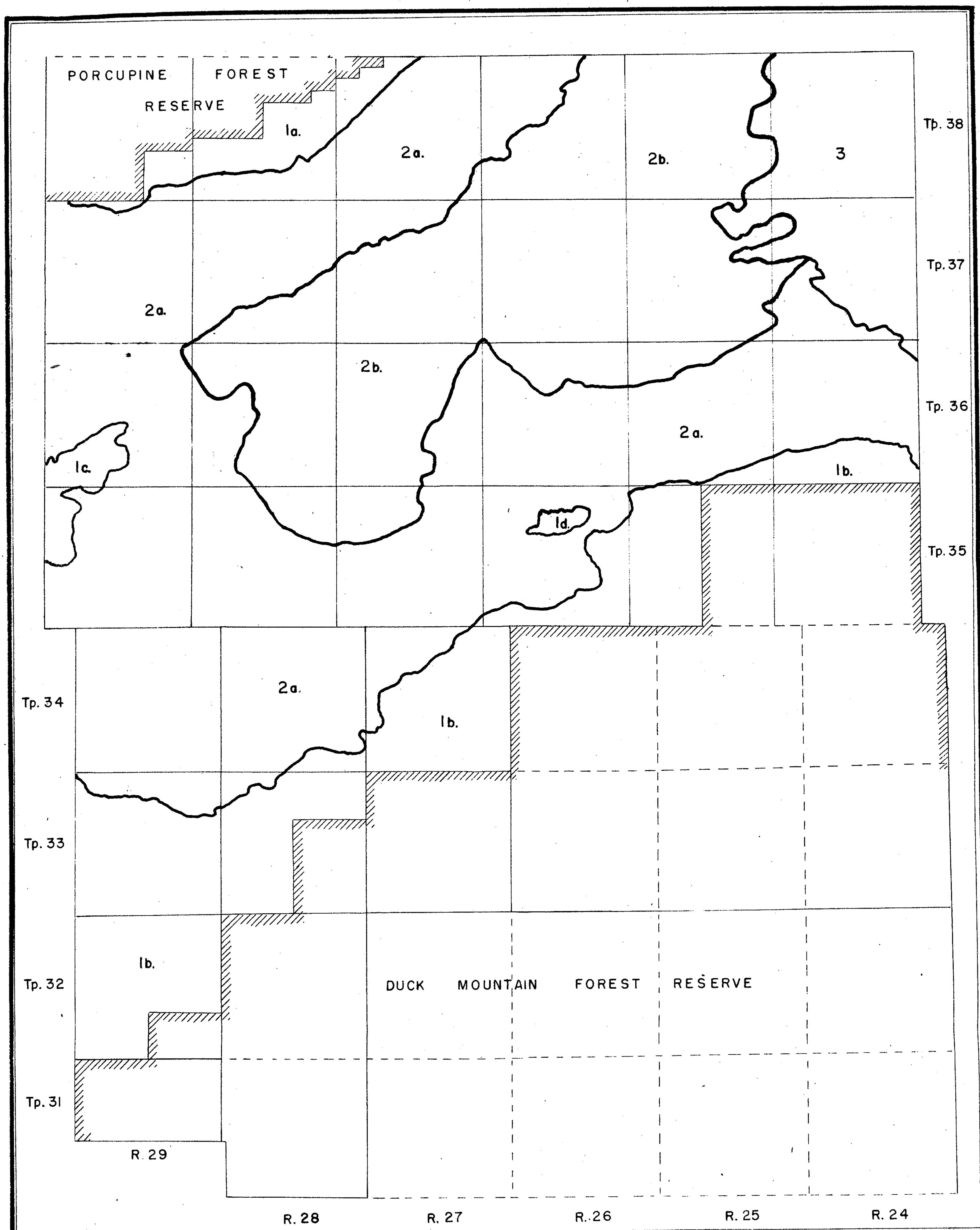
Recent Alluvium

Peat Deposits

Gravel Outwash

MAP NO. 3

# LANDSCAPE AREAS
# SWAN RIVER AREA, MANITOBA




**I. MOUNTAIN LANDSCAPE AREA**

a. Porcupine Mountain
b. Duck Mountain
c. Thunder Hill
d. Minitonas Hill

**2. VALLEY LANDSCAPE AREA**

a. Upper Valley Plain
b. Lower Valley Plain

**3. LOWLANDS LANDSCAPE AREA**