

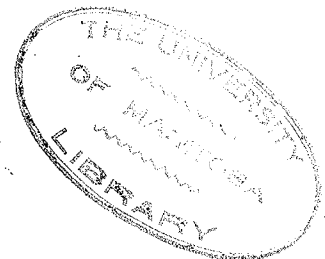
A STUDY OF THE EFFECT OF SOIL FORMING
PROCESSES ON SERPENTINE ROCK AT
CLANGULA LAKE, MANITOBA

A Thesis
Presented to
the Faculty of Graduate Studies
The University of Manitoba

In Partial Fulfilment
of the Requirements for the Degree
Master of Science

by
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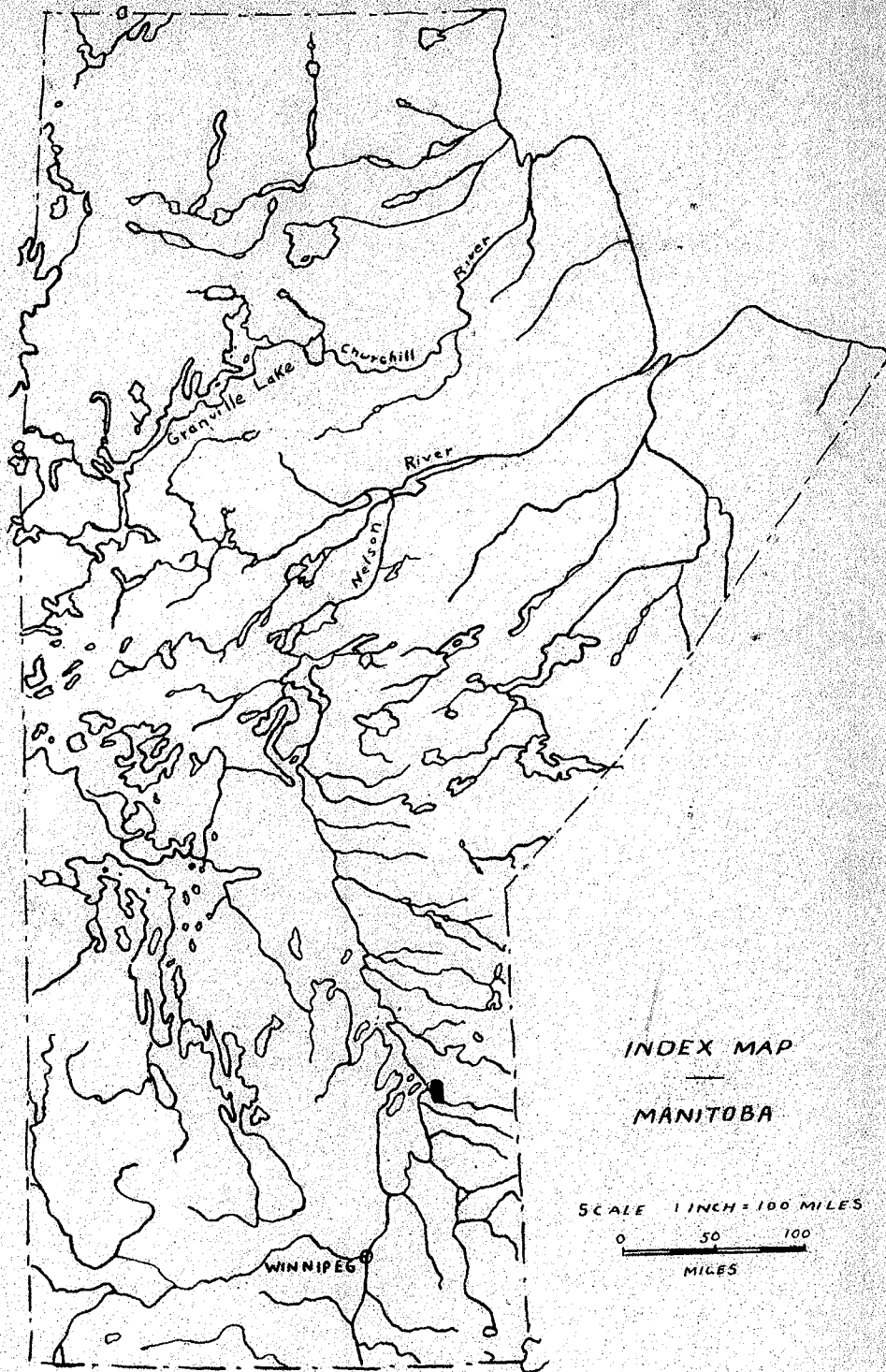
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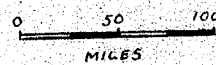
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INDEX MAP
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MANITOBA

SCALE 1 INCH = 100 MILES



CHAPTER I

THE PROBLEM

Extensive areas in the vicinity of Clangula Lake are covered by a reddish brown to greyish brown soil. This soil overlies a narrow zone of serpentinized peridotite which extends eastward from Clangula Lake for several miles. The most prominent exposure occurs at the serpentine quarries about half a mile east of the lake.

THE NATURE OF THE PROBLEM

It has been suggested that this soil is a residual weathering product of the underlying serpentine rock. If this assumption is correct, certain controversies arise regarding the origin of the soil and the nature of the weathering. The lack of a glacial drift mantle over much of the area would suggest either post-glacial denudation of the drift, followed by considerable chemical weathering of the serpentine rock, or pre-glacial weathering which was subsequently modified by glacial and post-glacial phenomena. The problem, therefore, is resolved into 1) a study of the weathering products to verify their residual character, and to determine the processes by which they were formed, and 2) a study of the Pleistocene geology of the area to determine the local effects of glaciation.

THE APPROACH TO THE PROBLEM

The field work on the problem was done in September, 1948, while the writer was employed by the Manitoba Mines Branch as a student assistant on a geological survey party in the English Brook area. Samples of soil profiles were taken from surface to "unweathered" bedrock from the quarries east of Clangula Lake. The area surrounding the quarries was mapped by pace and compass with the object of preparing a large-scale topographic and geologic map.

The laboratory procedures consisted primarily of chemical analysis of soil and rock samples. A petrographic study was attempted, but this was found to be of little value because of the highly altered condition of the bedrock. X-ray powder analysis was used in an attempt to correlate the chemical analyses with mineralogical changes.

SUMMARY OF CONCLUSIONS

1. The soil covering the exposures of serpentized peridotite is of a residual nature and appears to be a Brown Podzolic soil, formed since glaciation. This Brown Podzolic is a juvenile soil, representing the incipient stages of the process of podzolization.

2. The original "unweathered" exposures of serpentine rock were due to the fortunate position of the valley with

respect to a high ridge to the north which shielded the valley from the major portion of the drift carried by the glaciers. The finer drift, deposited in the valley, was removed subsequently in several places by glacial meltwaters which were concentrated in the valley after the retreat of the glaciers, leaving only scattered boulders on top of the exposed bedrock.

3. Colour differences in the residual soil are explained by a variation in the oxidation state of the iron. Areas of high ferric-ferrous ratio are characterized by an apple-green bedrock, comparatively high in ferric iron minerals, which was weathered to a reddish brown soil, whereas areas of low ferric-ferrous ratio are characterized by a greyish green bedrock, deficient in ferric iron minerals, which was weathered to a greyish brown soil. The colour differences are due to original differences in the parent material rather than to differences in the soil forming process.

CHAPTER II

THEORETICAL CONSIDERATIONS

It is only in recent years that the Brown Podzolic soil has been recognized as a separate soil type. As a result of this, there is a marked dearth of literature dealing with the quantitative aspects of the problem. The only literature available to the writer are textbooks which deal with the generalized problem rather than with specific examples (3, 5). However, since many geologists have only a scant knowledge of soil forming processes, the writer feels that an elementary discussion of the process of podzolization is a necessary addition to the clarification of the problem.

PODZOLIZATION

In general, the process of podzolization takes place in cool humid climates, where evaporation is at a minimum. The soil environment is distinctly acid due to the removal of bases by the percolating waters and to the development of organic acids in the surface layer. The first chemical change which takes place in the soil profile after the mechanical disintegration of the original rock is the depletion of the alkalis and alkaline earths in the form of bicarbonates due to the action of waters charged with

carbon dioxide, derived from the activity of soil organisms. With the development of greater acidity, minerals are attacked and the sesquioxides are leached out from the upper or A horizon of the soil profile, and then are redeposited in the lower or B horizon of the profile due in part to the mutual coagulation of the colloidal iron and humus and in part to a lowered porosity of the soil material. The silica of the decomposed silicates, which is stable in an acid medium, is precipitated and retained. Thus the A horizon, with time, becomes more siliceous and the B horizon becomes richer in iron. Also, as the bases are removed and the soil becomes acid, clay is dispersed. It becomes mobile and is carried down to the B horizon by the process of illuviation.

Soil Profile of a Podzol

A typical soil profile of a podzol, formed as a result of intense podzolization possesses the following morphological characteristics:

A₀ - consists of an accumulation of undecomposed or partly decomposed plant residues.

A₁ - impregnated with dead and living roots and humus; the organic matter content diminishes rapidly with depth; gray to brown in colour; no well defined structure; silty, mellow, and of loose consistency.

A₂ - lighter in colour than the A₁ horizon; the colour is ash-gray to white; the structure is powdery to granular and may be laminated in the lower portion.

B₁ - heavier in texture than the A horizon; brown to dark brown or reddish brown.

B₂ - brown to reddish brown in colour; compact in constitution; lighter texture.

Brown Podzolic Soils

The Brown Podzolic soils have been reported principally from the New England States and Eastern Canada. These soils may be characterized as imperfectly developed podzols, the A₂ horizon being feeble, or even lacking. The chemical composition of the soil material in the various horizons of brown podzolic soils is considerably more uniform than in podzols. Some leaching of bases has begun, but, owing to their juvenile condition, the sesquioxides and silica have not been removed to any appreciable extent. However, the minerals containing sesquioxides have been weathered, even though the oxides are not yet mobile. Thus such soils represent an incipient or juvenile stage of podzolization.

CHAPTER III

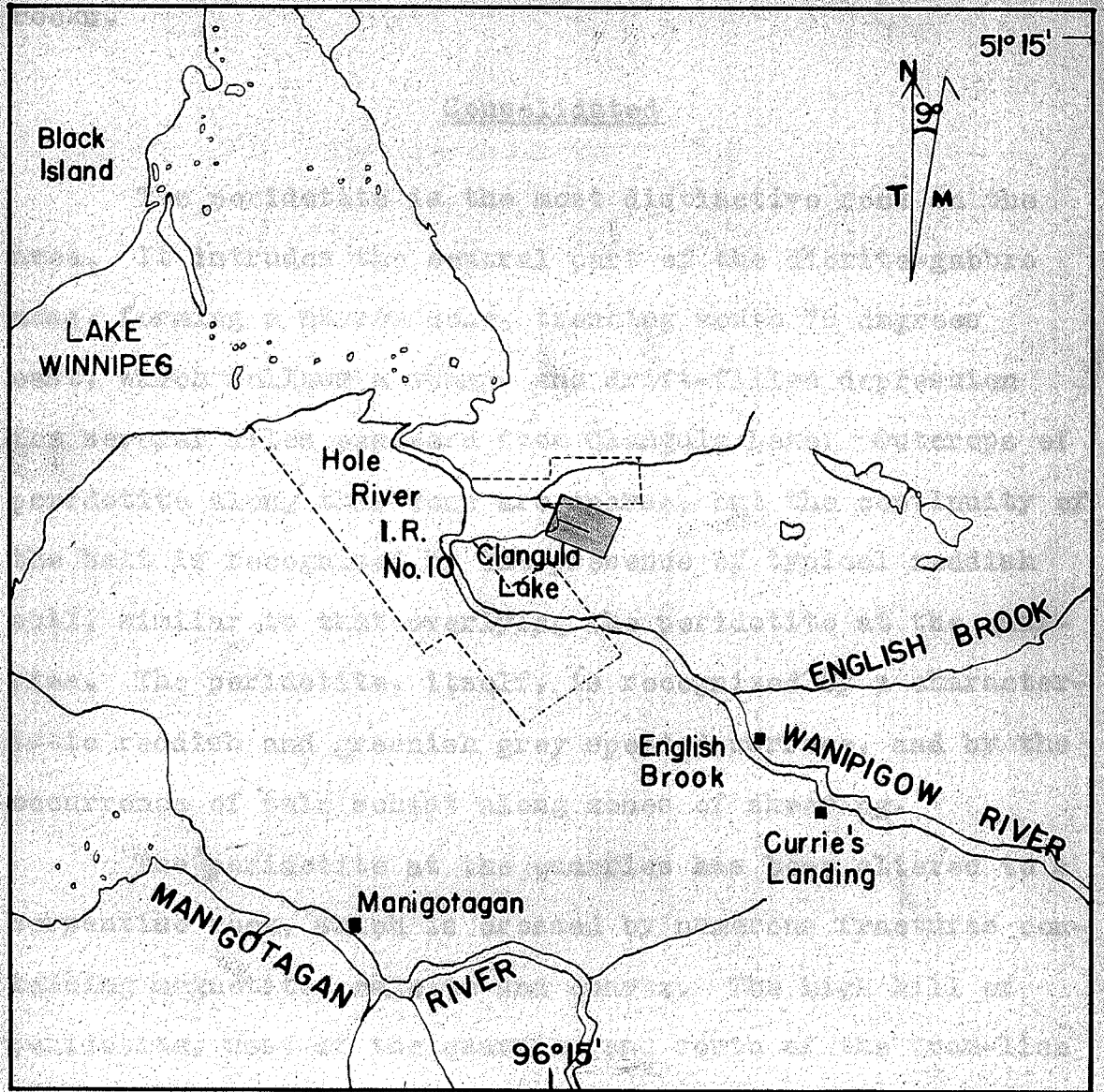
AREAL DESCRIPTION

The area under investigation extends eastward from the eastern extremity of Clangula Lake, which is about five miles north of Manigotagan Settlement and one hundred miles north-east of Winnipeg. Manigotagan Settlement, located at the mouth of the Manigotagan River, may be reached by aeroplane from Lac du Bonnet, or by lake boat from Winnipeg. A good road leads from Manigotagan to English Brook, via Currie's Landing, from which point Clangula Lake may be reached by a water route along the Wanipigow River.

GENERAL GEOLOGY (4, 9)

The rocks of the area are all Precambrian in age, and may be divided into three major units. The oldest unit is a belt of sedimentary rocks, interbedded with volcanic flows, which, in general, follows the course of the Wanipigow River. To the north of this is an intrusive mass, which parallels the sediments and which varies in composition from a quartz-diorite to a gabbro. It is this mass that forms the country rock for the peridotite at Clangula Lake. Further north again the area is overlain by a complex series of granitic

PLATE II



Scale: 2 Miles to 1 Inch



INDEX MAP OF THE CLANGULA LAKE AREA

rocks.

Consolidated

The peridotite is the most distinctive rock in the area. It intrudes the central part of the diorite-gabbro mass, forming a narrow zone, trending south 70 degrees east, which follows a swamp- and drift-filled depression for several miles eastward from Clangula Lake. Outcrops of peridotite along this zone are sparse, but the continuity of the belt is recognized by the presence of typical reddish soil, similar to that overlying the peridotite at the quarries. The peridotite, itself, is recognized by a characteristic reddish and greenish grey spotted surface, and by the occurrence of talc schist along zones of shearing.

The peridotite at the quarries has been altered to a serpentine rock, which is crossed by numerous fractures containing magnetite, calcite and quartz. The high hill of peridotite, west of the quarries and south of the tram-line is cut by a few small veinlets of cross-fibre serpentine asbestos and carbonate, up to a quarter of an inch wide. The serpentine bedrock, although highly altered, is denoted as "unweathered" throughout this report since it forms the parent material for the reddish soil which overlies it.

Unconsolidated

The unconsolidated material overlying the serpentine rock in the vicinity of the quarries may be divided into the two major units of residual material and glacial drift. The lithosolic material varies in colour from reddish brown to greyish brown. The reddish brown lithosolic material overlies an apple-green bedrock, whereas the greyish brown lithosolic material overlies a greyish green bedrock. Definite gradations from bedrock through the overlying lithosol to the surface soil may be seen along the quarry walls. Even in the upper portions of the profiles, the lithosol consists of angular to sub-angular fragments up to three inches in diameter. A difference in texture of the reddish brown and greyish brown weathering products is easily noticed. The red lithosol consists chiefly of equi-sized fragments, whereas the grey lithosol consists of larger fragments in a matrix of finer particles. Definite "contacts" are seen between the red and gray soils in vertical section, but these "contacts" cannot be traced horizontally.

The glacial cover, although extensive in neighboring areas, is comparatively sparse in the valley defined by the peridotite. In general, a fine clayey drift covers the lower-lying areas between the residual soil exposures, which occur on the top and sides of small knolls rising slightly above

the general valley level. Several large glacial boulders lie on top of the residual soil. An excavation was made with a pick under one of these erratics, and it was found that it was firmly embedded in the soil with no other material present. Glacial striae, observed on the peridotite hill, south of the tram-line trend at south 65 degrees west.

TOPOGRAPHY AND PHYSIOGRAPHY

The regional topography is typical of the Precambrian shield, consisting of numerous low ridges and intervening swampy depressions. The relief is seldom over 100 feet except in the area north-east of Clangula Lake, where there are several conspicuous hills. The bedrock topography has been only slightly modified by glacial erosion, because the trend of the rock ridges and of the drainage courses is closely related to the structure and type of underlying bedrock. Physiographically, the district, therefore naturally falls into divisions whose outlines are determined by the distribution of the volcanic and sedimentary rocks within the granites.

The topography in the vicinity of the quarries may be divided into two distinct units; namely, ridges formed by the diorite-gabbro intrusive mass, and the peridotite valley. To the south of the quarries, the diorite occurs as a low-lying, broad ridge slightly higher than the level of the valley. On

the north side, however, the diorite rises abruptly from the valley floor, forming a 150-foot ridge which marks the northern contact of the intrusive mass. The northern face of the ridge drops steeply into a narrow depression, which is, in turn, flanked on the north by a series of granite ridges forming a maturely dissected plateau.

The valley trends at south 70 degrees east, following the serpentine belt. The low-lying parts of the valley are swamp- and drift-covered. The drainage course through the valley to Clangula Lake lies between the quarries and the high diorite ridge to the north, in a marked swampy depression. The exposures of peridotite and residual soil occur, for the main part, as slight knolls rising above the general elevation of the southern slope of the valley. The trend of these exposures is north 65 degrees east, as opposed to the south-easterly trend of the valley. In general, they are comparatively steep on the north-east side, and slope off gently towards the south-west. A prominent hill of peridotite which rises 60 feet above the valley slope and which conforms to the general trend and shape of the soil and rock exposures, occurs to the west of the quarries and south of the tram-line.

CHAPTER IV

FIELD PROCEDURES

The field work necessary for the problem, was completed by the writer in September, 1948, and consisted of three projects. The area was mapped by refined pace and compass methods with the object of preparing a detailed geologic and topographic map. Samples were obtained of characteristic weathering profiles and glacial drift to determine the chemical nature of the soil, and typical locations were photographed to illustrate various points of interest.

MAPPING

A base-line for the mapping was established along the old tram-line which runs south 70 degrees east from the wharf on Clangula Lake to the quarries, and it was extended eastward at the same bearing to the boundary of the map area. Crosslines were plotted, perpendicular to the base-line, every 500 feet. The horizontal control for the mapping was by pace and compass. This was considered sufficiently accurate for the work, because all cross-line traverses originated at and were tied-in to definite points on the base-line, within the limits of mappable error. The vertical control for elevations was by Brunton compass used as a hand-level. The

elevations were checked back to established points as a proof of sufficient accuracy. Elevations were carried from a datum level of 0.0, which was established for Clangula Lake, along the base-line and along the parts of the cross-lines which were not covered by extensive swampy areas. Extra elevations were taken at critical points in order to have sufficient data to complete the contours. The height of the diorite ridge to the north of the quarries was measured by vertical angles, so the contours on the map represent only an idealized slope.

A topographic and geologic map of the area was drawn up at the scale of 200 feet to one inch. From the map a north-south profile was constructed, passing through the quarries, with the vertical scale exaggerated four times the horizontal scale. The quarries were mapped in detail by tape and compass, and a plan was drawn, showing the outlines and depths of the pits and the sample locations.

SAMPLING

Sampling was carried out in as systematic manner as possible to avoid contamination and to ensure a representative portion of the whole mass. The profile samples were obtained by taking a bulk sample of the unconsolidated material from a foot-square pit between the depths indicated in Table II. Each bulk sample was rolled and quartered on a

TABLE I

SAMPLE DESIGNATIONS

PROFILE A - NORTH SIDE OF MAIN QUARRY		
Depth in inches	Designation	Description
0 - 8	A1	Reddish brown soil
8 - 16	A2	Soil and rock rubble
16 - 24	A3	Soil and rock rubble
24 - 32	A4	Soil and rock rubble
32 - 40	A5	Rusty serpentine rock
40 - 45	A6	Apple-green serpentine rock

PROFILE B - EAST SIDE OF MAIN QUARRY		
Depth in inches	Designation	Description
0 - 15	B1	Greyish brown soil
15 - 30	B2	Soil and rock rubble
30 - 40	B3	Greyish green serpentine rock

clean piece of canvas until it was reduced to a convenient size for transportation. The bedrock samples are chip samples of the relatively hard rock at the bottom of each pit, rather than a portion of a bulk sample.

Six samples of equally-spaced volumes, from surface to bedrock were taken of a profile at the north side of the main quarry, representative of the reddish brown residual soil overlying an apple-green "unweathered" serpentine rock. Three samples were taken of a profile, representative of the greyish brown soil overlying a greyish green bedrock. Other samples used were a grab sample of the glacial drift south of the quarries, and chip samples for thin sections of the freshest serpentine rock observed.

PHOTOGRAPHS

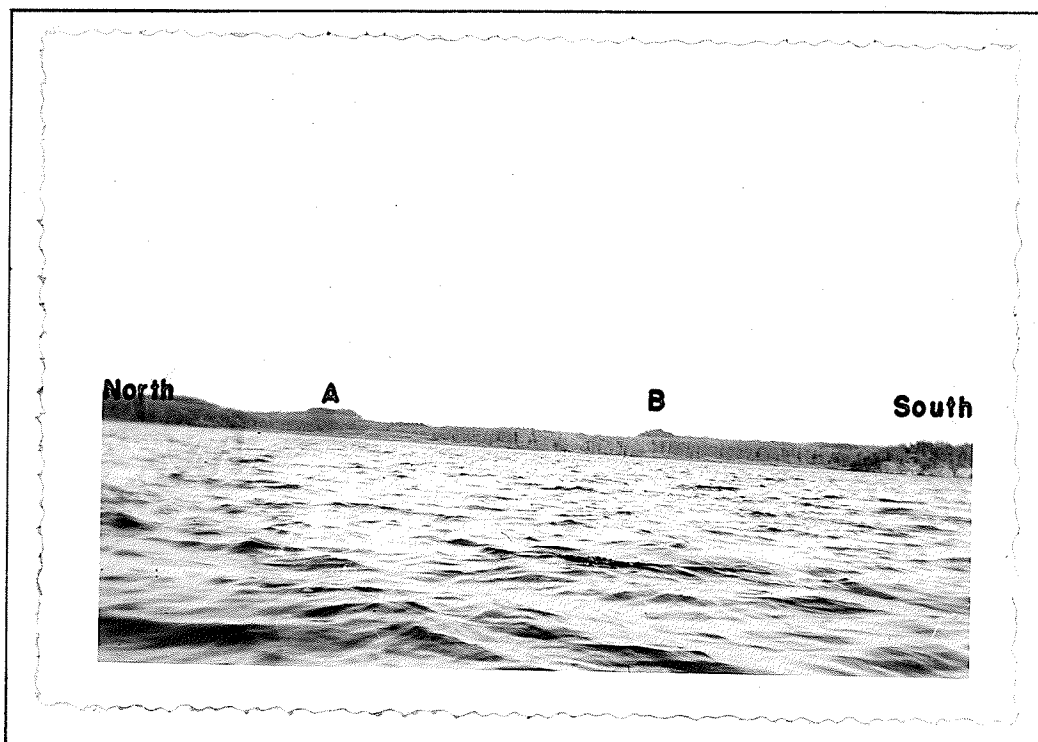
Points of interest to the problem were photographed. These photographs were considered an integral part of the field work, and are described in Plate III to Plate VIII on the following pages.

PLATE III



Panorama of the map area, taken from the top of the ridge, north of the quarries. Patches of weathered serpentine not covered by glacial drift are delineated by sparse vegetation.

PLATE IV



North-south skyline profile taken from Clangula Lake showing the high diorite ridge (A) north of the valley and the peridotite hill (B) south of the tram-line.

PLATE V.



Northern part of the main quarry showing locations of analyzed profiles. Red profile is at A; grey profile, at B.

PLATE VI



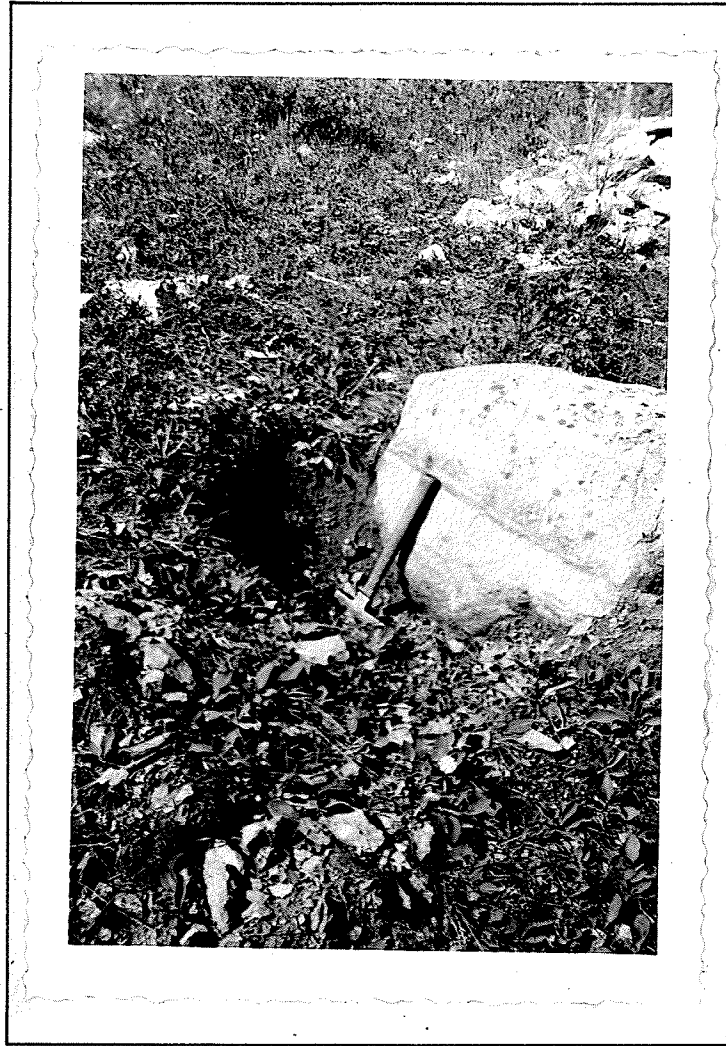
South face of the main quarry showing gradation from apple-green serpentine rock below to brown podzolic soil above. Notice the glacial erratic directly on top of the residual soil.

PLATE VII



Weathered exposure in the cut on the tram-line, showing textural differences in the grey (left) and red (right) weathering products. A vertical "contact" between the two types of weathering is seen near the centre of the photograph.

PLATE VIII



Glacial erratic resting directly on weathered serpentine. Notice absence of glacial soil.

CHAPTER V

LABORATORY PROCEDURES

Owing to the highly altered nature of the serpentinitized peridotite, the major laboratory study was limited to chemical analyses of soil profiles. The result of this study is supplemented by information from X-ray powder photographs and thin-sections in an attempt to correlate changes in the chemical properties with mineralogical changes.

X-RAY POWDER PHOTOGRAPHS

X-ray powder photographs were taken of the top and bottom portions of profile A to determine the changes in the major constituents. Powder photographs were also used to determine possible differences between the red soil overlying the outcrops of serpentine and the drift surrounding the outcrop areas.

Profile A

X-ray powder photographs were taken of samples A5 and A1. The spacings obtained are compared in Table III and Table IV with standard ASTM values. In both photographs, the major lines represent serpentine, indicating that both samples are composed primarily of this mineral, with limited undetectable

TABLE III

SPACINGS OF X-RAY POWDER PHOTOGRAPH OF SAMPLE A5

Measured values		Serpentine ASTM-II-138		Dolomite ASTM-II-1579	
I	d	I	d	I	d
10	7.35	10	7.38		
2	4.63	5	4.62		
10	3.70	9	3.65		
4	2.90			10	2.881
8	2.53	8	2.51		
1	2.18	6	2.15	6	2.189
0.5	2.01			5	2.012
1.5	1.795			7	1.801
0.5	1.501	2	1.498		
0.5	1.459			4	1.462
0.5	1.415	2	1.407		
0.5	1.382			6	1.386
1	1.314	6	1.309		
0.5	1.165			5	1.164
0.5	1.113			4	1.120
0.5	1.054	4	1.099		
1	.998	4	.991		

TABLE III

SPACINGS OF X-RAY POWDER PHOTOGRAPH OF SAMPLE A1

Measured values		Serpentine ASTM-II-138	
I	d	I	d
10	7.29	10	7.38
4	4.63	5	4.62
8	3.62	9	3.65
9	2.47	4	2.46
3	2.14	6	2.15
0.5	1.805	2	1.821
0.5	1.714	4	1.710
5	1.528	7	1.522

TABLE IV

SPACINGS OF X-RAY POWDER PHOTOGRAPH OF DRIFT
SURROUNDING OUTCROP AREAS

Measured values		Quartz ASTM-II-1007		Serpentine ASTM-II-138	
I	d	I	d	I	d
4	7.29			10	7.38
2	4.19	6	4.29		
3	3.65			9	3.65
10	3.34	10	3.35		
1	2.50	6	2.45	8	2.51
0.5	2.28	6	2.28		
1	2.13	6	2.11		
0.5	1.979	4	1.97		
1	1.812	8	1.81		
0.5	1.667	6	1.66		
2	1.537	8	1.537		
0.5	1.456	4	1.454		
2	1.372	8	1.371		

amounts of accessory minerals. In the photograph of sample A5, several of the spacings of lower intensities are unaccounted for by the ASTM values for serpentine. These were found to correspond to the values for the more intense dolomite spacings. Since carbonate veinlets were observed in thin sections of the "unweathered" rock, it is logical to interpret the spacings as those of dolomite. The presence of only a few dolomite spacings indicates a comparatively small amount of dolomite in the sample.

Soil and Drift

An X-ray powder photograph was taken of the drift surrounding the outcrop areas to determine the difference between this and the red soil overlying the serpentine rock. A comparison of measured spacings with ASTM values shows that the drift is composed principally of quartz with a small amount of serpentine.

PETROGRAPHIC STUDY

Several thin sections were cut from different profile levels of the weathered serpentine to compare mineralogical characteristics of the red and grey profiles. A limonitic coating which obscured all other minerals in the upper portions of the profiles made this method of comparison of little value. The prime use of the petrographic study, therefore,

became the description of the "unweathered" serpentine rock, as observed in the freshest samples obtainable.

Petrographic Description of Serpentine Rock

The serpentine rock is composed of antigorite with small amounts of magnetite, carbonate, and chrysotile. The antigorite constitutes the main mass of the rock and occurs as a felted mat of fibres with each fibre having parallel extinction under crossed nicols. The fibres are arranged in two definite directions perpendicular to each other so that when one set of fibres shows maximum interference colours, the other set is at extinction. One set of fibres is developed to a much greater degree than the other.

Magnetite occurs as irregular-shaped masses, small anhedral grains, disconnected rings, and streaks. Even in the freshest sections, it is covered in scattered areas by a translucent coating of limonite. The first two modes of occurrence bear no textural relationship to the felted antigorite matrix. On the other hand, however, the narrow disconnected rings of magnetite, surround areas of antigorite forming a "crystal outline", suggestive of that of olivine. The streaks of magnetite occur parallel to the major direction of the antigorite fibres.

The carbonate, shown by X-ray powder analysis to be dolomite, occurs as narrow veinlets which generally cross-cut

the major direction of the antigorite. However, in some areas, the dolomite occurs as streaks, parallel to the antigorite fibres.

The chrysotile which is commonly associated with the dolomite, occurs as veinlets, filling fracture cracks in the antigorite matrix. It is distinguished from antigorite by the absence of the felted texture, and by its characteristic orientation perpendicular to the walls of the veinlets.

CHEMICAL ANALYSIS

Two soil profiles were analyzed from bedrock to surface. Profile A, consisting of six samples, is representative of the apple-green bedrock overlain by a reddish brown soil. Profile B, consisting of three samples, is representative of the greyish green bedrock overlain by a greyish brown soil. The analyses were carried out with the objectives of verifying the residual origin of the soil, and of determining the chemical nature of the soil and the chemical differences responsible for the colour variations of the two profiles. The results obtained are tabulated on the following page.

The methods of chemical analysis as outlined below and as shown diagrammatically on Plate IX, are a compilation by the writer of the procedures recommended by several standard references (1, 7, 8). The methods chosen are those that

TABLE V

CHEMICAL ANALYSES OF PROFILE A

Constituent	Sample number					
	A6	A5	A4	A3	A2	A1
SiO ₂	30.25	32.32	33.14	34.07	35.77	35.12
Al ₂ O ₃	9.12	8.56	9.18	9.72	10.35	20.34
Fe ₂ O ₃	4.62	5.35	5.21	5.64	6.05	7.01
FeO	.16	.15	.15	.11	.07	.06
MgO	35.31	34.89	34.30	33.86	33.48	26.02
CaO	5.39	3.80	2.51	.61	.17	.31
Na ₂ O	.04	.04	.04	.03	.02	.02
K ₂ O	.09	.08	.08	.07	.06	.05
H ₂ O _f	10.17	11.07	10.98	11.33	9.73	6.57
H ₂ O-	.79	1.19	1.44	1.61	1.91	3.43
CO ₂	3.25	1.61	1.44	1.27	.61	.06
TiO ₂	trace	trace	trace	trace	trace	trace
P ₂ O ₅	.34	.43	.66	.78	.88	.93
MnO	.16	.15	.16	.17	.18	.18
NiO	.16	.12	.26	.31	.33	.34
Total	99.85	99.64	99.55	99.58	99.61	100.44

TABLE VI

CHEMICAL ANALYSES OF PROFILE B

Constituent	Sample number		
	B3	B2	B1
SiO ₂	31.90	32.41	32.97
Al ₂ O ₃	7.66	10.36	21.45
Fe ₂ O ₃	3.07	4.68	6.15
FeO	1.53	1.39	.62
MgO	40.50	36.15	27.61
CaO	.77	.40	.12
Na ₂ O	.05	.04	.02
K ₂ O	.08	.06	.04
H ₂ O _f	11.89	11.10	7.95
H ₂ O ₋	.71	1.49	2.04
CO ₂	1.34	.93	.23
TiO ₂	trace	trace	trace
P ₂ O ₅	trace	trace	trace
MnO	.11	.14	.15
NiO	.31	.36	.39
Total	99.92	99.51	99.74

are consistent with both speed and accuracy of analysis, and that take into consideration the available facilities.

Preparation of the Sample

The bulk sample from the field was quartered down to analysis size by the conventional methods. The total sample was rolled on glazed paper, by lifting alternate corners of the sheet, and pulling them towards the opposite corner. Care was taken that the sample rolled with the paper. After the sample was thoroughly mixed, it was piled in the centre of the paper, and divided into approximately equal quarters. Alternate quarters were rejected and the procedure was repeated with the remaining portions of the sample until it was reduced to a convenient amount for analysis. The sample was then broken down in a Plattner diamond mortar until the individual particles would pass through a -35 mesh screen. The final step in the preparation was to powder the sample in an agate mortar until it would pass through a -80 mesh screen. The resulting powder was rolled on glazed paper to ensure thorough mixing, and then was transferred in small portions on a spatula to a test-tube. Precaution was observed throughout the process of quartering and crushing, to avoid loss of the sample and contamination by foreign material.

Chemical Analysis

Eight separate portions of the sample were used for the chemical analysis. The main portion was analyzed in duplicate for moisture content, silica, aluminium, titanium, calcium and magnesium. Separate portions were analyzed in duplicate for total iron, ferrous iron, and combined water. Single analyses were made for nickel, manganese and phosphorus, sodium and potassium, and carbon dioxide.

The Main Portion

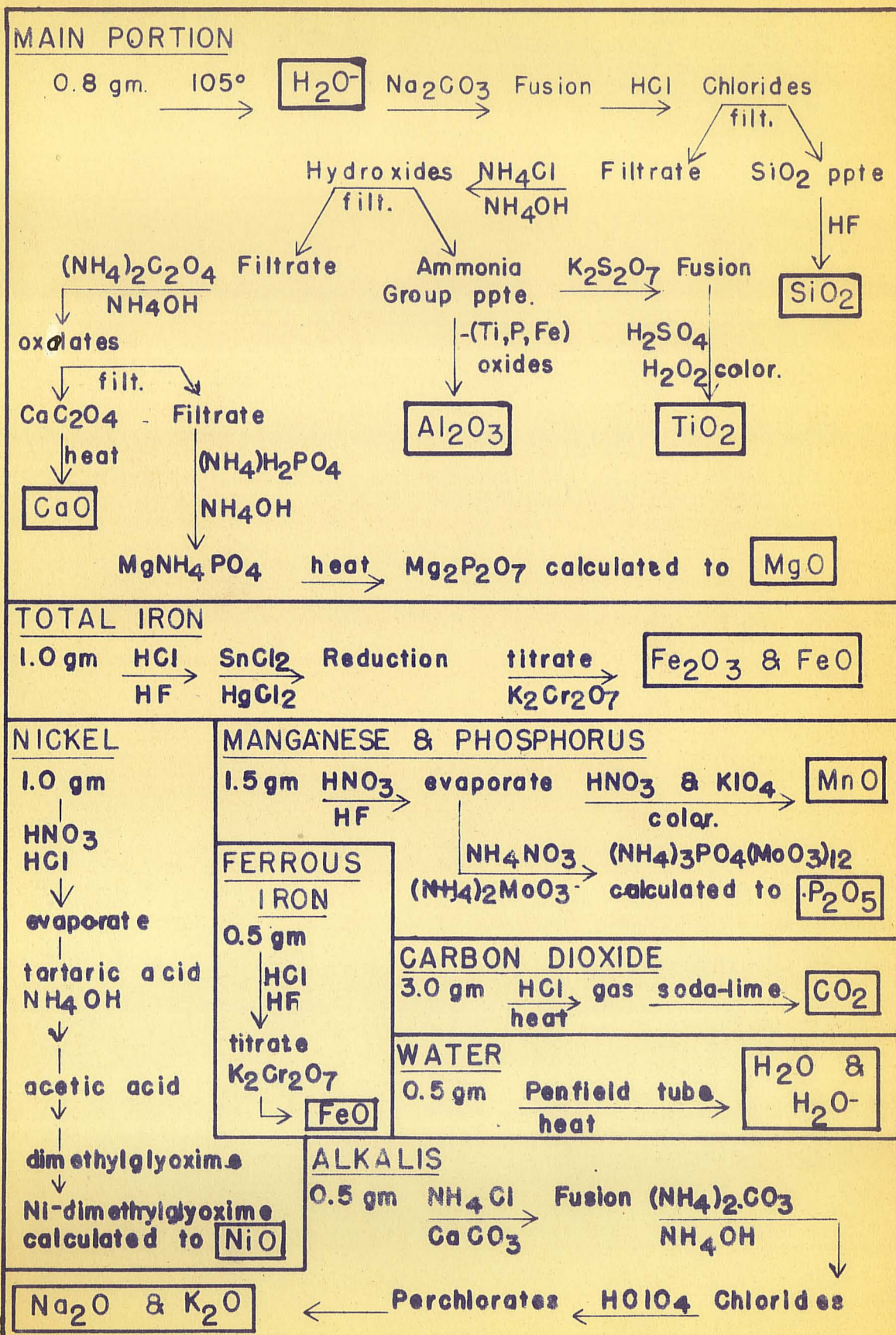
Moisture. A 0.8000 gram portion of rock powder is placed in an ignited weighed platinum crucible. The crucible is weighed again, heated in an oven at 105°C for one hour, cooled and reweighed. The loss in weight is the moisture content, recorded as H₂O-.

Silica. Four grams of sodium carbonate are added in small portions to the sample in the crucible, with thorough mixing after each addition. The mixture is then heated over a choked Tyrell burner for 5 minutes, over a full Tyrell burner for 10 minutes, and finally over a Meker burner for 20 minutes.

After the crucible is cool, the melt is transferred with water to a porcelain crucible. The casserole is covered, and 15 ml. of concentrated hydrochloric acid is added in

PLATE IX

FLOW SHEET OF CHEMICAL ANALYSIS



small portions. Part of the acid is used to clean out the crucible before it is added to the casserole. The crucible is washed with water, ignited, cooled and weighed.

The casserole is placed on a steam bath and is evaporated to dryness. Five ml. of concentrated hydrochloric acid and 40 ml. of water are added to the evaporated salts. The casserole is replaced on the steam bath until all the salts are in solution, and the contents are filtered to separate the insoluble silica. The filtrate is returned to the casserole and the operations of evaporation and solution are repeated. The solution is filtered through a second paper to separate the remaining silica.

The two papers containing the silica residue are placed in the platinum crucible. The crucible is heated over a low flame with the cover partially open until the volatiles are discharged, over a moderate flame until the carbon is burned off and over a Meker burner with the cover closed for one hour. The crucible is cooled in a dessicator, weighed, reheated for half an hour, cooled and weighed to constant weight.

The silica residue is wet with one ml. of water and 6 drops of 1:1 sulphuric acid. Ten ml. of hydrofluoric acid are added, and the solution is evaporated until sulphuric acid fumes appear. The crucible is heated over a Meker burner for 10 minutes, cooled and weighed. The difference is

the weight of silica present in the sample.

The ammonia group. Eight grams of ammonium chloride are added to the filtrate from the silica determination. The solution is heated with stirring, until a precipitate is formed. Ammonium hydroxide is added dropwise until the solution is alkaline to brom-cresol purple indicator. If the neutral point is passed, 1:1 hydrochloric acid may be added, and the procedure repeated.

The solution is boiled for one minute, the precipitate is allowed to settle, and the hot solution is then filtered. The paper and the precipitate are transferred to the original beaker, and the precipitate is dissolved by 5 ml. of hydrochloric acid in 100 ml. of water. The solution is heated and stirred until the paper becomes pulp, and the precipitation and filtration are completed as before.

The precipitate and paper are added to the residue remaining in the platinum crucible after the silica determination. The crucible is heated over a small flame, to discharge volatiles, over a moderate flame to burn off the carbon, over a Meker burner for 40 minutes and over a Tyrell burner for 10 minutes with the cover open. The crucible and precipitate are weighed to a constant value.

Titanium. The precipitate is added to 6 grams of potassium pyrosulphate in a porcelain crucible. The mixture is heated over a small flame until it melts, and is then

heated for an hour over a flame just large enough to produce white fumes. The melt is brought to a dull red heat over a Meker burner until everything is in solution. It is then cooled and transferred with water to a beaker. Meanwhile the platinum crucible is cleaned out over a small flame with one gram of potassium pyrosulphate. When everything in the crucible is in solution, the melt is cooled and transferred to the beaker containing the bulk of the melt. The crucible is ignited and weighed to obtain the tare for the ammonia group determination above, and the calcium determination which follows.

The melt in the beaker is acidified with 10 ml. of 1:1 sulphuric acid, diluted to 60 ml. and heated until everything is in solution. The solution is filtered into a volumetric flask, to which is added 10 ml. of concentrated sulphuric acid and 10 ml. of hydrogen peroxide. The solution is diluted to fill the volumetric flask and is compared colorimetrically with a standard titanium solution to obtain the amount of titanium in the sample. This result, combined with the results for total iron, and phosphorus is subtracted from the total value of mixed oxides in the ammonia group determination to obtain the amount of aluminium in the sample.

Calcium. The filtrate from the ammonia group determination is acidified with hydrochloric acid and heated to boiling. Two grams of ammonium oxalate, dissolved in 50 ml.

of water are added to the hot solution. The solution is boiled for several minutes, made alkaline with 8 ml. of ammonium hydroxide and is allowed to stand overnight. The solution is filtered, and the resulting precipitate is dissolved in concentrated hydrochloric acid, diluted to 125 ml. and reprecipitated with ammonium oxalate and ammonium hydroxide. The solution is filtered and the precipitate is placed in the weighed platinum crucible from the pyrosulphate fusion, and is ignited to constant weight.

Magnesium. To the filtrate from the calcium determination is added 4 grams of dibasic ammonium phosphate in 25 ml. of water, and 30 ml. of ammonium hydroxide. The solution is stirred and allowed to stand overnight. The solution is filtered, and the precipitate is dissolved in 1:20 hydrochloric acid, and reprecipitated with dibasic ammonium phosphate and ammonium hydroxide. After the solution is filtered, the precipitate is heated over a period of several hours to constant weight.

Total Iron Portion

A moistened one gram sample is treated in a large platinum crucible with 5 ml. of concentrated hydrochloric acid and 5 ml. of hydrofluoric acid. The covered crucible is heated for 20 minutes in a radiator over a small flame. Water is added to cool the crucible, and the contents are

placed in a beaker with 25 ml. of concentrated hydrochloric acid and heated to boiling. The solution is reduced by adding stannous chloride solution dropwise until the liquid has a green colour. It is then cooled rapidly under the tap with protection from the air, and the excess of stannous chloride is removed by 10 ml. of a saturated solution of mercuric chloride. After the addition of 200 ml. of water, 10 ml. of 1:5 sulphuric acid, 5 ml. of 85% phosphoric acid and 3 drops of diphenylamine indicator, the solution is titrated slowly with standard potassium dichromate solution to a violet-blue end-point.

Ferrous Iron Portion

A 0.5000 gram sample is placed in a large platinum crucible. A hot mixture of 5 ml. of water, 5 ml. of concentrated sulphuric acid, and 5 ml. of hydrofluoric acid is added to the sample and the crucible is covered as quickly as possible. The crucible is heated over a small flame for 10 minutes. The crucible and contents are placed in a solution of 200 ml. of water, 5 ml. of concentrated sulphuric acid, 5 ml. of 85% phosphoric acid, 50 ml. of saturated boric acid, and 3 drops of diphenylamine indicator. The crucible is kept tightly closed with a stirring rod until it is completely covered. The solution is titrated as quickly as possible with standard potassium dichromate solution to a violet-blue end-

point.

Nickel Portion

A one-gram sample is treated with 5 ml. of nitric acid and 10 ml. of hydrochloric acid. The solution is evaporated to dryness, acidified with 5 ml. of hydrochloric acid, and again evaporated to dryness. The residue is taken up with 5 ml. of hydrochloric acid and 50 ml. of water, warmed and filtered. The filtrate is diluted to 300 ml., acidified with 5 gm. of tartaric acid, made faintly alkaline with ammonium hydroxide and distinctly acidified with acetic acid. The solution is boiled and removed from the heat. 25 ml. of 1% alcoholic solution of dimethylglyoxime are added and the solution is made faintly alkaline with ammonium hydroxide, and allowed to stand in a warm place for 15 minutes. The solution is filtered through a weighed Gooch crucible, and the precipitate is dried at 110°C to constant weight.

Manganese and Phosphorus Portion

8 ml. of nitric acid and 8 ml. of hydrofluoric acid are added to a 1.5000 gram sample in a small platinum dish. The mixture is evaporated slowly to dryness, wet with water, 5 ml. of nitric acid and 5 ml. of hydrofluoric acid, and again evaporated to complete dryness. The residue is repeatedly taken up with 5 ml. of nitric acid, and evaporated

to dryness, until it becomes brown. The residue is then transferred to a beaker with 5 ml. of nitric acid and 20 ml. of water, heated until all salts are in solution, and filtered into a 100 ml. volumetric flask. When the filtrate is cooled, it is diluted volumetrically to 100 ml. and divided by a pipette into two exactly equal portions.

Manganese. One of the portions above is boiled for a few minutes with one ml. of nitric acid, and removed from the heat. 0.5 gram of potassium periodate are added and the solution is boiled gently for 15 minutes, cooled, and transferred to the original volumetric flask. 5 ml. of phosphoric acid are added and the solution is diluted volumetrically to 100 ml. Manganese is determined colorimetrically against standard potassium permanganate solution.

Phosphorus. The second portion of the filtrate is boiled with 5 ml. of nitric acid and 15 ml. of a 50% solution of ammonium nitrate, and cooled to 70°C. 20 ml. of 10% ammonium molybdate solution is added to the sample which is allowed to stand overnight. The solution is filtered through a weighed Gooch crucible, and the precipitate is dried at 158°C to constant weight.

The Alkali Portion

A 0.5000 gram sample is ground thoroughly in an agate mortar with 0.50 gram of ammonium chloride. The resulting

powder is transferred with 6 gram of calcium carbonate to a Smith crucible, in which it is heated slowly until the crucible is red, and then fused over a Meker burner for one hour. The fused cake is transferred with 60 ml. of water to a beaker, and boiled. The precipitate is leached three times by successive boiling and filtering of 50 ml. portions of water. The combined filtrates are boiled vigorously for one minute with 5 ml. of ammonium hydroxide and 10 ml. of saturated ammonium carbonate solution. After the precipitate has settled, the solution is filtered into a silica dish, and evaporated to dryness. The salts are washed with water and again evaporated to dryness. The residue is heated until fumes of ammonium chloride disappear, cooled and dissolved in 10 ml. of water. The solution is treated with 5 drops of ammonium hydroxide and 5 drops of saturated ammonium carbonate solution, heated on a steam bath for 15 minutes and filtered. The filtrate is caught in a platinum dish and evaporated to dryness. Ammonium chloride is fumed off, and the residue is again treated as before, and then heated to constant weight.

The weighed mixture of chlorides is dissolved in a few millilitres of water, and transferred to a porcelain evaporating dish. The platinum dish is ignited and weighed to obtain the tare for the chloride weighing above. The mixed chlorides are replaced in the platinum dish with 5 ml. of perchloric acid, evaporated on a steam bath and heated carefully

until perchloric acid fumes appear. The evaporation with perchloric acid is repeated and when the residue is cool it is treated with 15 ml. of ethyl alcohol. The supernatant liquid is decanted through a weighed Gooch crucible and the residue is dried at 130°C to constant weight.

Carbon Dioxide Portion

Carbon dioxide is evolved by dropping 1:1 hydrochloric acid on a three-gram sample placed in an Erlenmeyer flask in a gas-tight absorption train. The evolved gas passes successively through sulphuric acid to remove water vapour, dehydrated copper sulphate on pumice to remove acid vapours, and anhydrous calcium chloride to remove the remaining water, and is then absorbed by soda-lime in a weighed absorption tube. The water evolved in the reaction is absorbed by calcium chloride. The absorption tube is reweighed to obtain the amount of carbon dioxide.

Combined Water Portion

A 0.5000 gram sample is placed at the closed end of a weighed Penfield tube and the tube is heated gradually in a horizontal position until the glass is red. The tube is rotated to prevent the glass from sagging. The water evolved is condensed in the bulb of the tube by a moist strip of cloth wrapped around the tube above the bulb. After 15

minutes of strong heat, the part containing the powder is drawn off, and the end of the tube is resealed. The tube and water are cooled and weighed. The water is drawn off by heat and suction and the tube is cooled and reweighed to obtain a tare.

PH VALUES

As a further aid to the interpretation of the soil forming processes in operation at Clangula Lake, pH values were determined for each sample of Profile A and Profile B. The results obtained are shown in Table VII.

TABLE VII

PH VALUES OF PROFILE A AND PROFILE B

Sample	pH
A1	5.00
A2	6.12
A3	6.13
A4	6.43
A5	6.24
A6	6.73
B1	6.39
B2	6.70
B3	6.86

CHAPTER VI

DISCUSSION

The conclusions regarding the weathering products at Clangula Lake are the result of field interpretations and laboratory studies. The field interpretations are based primarily on the topographic expression of the exposures and the topographic control of glaciation. Laboratory conclusions are founded on X-ray powder analysis, petrographic study, and chemical analysis.

FIELD STUDIES

The exposures of weathered serpentine rock in the valley are the result of the fortunate position of the valley with respect to the high diorite ridge to the north. The advance of the glaciers, loaded heavily with debris carried chiefly in the lower portions, would have been stopped by the ridge. In this event, the greater amount of debris would be deposited on the north side of the ridge, and only the higher parts of the glacier, relatively free of foreign material would override the ridge into the valley. The thin mantle of drift which would therefore have been deposited could have been easily removed by glacial streams subsequent to the retreat of the ice. This would leave the "unweathered" serpentine rock with glacial erratics resting directly on

top. The map of the area shows that the exposures of weathered serpentine rock have a definite trend of south 75 degrees west, which corresponds to the direction of glacial movement. It is suggested that this direction is a consequence of glacial erosion, and that the original "unweathered" serpentine rock was shaped to the present outlines by the glaciers.

LABORATORY STUDIES

The main conclusions from the laboratory were reached from a consideration of the chemical nature of the residual soil. However, X-ray powder analysis and petrographic methods provided auxiliary information on the mineralogical composition of the residual soil and its underlying bedrock.

X-ray Powder Analysis

X-ray analysis was used to determine the major constituents of the "unweathered" serpentine rock, the residual soil, and the glacial drift.

The main mineral constituent of both the "unweathered" bedrock and the residual soil is serpentine. The presence of serpentine in such large amounts in the soil, definitely proves that the soil is a residual weathering product of the underlying serpentine rock. The increase of dolomite in the lower portions of the profile is shown by petrographic study to be

due to dolomite in fractures of the original rock.

The residual nature of the soil is again shown by its difference in composition from the surrounding glacial drift which is predominantly quartz. The little amount of serpentine which to be present in the drift is probably the result of transportation by glaciers or by subsequent glacial streams.

Petrographic Interpretation

It is suggested that the bedrock was originally composed chiefly of olivine. The existence of olivine rather than pyroxene or amphibole as the parent material for the antigorite, is based on two separate observations. The magnetite, in many places, forms definite rings, which conform to the outlines which would be shown by cross-sections of olivine crystals. Also the two major directions of the antigorite fibres are exactly perpendicular to each other. If it is assumed that the antigorite would probably develop along the more prominent cleavages of the original mineral, the common amphiboles and pyroxenes are excluded, and the only logical parent mineral is olivine.

The original peridotite was altered to serpentine rock consisting of antigorite and magnetite as the major constituents. Subsequent weathering at depth produced dolomite and chrysotile which filled fractures in the serpentine rock. The

origin of the preferred alinement of the antigorite may be primary, resulting from the original orientation of the olivine, or may be secondary, resulting from later deformation.

Chemical Analysis

There are numerous methods of recalculating chemical analyses to illustrate their major characteristics. That method which appears to be most applicable in this instance is gain and loss diagrams. Direct observations of the chemical analyses also provides valuable information.

Gain and Loss Diagrams (2)

In general, weathering changes in rocks involve changes in the chemical composition due to losses and gains in the constituents. Direct comparison of chemical analyses can be made only when there has been no change in weight. If there is a change in weight, it is necessary to reduce the analyses to a common basis for comparison. When weight relations are not known, it is possible in some cases to select a constituent which has remained nearly constant in absolute amount during alteration and recalculate the analyses on a comparable basis. In the general case in which no constituent has remained constant in amount, the relative gains and losses may be expressed by the quotients obtained by dividing the percentage of each constituent in the unaltered phase by its percentage in the altered phase. These values times 100

plotted from a single zero point constitute a gain and loss diagram. They indicate for each constituent the number of grams of altered rock required to furnish the amount of that constituent originally present in 100 grams of unaltered rock. The values for the several constituents are plotted on separate lines. Because values may vary from zero, for a constituent not present in the original rock but present in the altered rock, to infinity for a constituent present in the unweathered rock, but removed completely in the altered rock, it is convenient to use a special logarithmic scale on which equal gains and losses are recorded equal distances on either side of the origin. It is to be noticed, that owing to the nature of the diagrams, gains are represented by points to the left of the origin, and losses by points to the right of the origin.

In the particular instance of the analyses of the profiles at Clangula Lake, weight relations are unknown and no constituent can be assumed as remaining constant. Therefore, a general gain and loss diagram must be used. Gain and Loss ratios for profile A and profile B are calculated in Table VIII and Table IX respectively. The ratios obtained for bedrock and surface samples for both profiles are plotted on Plate X.

To represent a series of analyses, a composite gain and loss diagram may be used. In this type of diagram, the

TABLE VIII

GAIN AND LOSS RATIOS - PROFILE A

Constituent	A6/A5	A6/A4	A6/A3	A6/A2	A6/A1
SiO ₂	93.6	91.1	88.8	84.6	86.1
Al ₂ O ₃	106.5	99.3	93.8	88.1	44.8
Fe ₂ O ₃	86.3	88.7	81.9	76.4	65.9
FeO	106.7	106.7	145.4	228.6	266.7
MgO	101.2	102.9	104.3	105.5	135.7
CaO	141.9	214.7	883.6	3170.6	1738.7
Na ₂ O	100.0	100.0	133.3	200.0	200.0
K ₂ O	112.5	112.5	128.6	150.0	180.0
H ₂ O _f	91.9	92.6	89.6	104.5	154.8
H ₂ O-	66.4	54.9	49.1	41.4	23.0
CO ₂	201.9	225.7	255.9	532.8	5416.7
P ₂ O ₅	79.1	43.6	43.6	38.6	36.5
MnO	106.7	94.1	94.1	88.9	88.9
NiO	133.3	51.6	51.6	48.5	47.1

Values below 100 represent relative gains.

Values above 100 represent relative losses.

TABLE IX

GAIN AND LOSS RATIOS - PROFILE B

Constituent	B3/B2	B3/B1
SiO ₂	98.4	99.5
Al ₂ O ₃	73.9	35.7
Fe ₂ O ₃	65.6	49.9
FeO	110.1	246.8
MgO	112.0	146.7
CaO	192.5	641.7
Na ₂ O	125.0	250.0
K ₂ O	133.3	200.0
H ₂ O ⁺	107.1	149.5
H ₂ O ⁻	47.6	34.8
CO ₂	144.1	582.6
MnO	78.6	73.3
NiO	86.1	79.5

Values below 100 represent relative gains.

Values above 100 represent relative losses.

GAIN AND LOSS DIAGRAM
 PROFILE A & PROFILE B

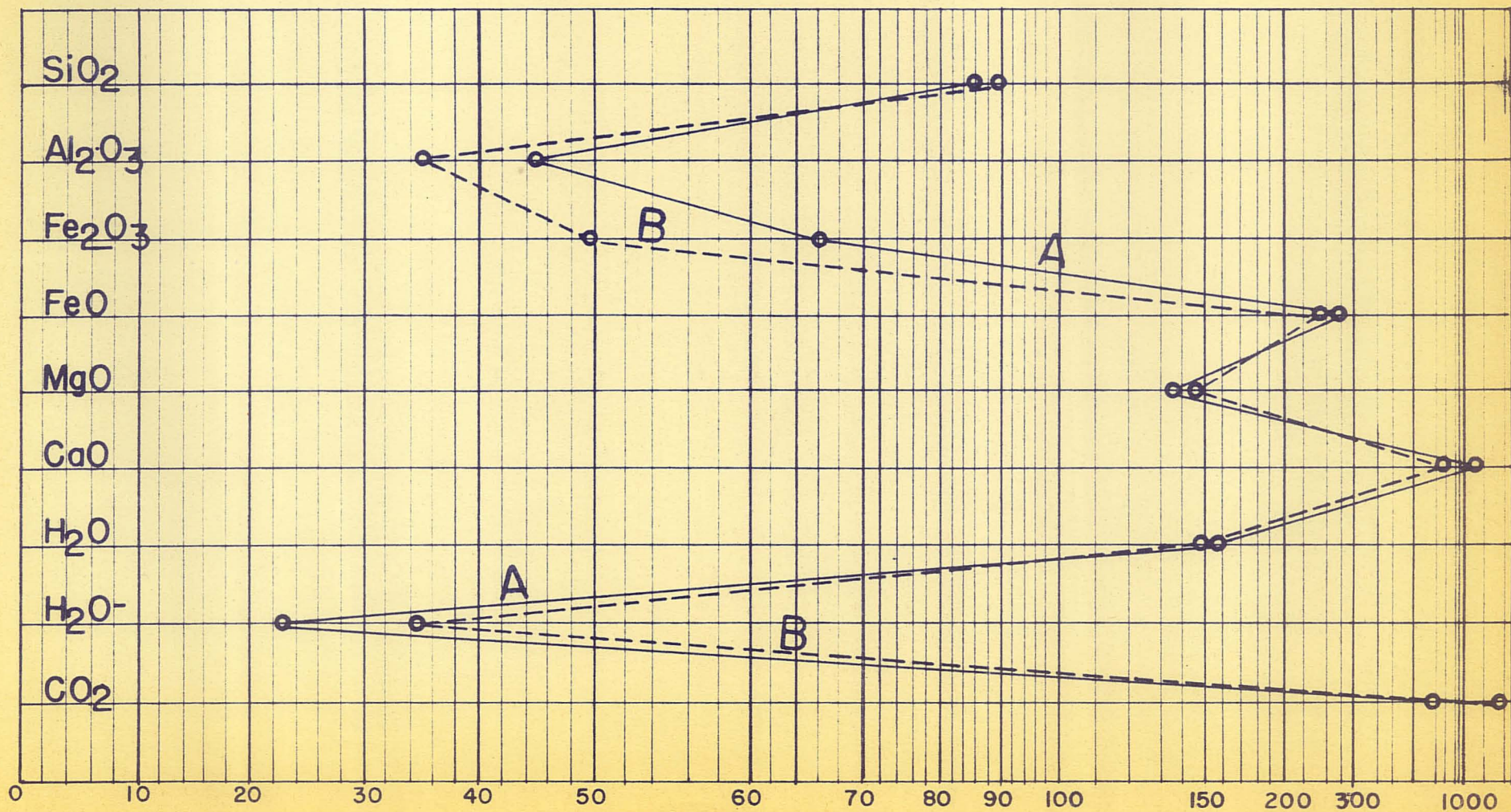
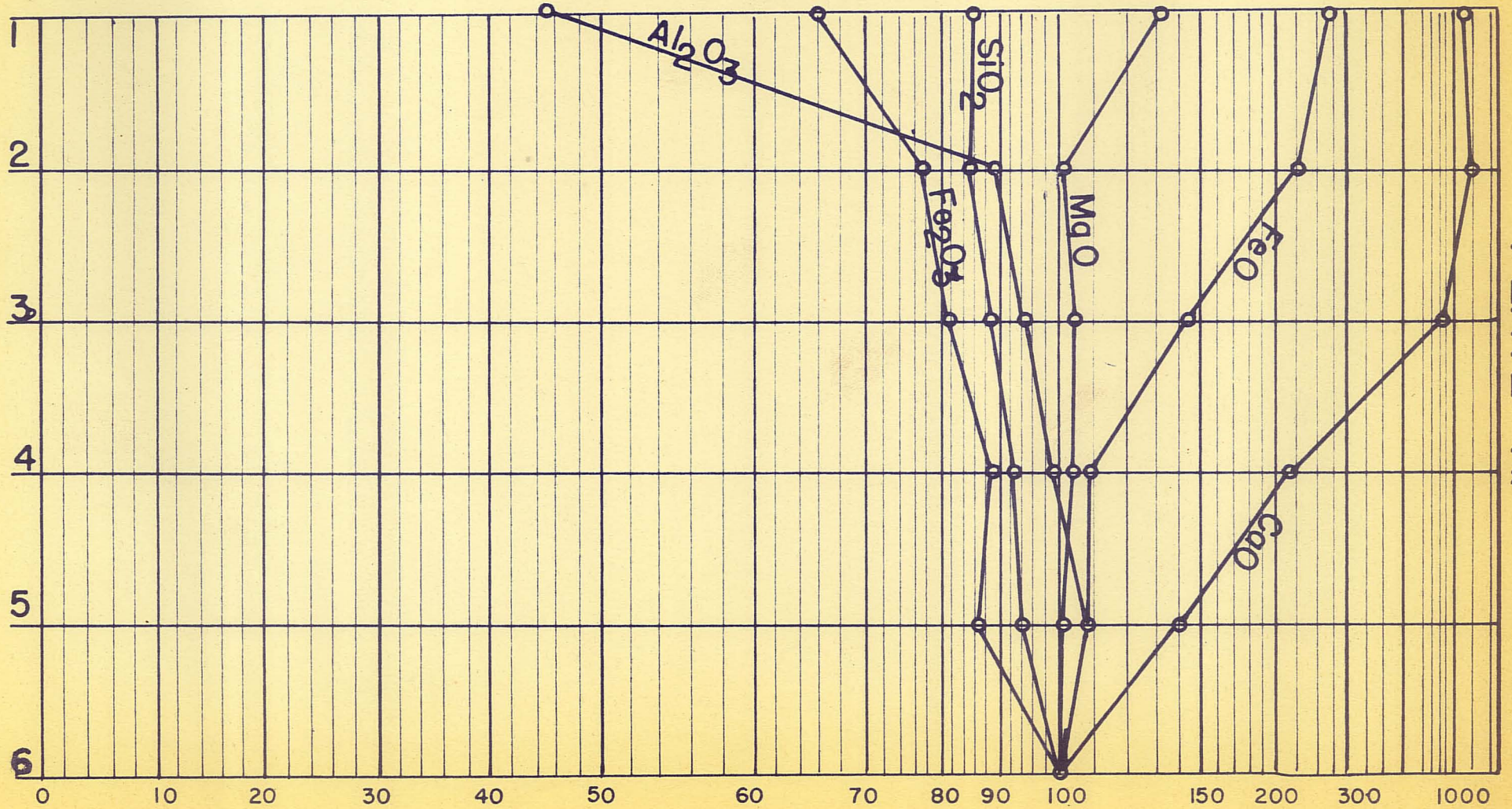


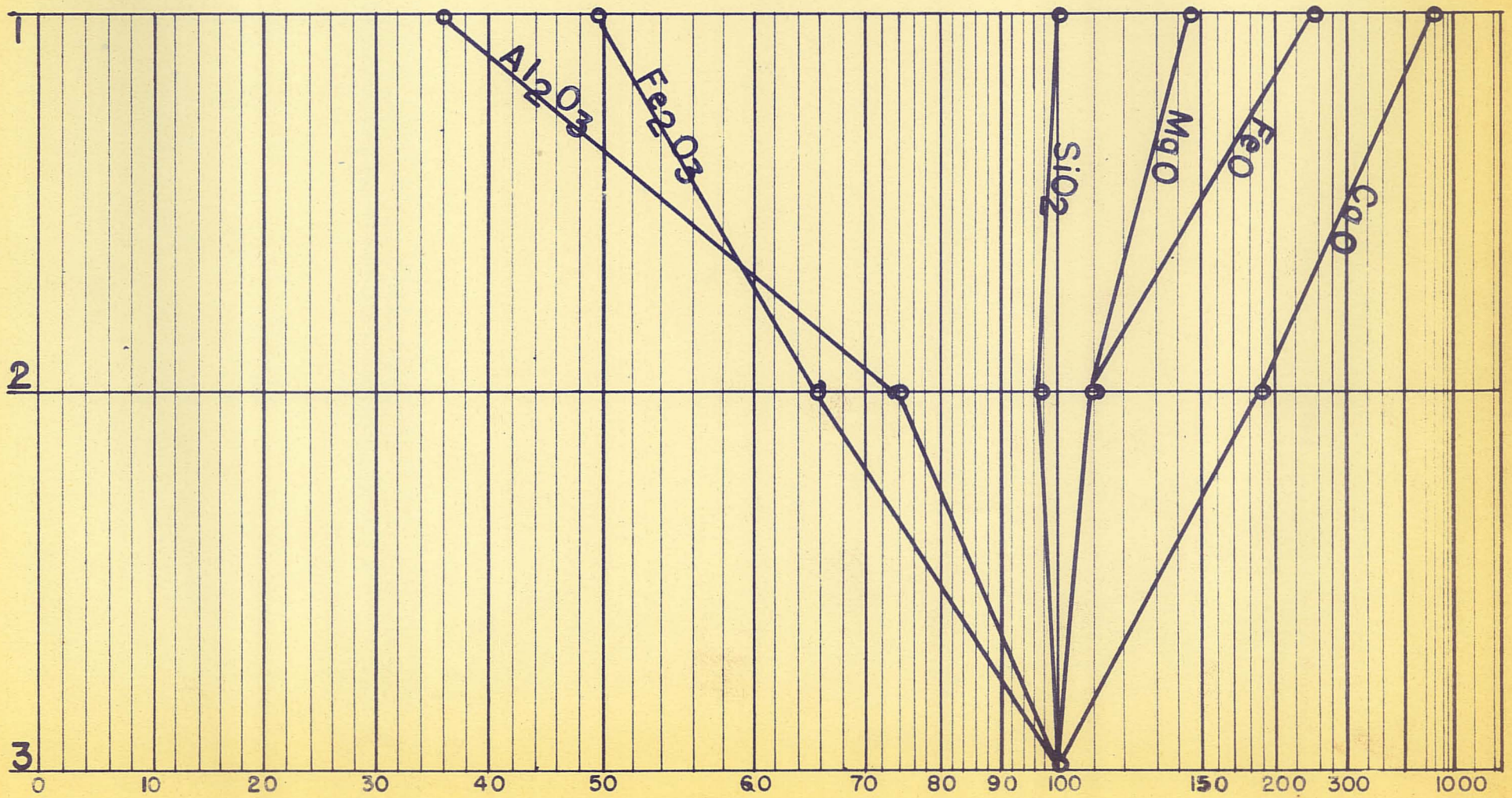
PLATE X

COMPOSITE GAIN AND LOSS DIAGRAM

PROFILE A



COMPOSITE GAIN AND LOSS DIAGRAM
PROFILE B



analyses, each compared with the original phase, are plotted on separate lines, arranged according to depth. The values calculated for profile A and profile B for the major constituents are plotted on Plate XI and Plate XII respectively. Although these diagrams are, to some extent, a repetition of Plate X they are included to emphasize the chemical changes produced by the weathering.

Discussion and Interpretation

For the purpose of our discussion, the common chemical elements occurring in rocks and soils may be divided into four major groups: 1) R_2O group or alkalies, 2) RO group or alkaline earths, 3) R_2O_3 groups or sesquioxides, and 4) silica. In the instance of the soil profiles at Clangula Lake the Alkalies are very limited in amount, and may be conveniently classified with the alkaline earths as bases.

Before the separate groups, outlined above, are discussed, we shall look at the general pattern of the analyses as a whole. It is noticed that in both profile A and profile B there is a uniform, though diverse, gradation in the percentages of all elements, from bedrock, through the lithosol, to surface. This was expected from field studies because no marked differences in soil horizons were observed. Such a gradation is seldom to be found in mature soil profiles, and therefore is an indication of youth or immaturity. This

uniformity also provides further proof of the residual nature of the soil, since it would be extremely unlikely that such a gradation would be observed of the soil were a foreign material. The two profiles are essentially the same in chemical composition. The only apparent difference to account for the colour variation is the oxidation state of the iron. In profile A almost all of the iron, even in the "unweathered" serpentine rock is in the ferric state. On the other hand, in profile B, there is a marked increase in the percentage of ferrous iron. This difference in the state of the iron logically accounts for the red colour of the soil of profile A, resulting from the predominance of ferric iron, and for the drabber colours of profile B, resulting from the increase of ferrous iron. The difference in colour, existing even at the surface, shows that the influence of the original composition of the parent material of the soil is a determining factor of the composition of the soil, despite the fact that the same soil forming processes have been active on both profiles. This, again, is an indication of a juvenile soil.

If the base elements of the RO and R_2O groups are now observed in detail, it is seen, both from the chemical analyses themselves and from the gain and loss diagrams, that these elements have been leached from the surface. Such a procedure is to be expected within the range of pH values observed for the profiles. In these soils at Clangula Lake it is apparent

that the base elements have been transported downward in solution, probably as bicarbonates, and carried out of the soil profile. The chemical analyses of the two soil profiles present no definite evidence for the deposition of these elements at the lower levels of the profile. Thus it may be concluded that the base elements have been leached from the upper portions of the profile, and as a result the soil has developed an acid reaction.

Both the sesquioxides and silica appear to be concentrated in the upper portions of the profile. This is logically the result of a relative increase due to the loss of the base elements rather than of an absolute increase in the amounts of silica and sesquioxides. There is no evidence of movement of either of these groups in the soil profile. Such stability is further evidence of the juvenile nature of the soil. A decrease of ferrous iron is noted at the surface of both profiles. This may be explained either as the result of oxidation to the ferric state, or as the result of leaching in the form of ferrous bicarbonate. Since there is no evidence of deposition of iron in the lower portion of the profile, it seems logical to conclude that the decrease in ferrous iron is due to its oxidation to the ferric state.

CHAPTER VII

CONCLUSIONS

The major conclusions regarding the soil profiles studied at Clangula Lake may be divided into two general categories: 1) the nature of the soil profile, and 2) the cause of the colour differences. While a discussion of one of these is dependent on the other, a clearer picture is presented if they are discussed separately.

THE NATURE OF THE SOIL PROFILE

A petrographic study of the "unweathered" bedrock shows that it was probably an olivine-rich peridotite which was subsequently serpentized. This serpentine rock was exposed due to the fortunate position of the valley with respect to a high diorite ridge to the north which shielded the valley from the major portion of the drift carried by the glaciers. Subsequently it was weathered to a brown podzolic soil. The residual nature of the soil is verified by the abundance of serpentine in both bedrock and surface samples, as shown by X-ray powder analysis, and by the uniform gradations in the percentage amounts of the several chemical constituents.

Under the climatic conditions which are believed to have prevailed in the area since glaciation, the typical soils

of this region are podzols. The chemical changes in the soil profile produced by podzolization result in an acid medium. The base elements are removed by percolating waters and the sesquioxides are mobilized and leached from the A horizon and precipitated in the B horizon, forming a brown zone overlain by a gray leached zone. In the soil profiles at Clangula Lake, a leached A and an illuvial B horizon were not observed. Acid weathering obviously has been in progress but the soils are too immature to show evidence of movement of the sesquioxides that have been released. Chemical analyses of the soil profiles, however, shows that the base elements must have been removed by percolating water, but that the sesquioxides and silica have remained in position in the profile. Such a procedure is interpreted as a juvenile stage of the process of podzolization; that is, weathering without mobilization. The juvenile nature of the soil profile is further verified by the uniform gradation of composition and colour from bedrock to surface. Therefore it is concluded that the serpentine rock has weathered since glaciation to a brown podzolic soil, representing the juvenile stage of podzolization.

COLOUR DIFFERENCES

A problem associated with the nature of the two soils studied is the difference in colour of the soil profiles at various locations within the area. The colour of the soils varies from reddish brown to greyish brown. Van Houten(6)

has suggested that the presence of red or gray colours depends on the ratio of ferric iron to ferrous iron. Red colours result with a ferric-ferrous ratio greater than two to one and drab colours result with a ferric-ferrous ratio less than this. Chemical analyses of profile A and profile B differ only in the proportions of ferric and ferrous iron. In accordance with the conclusions of Van Houten the areas of high ferric-ferrous ratio are reddish brown, whereas the areas of low ferric-ferrous ratio are greyish brown. It is also seen that colour differences prevail throughout both profiles to bedrock. This indicates that the difference is inherent in the parent materials, and that the influence of the original composition of the parent rock is a determining factor of the composition of the soil, despite the fact that the same soil forming processes have been active on both profiles. This, again, is an indication of a juvenile soil.

SUMMARY OF CONCLUSIONS

1. The soil covering the exposures of serpentized peridotite is of a residual nature and appears to be a brown podzolic soil, formed since glaciation. This brown podzolic soil is a juvenile soil, representing the incipient stages of the process of podzolization.
2. The original "unweathered" exposures of serpentine rock were due to the fortunate position of the valley with

respect to a high ridge to the north which shielded the valley from the major portion of the drift carried by the glaciers. The finer drift, deposited in the valley was removed subsequently in several places by glacial meltwaters which were concentrated in the valley after the retreat of the glaciers, leaving only scattered boulders on top of the exposed bedrock.

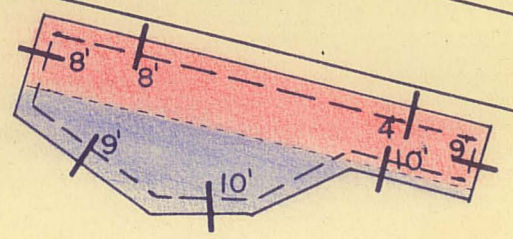
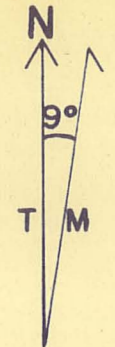
3. Colour differences in the residual soil are explained by a variation in the oxidation state of the iron. Areas of high ferric-ferrous ratio are characterized by an apple-green bedrock comparatively high in ferric iron minerals, which was weathered to a reddish brown soil, whereas areas of low ferric-ferrous ratio are characterized by a greyish green bedrock, deficient in ferric iron minerals, which was weathered to a greyish brown soil. The colour differences are due to original differences in the parent material rather than to differences in the soil forming process.

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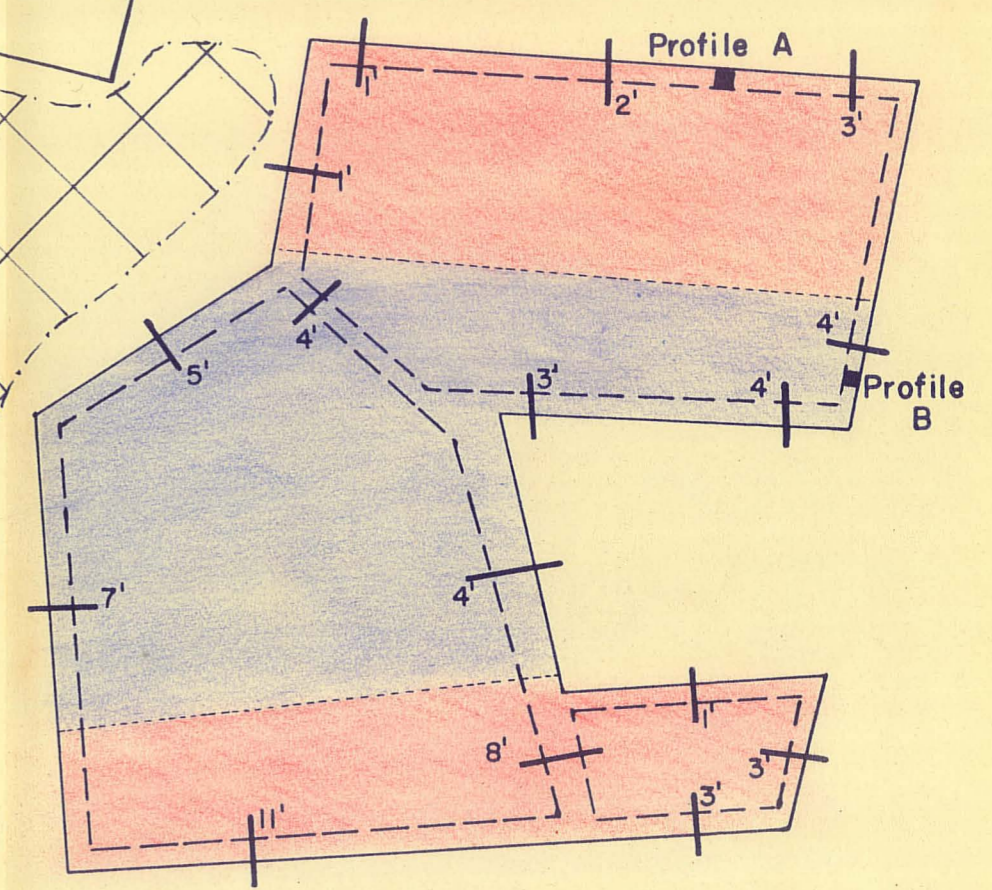
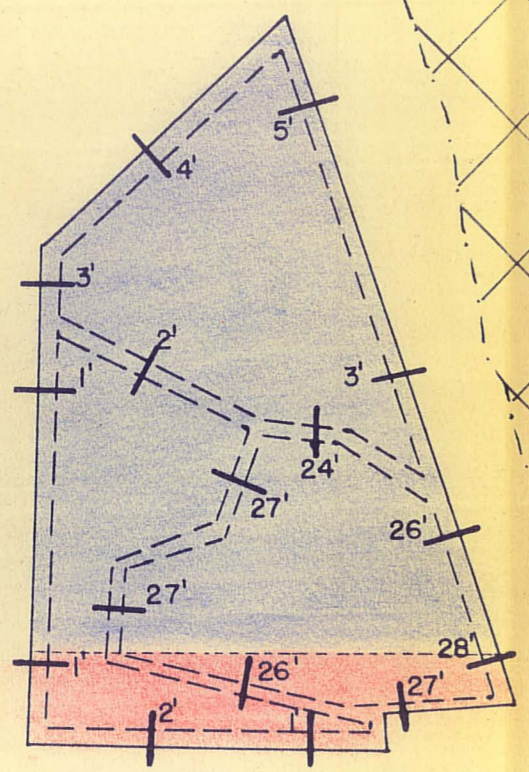
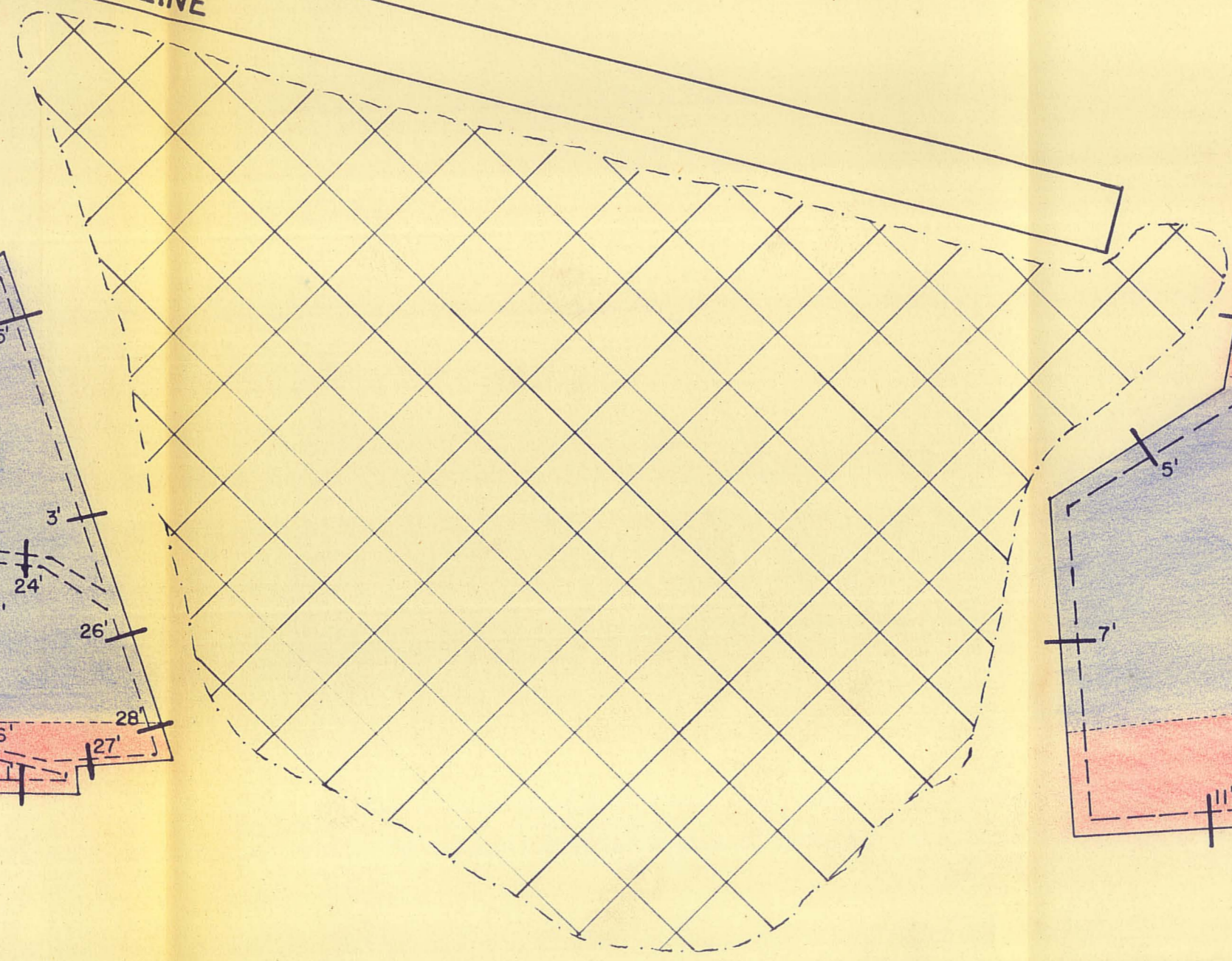
1. Kolthoff, and Sandell, A Textbook of Inorganic Analysis.
2. Leith, C.K., and W.J. Mead, Metamorphic Geology, 1915.
3. Lutz, H.J., and R.F. Chandler, Forest Soils, 1946.
4. Russell, G.A., Geology of the English Brook Area. Mines Branch, Department of Mines and Natural Resources, Province of Manitoba, Publication 48-3, 1949.
5. Soils and Men. Yearbook of Agriculture, United States Department of Agriculture, 1938.
6. Van Houten, F.B., "Origin of the red-banded Early Cenozoic Deposits in the Rocky Mountain Region", American Association of Petroleum Geologists, XXXII (1948), 2083-2126,
7. Vogel, A Textbook of Inorganic Analysis.
8. Washington, H.S., The Chemical Analysis of Silicate Rocks. 1919.
9. Wright, J.F., Geology and Mineral Deposits of a Part of Southeastern Manitoba. Geological Survey of Canada, Memoir 169, 1932.

MAIN QUARRY AT CLANGULA LAKE

Showing pit detail and sample locations

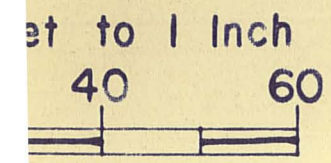


TRAM-LINE



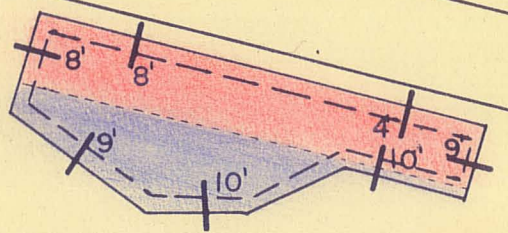
END

- brown soil
- brown soil
- ne
- feet— numbers on side
- ock piles








MAIN QUARRY AT CLANGULA LAKE

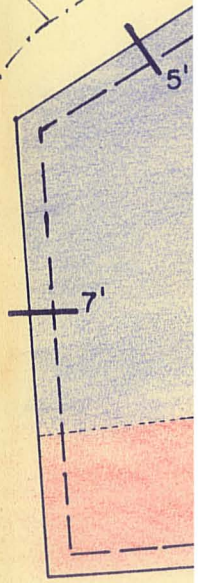
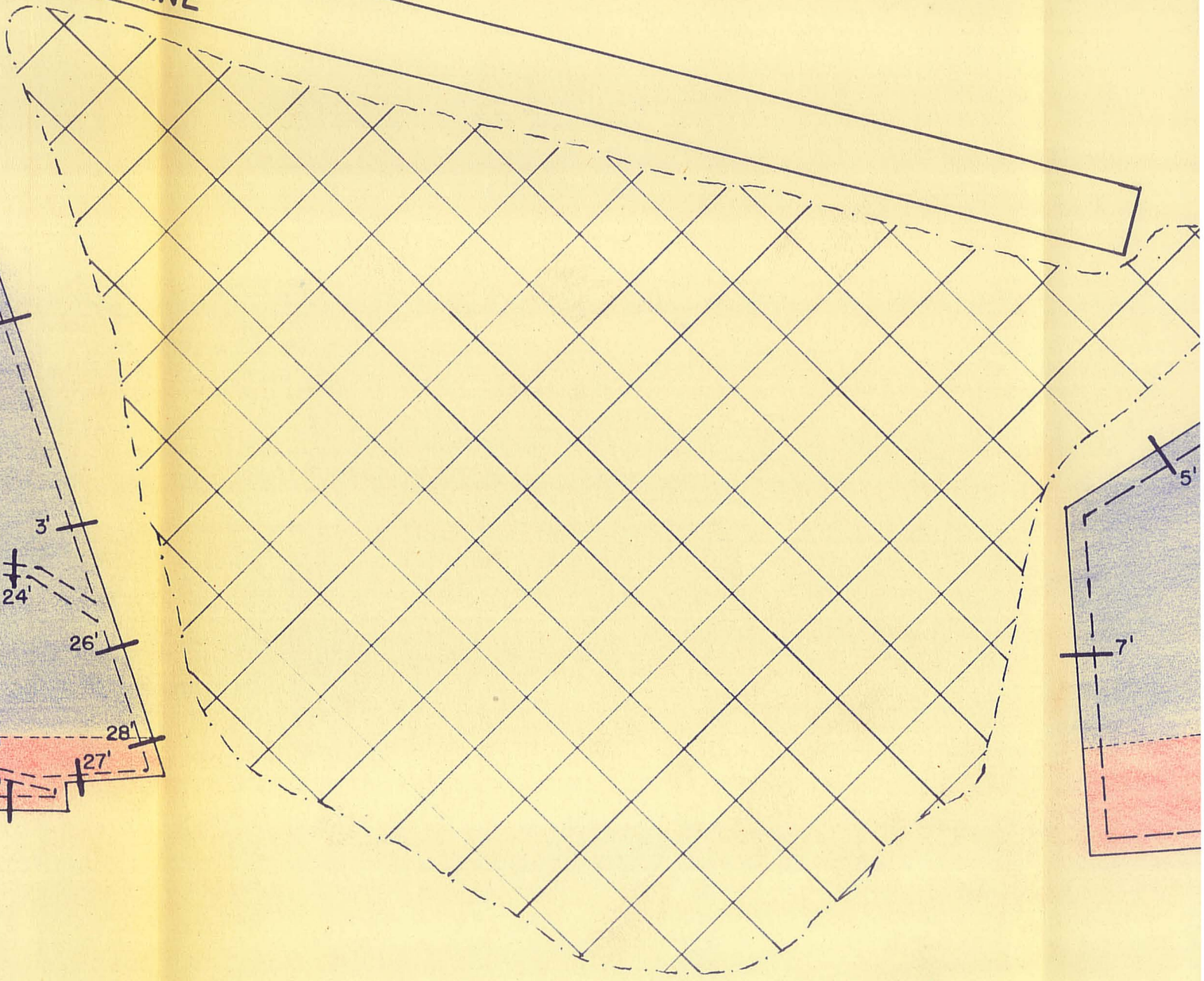
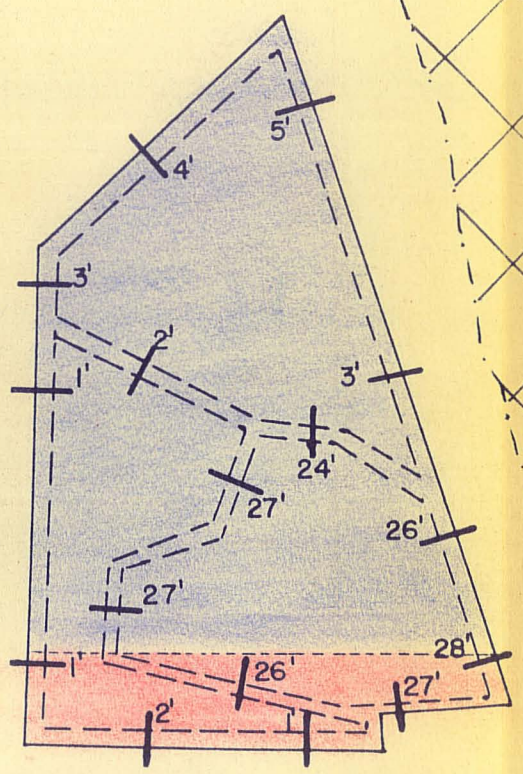
Showing pit detail and sample locations

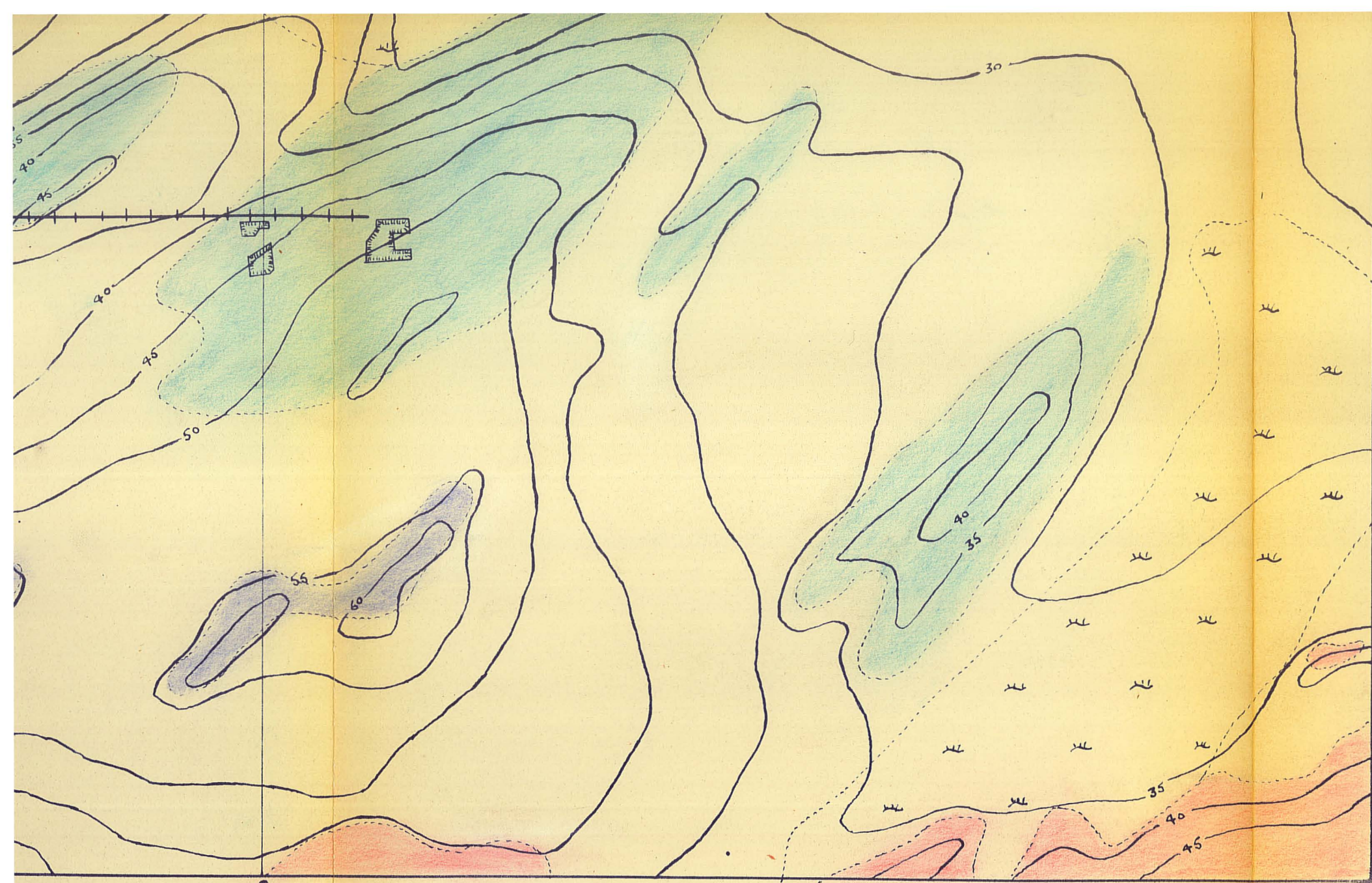


TRAM-LINE

LEGEND

-  Reddish brown soil
-  Greyish brown soil
-  Pit outline
-  Depth in feet— numbers on lower side
-  Waste rock piles





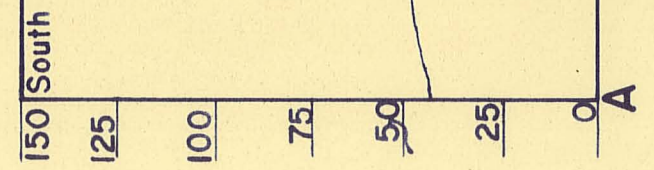
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Scale: 200 feet to 1 inch

Contour interval: 5 feet

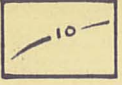
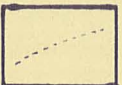
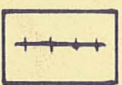

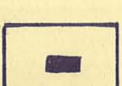
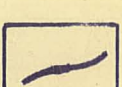
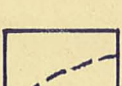
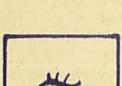
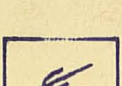
datum is elevation of Glangula Lake

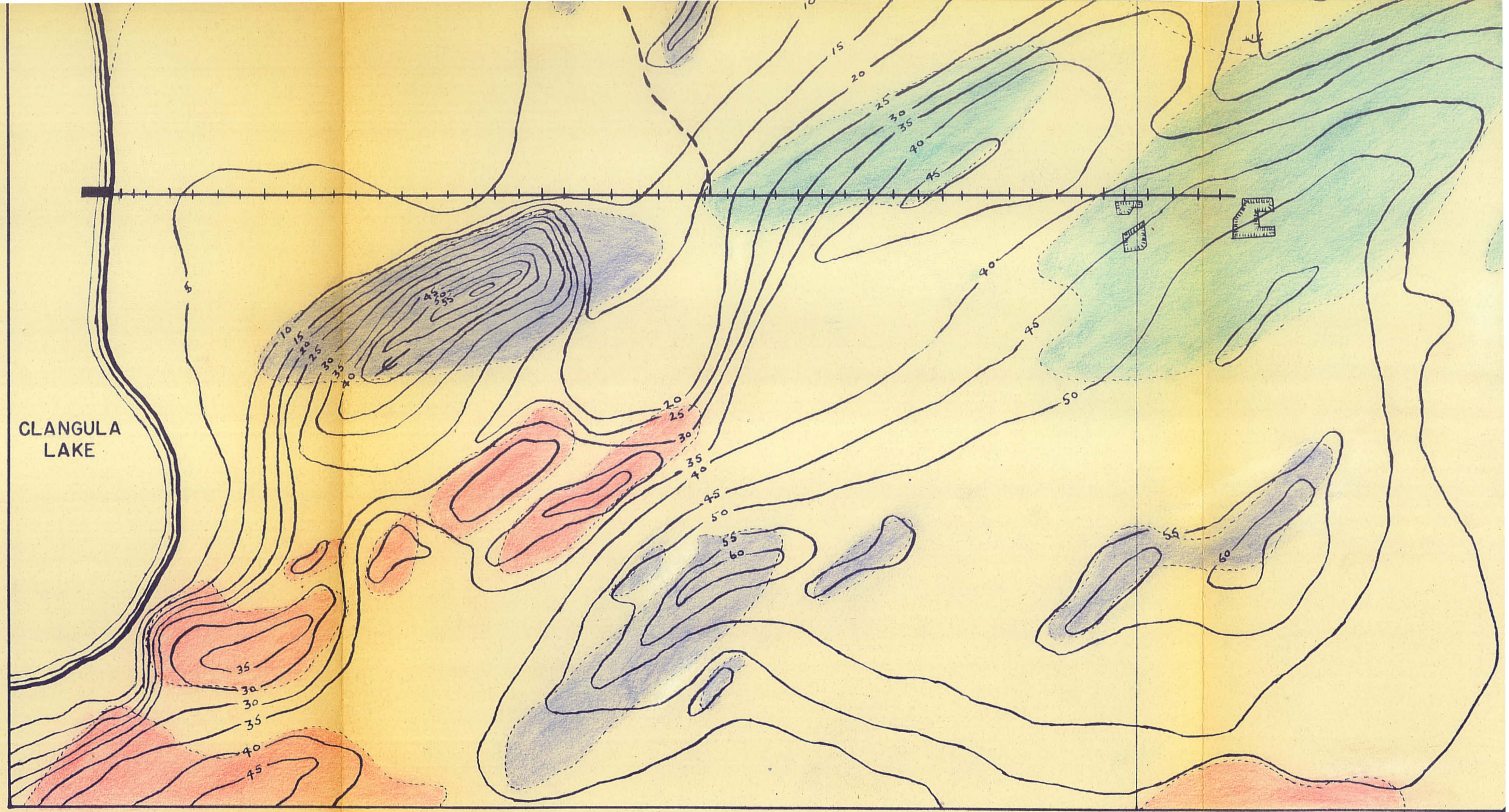


TOPOGRAPHIC SECT

Horizontal Scale: 200 f

Vertical Scale: 50 f

-  Contour
-  Outcrop and swamp boundaries
-  Tram-line
-  Quarry
-  Wharf
-  Creek
-  Trail
-  Swamp
-  Glacial striae



CLANGULA LAKE

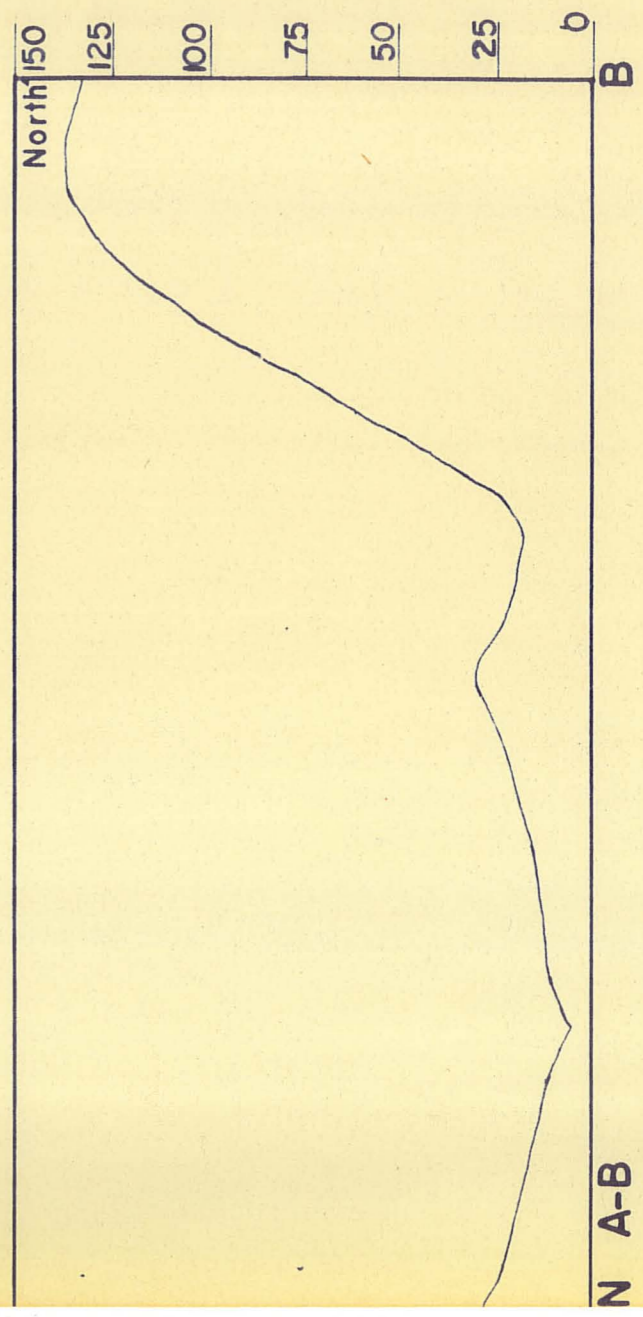
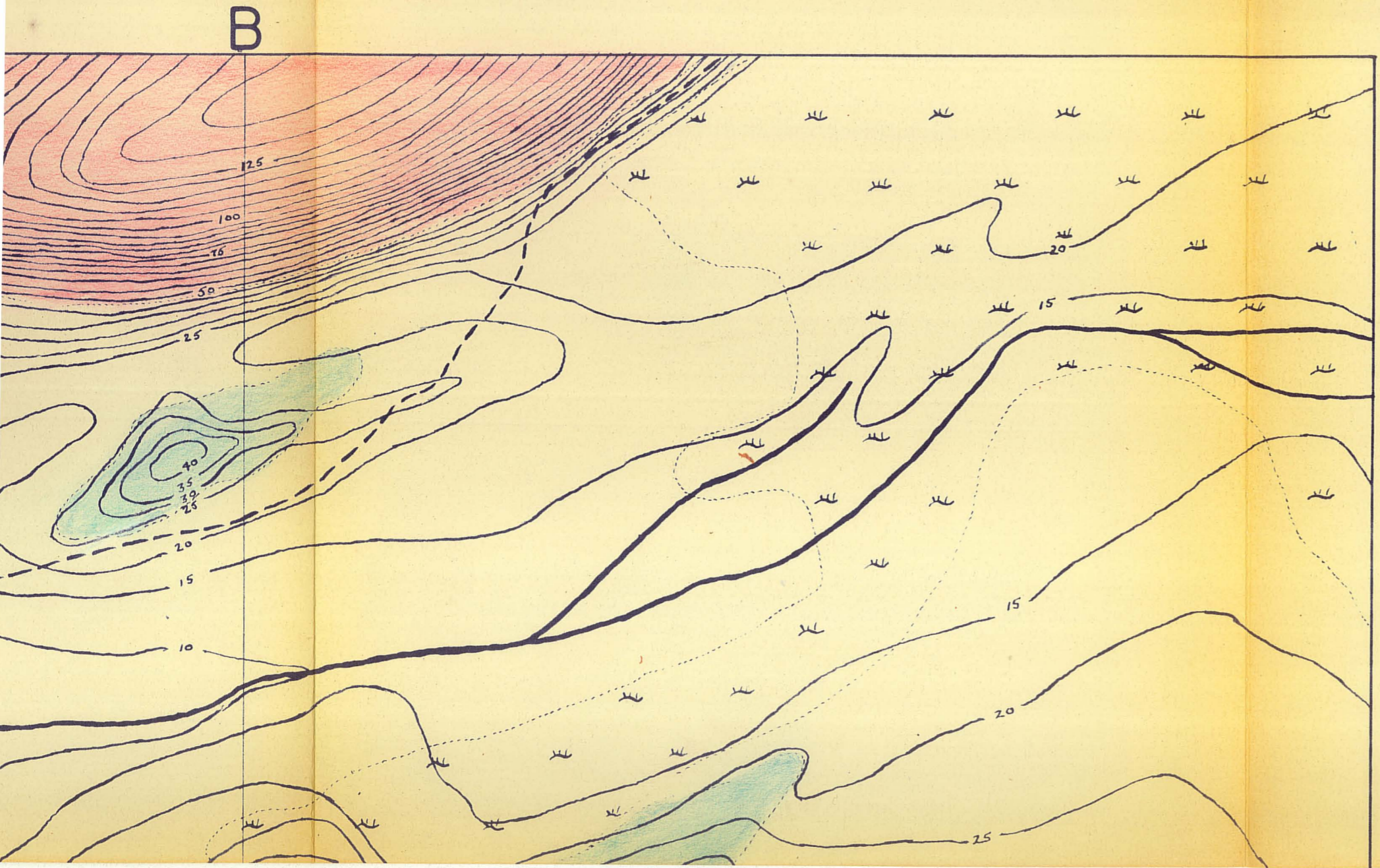
A



Scale: 200 feet to 1 inch

Contour interval: 5 feet
 Datum is elevation of Clangula Lake





GEOLOGIC MAP OF THE LAKE AREA



N A-B
to 1 inch
to 1 inch

TOPOGRAPHIC AND GEOLOGIC MAP CLANGULA LAKE AREA

-LEGEND-

-  Glacial drift
-  Brown podzolic soil
overlying serpentine
-  Serpentine rock
-  Intrusives— quartz-
diorite to gabbro

