THE DETERMINATION OF A SET OF TERRAIN UNITS

FOR

DURHAM COUNTY, ONTARIO,

USING AERIAL PHOTOGRAPHS.

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By

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SCOPE AND CONTENTS:

This study attempts to evolve a methodology for defining terrain types from vertical aerial photographs; to determine the extent to which aerial photographs can serve as a basis for terrain unit mapping; to produce a classification of terrain types for Durham County and by so doing to provide a small contribution towards the knowledge about the study area.

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CONTENTS

LIST OF ILLUSTRATIONS

CHAPTER I

INTRODUCTION

(i) Objectives

The objective of this thesis is to determine the extent to which air photo interpretation can serve as a basis for terrain unit mapping, within Durham County, Ontario.

To accomplish this it will be necessary:

First, to evolve a methodology, incorporating the use of aerial photographs, by which Durham County can be sub-divided into a series of terrain types.

Second, to provide, in the form of terrain types, a regional description of Durham County, which is complete in terms of all the physical criteria investigated.

Third, to produce an air photo interpretation key for the identification of superficial deposits in Durham County.

Fourth, to provide additional information on two specific geomorphic topics: the extent, types and problem of erosion in the area; and the form of the Lake Iroquois shoreline.

(ii) The Terrain Unit - A Definition

A 'terrain unit' has been defined, for the purposes of this study, as an area which has 'homogeneous and mutually exclusive physical characteristics'. On the ground such a unit will comprise an area within which there exists a specific combination of landform types and origins, drainage patterns, slope angles, relief ranges, soils and vegetation - a combination which is, as nearly as is possible in the physical environment, homogeneous throughout the unit and exclusive to it. Where there are several areally distinct terrain units exhibiting similar characteristics, they constitute a terrain type, of which there have been twenty-seven distinguished in Durham County.

The basis for this study lies in the hypothesis that if a terrain unit can be defined on the ground, it will be visible as a specific, homogeneous pattern on an aerial photograph of given scale.

(iii) Fundamentals of Air Photo Interpretation

Many authors have written comprehensive treatises on the fundamentals of air photo interpretation, making any reiteration thereof unnecessary in this context. However, it is necessary to consider certain factors prior to the use of aerial photographs in any geomorphic study.

First, there is the influence of photographic tone, texture, pattern, image shape, shadow, the relationship of associated features and image size on the interpretation of the photographs.

Tone or shades of grey is ".... a measure of the relative amount of light reflected by an object and actually recorded on a black and white photograph ...." (Ray 1960, p. 10). It is fundamental to all other recognition elements, but has limited usefulness in its own right because so many factors can influence it. These latter may be divided into three: terrain factors, technical factors and meteorological and climatological factors.

Terrain factors include the surface topography and surface texture, that is the aggregate micro-conformation of the earth's surface, as they affect the diffusing-reflecting character of the photographed surface. Also included are soil, rock and vegetation colours; stage of vegetation growth according to the season; soil moisture and organic content; vegetation density and the location of the portion of the ground with respect to the sun.

Technical factors are even more numerous. These include the speed, resolving power, wavelength sensitivity, uniformity and composition of the photographic emulsion and the paper on which the film is printed. Then lens characteristics can alter the tone of the print from the centre outwards, a factor which can be compensated for by the correct use of filters. Various film-filter combinations will also alter the tone as will the method of processing.

Meteorological and climatological factors influence the angle of the sun at a particular season of the year; they determine the amount of haze and diffusion, reflectivity and emissivity of the atmosphere.

In certain circumstances, however, tone can be useful as an interpretation element in the differentiation of significantly different terrain types. In such cases the frequency of tone changes, as well as tonal values, could be instrumental in outlining terrain units in the broadest sense of the word, if the photography was sufficiently good. Initial studies by Ray and Fischer (1960) involving measurement of frequency and magnitude of tone changes across two glacial moraines of different ages, showed differences that are believed significant with respect to the relative ages of the moraines. The graphs obtained from the densitometer are shown in Figure 1 - 1. Measurements across different landforms were also seen to be markedly different, Figure 1 - 2, although this was to be expected when an alluvial area of low relief was contrasted with an area of hummocky moraine that included many small lakes. A further study by Leuder (1959, p. 88-90) attempted to link

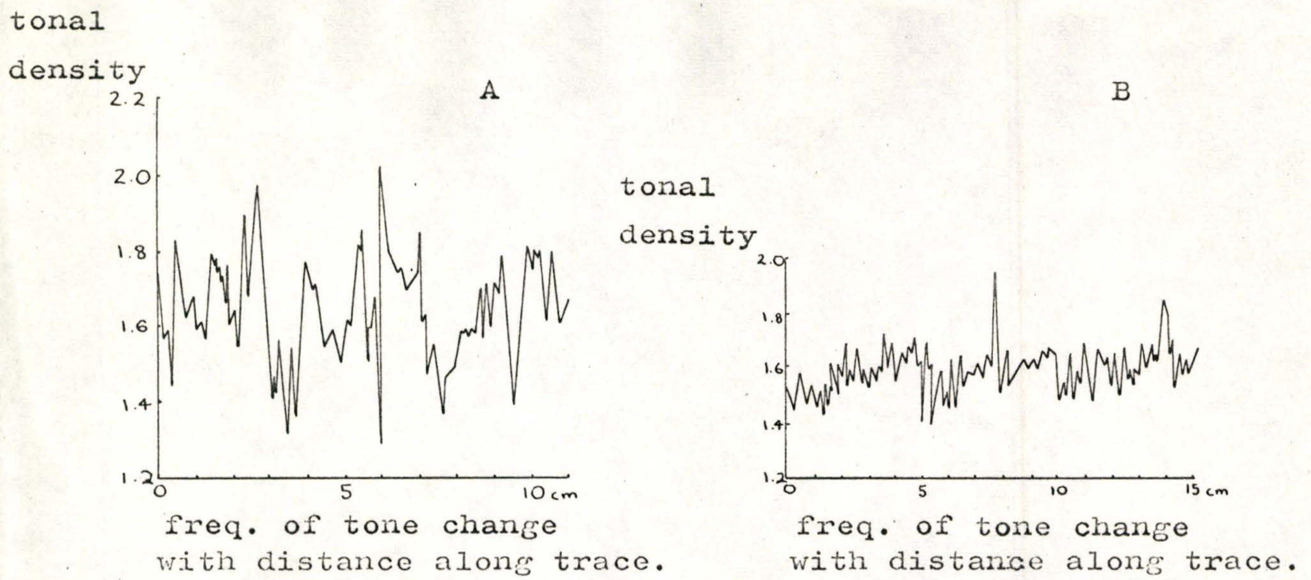


Fig1-1 Densitometer traces showing relation of magnitude and frequency of tone changes across two glacial moraines of different ages. A-older moraine; B-younger moraine. (after Ray & Fischer 1960)

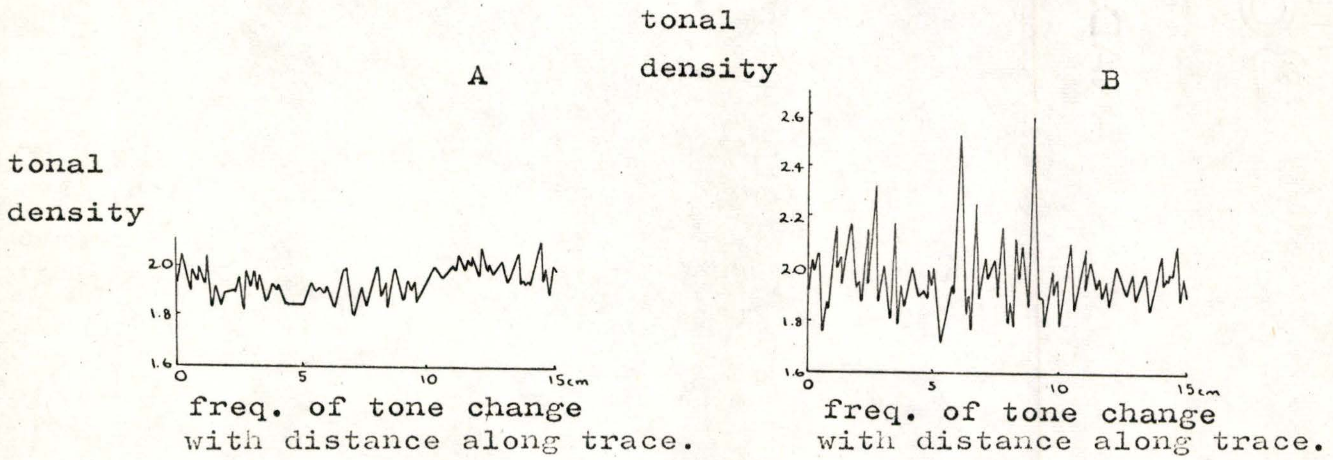


Fig1-2 Densitometer traces showing relation of magnitude and frequency of tone changes across two different land forms. A-an alluvial area of low relief; B-a glacial moraine. (after Ray & Fischer 1960)

the tonal variations between beaches, for which certain conditions were constant, with the grain size of the beach material.

Texture was defined by Colwell (1952, p. 538) as "....the frequency of tone change within the image .... and .... is produced by an aggregate of unit features too small to be clearly discerned individually on the photograph." Thus the scale of the photograph and/or the phenomena being observed from it, has an important bearing on the identification of texture. Although tone is a fundamental element, the conditions that affect tone may vary without affecting the usefulness of texture as an element of recognition. This is due to the fact that texture is really a composite function of tone, shape, size and pattern, so any slight variation of the former would have little significance.

Objective description of texture is extremely difficult, although it has been attempted by several researchers, (Spurr 1948; Raup and Denny 1950). An attempt has been made by Rosenfeld (1962) to define it mathematically, using a characteristic curve derived from video traces of the magnitude and frequency of tone changes across black and white aerial photographs, obtained with the aid of a flying spot scanner. Photographic texture has been compared, qualitatively, with the texture of photographed sand paper and a standardised set of textile samples - distributed for this purpose by the

Cotton Textile Institute of the U.S. (Rosenfeld 1962) - but it is most frequently illustrated by field examples, without which any use of descriptive terminology seems of little use in this context.

Pattern is the "orderly, spatial arrangement of ecologic, topographic or vegetative features in a two dimensional plane", (Ray 1960, p. 10) and will often become identified with texture when small scale photographs are used.

Image shape On untilted aerial photography, areas of little or no relief appear as images having correct geometry, whereas vertical objects undergo distortion when they appear at some distance from the centre of the print. This phenomenon can be eliminated, for all practical purposes, by using only the central portions of the prints, where distortion is least.

Image shape as a recognition element is significant in geomorphic interpretation only in its broadest sense, that is, in the identification of individual relief forms such as beach ridges, drumlins, eskers, et cetera. Belcher (1945, p. 140-141) and his associates at Purdue University further recognise the value of using the shape of gully cross sections as a guide to the interpretation of superficial deposits.

Shadow is primarily a function of shape and tone and, although it may assist in the determination of image shape, it probably contributes little towards the direct identification of most natural features. Moreover, in areas of dissected relief, it can exercise a detrimental effect by obscuring features on shaded hill slopes and in making more difficult the comparaison of elements on slopes having different illumination. In so far as shadows contribute to texture and pattern they are of great importance.

The Relationship to Associated Features has been called the site factor (Colwell 1952) and is important because a single image divorced from its surroundings may not in itself be distinctive enough to permit its identification. Scale is obviously crucial in determining the degree to which an image may be interpreted directly or only in association with its surroundings.

A second set of factors, which should be considered prior to the use of aerial photographs, concerns their potential usefulness in elucidating the problems under consideration.

Thomas, as early as 1920, stated that "aeroplane photography may become a valuable means of research, especially in connection with river development or denudation in a region which is somewhat inaccessible, or where the surface of the ground is complicated and the main features are obscured by a mass of less important detail", (Thomas 1920, p. ii).

Aerial photographs provide an instantaneous and complete record of all ground conditions at any point or series of points through time. They also provide a wider view point and often reveal an orientation of landforms and pattern of topography not easily observed from the ground, even though such details could be mapped in the field and their relationships studied from map symbols. They may even reveal phenomena not visible from the ground at all. Aerial photographs can extend the horizon of ones field of view, and cut out spurious detail in generalisations which for any large scale planning may be of far greater significance.

An economic advantage which the use of aerial photographs has over the ground survey method, is the efficiency with which they can be used to plan traverses across wide areas of terrain, in such a way that ground sampling can reveal an accurate picture of the area in question. As a result of this use, all types of ground survey can be considerably speeded up.

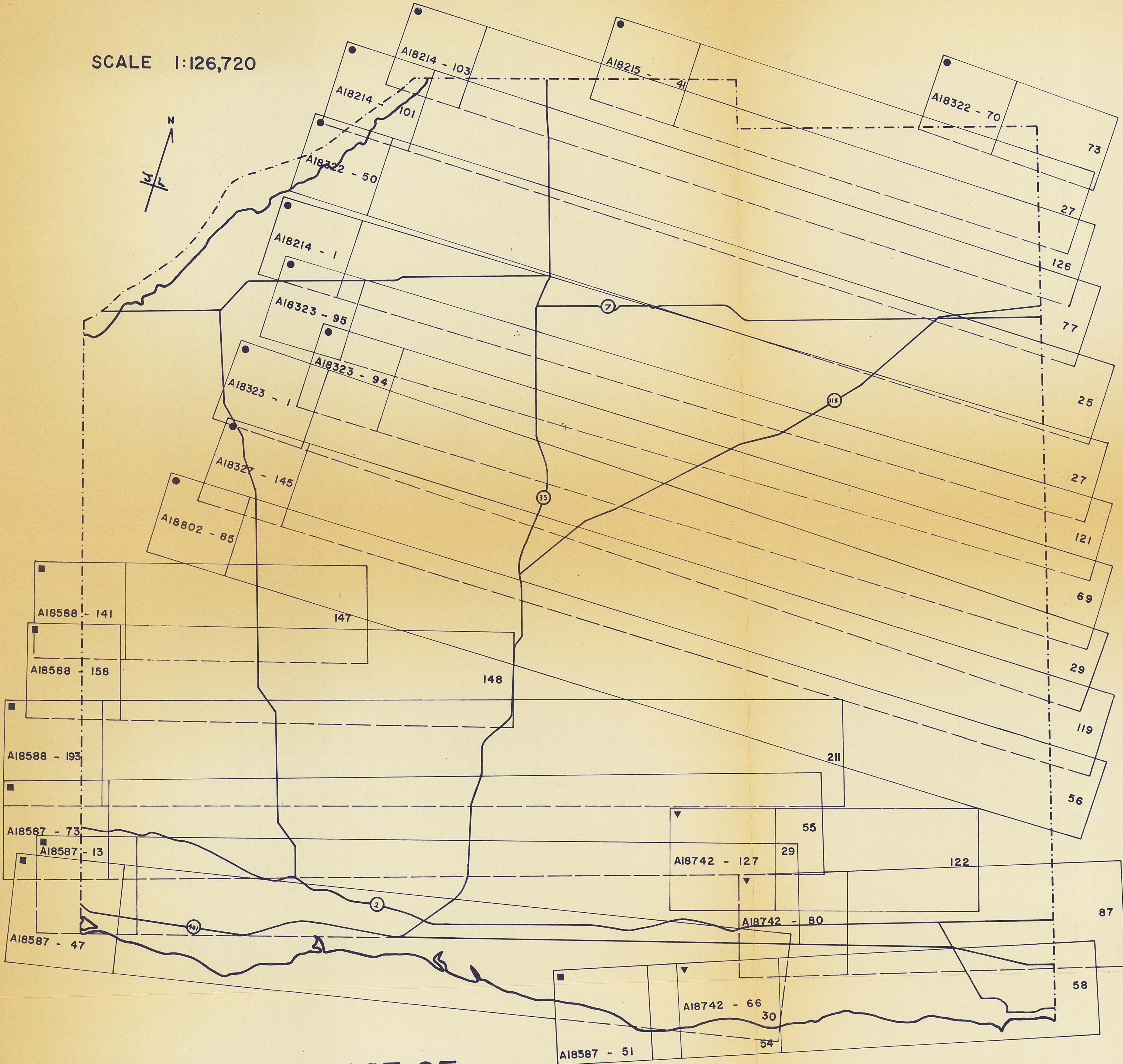
The usefulness of any photographis, however, determined by the scale, the quality and, most important of all, the ability of the interpreter in both interpretation and application of a wide field of experience of the phenomena which he is trying to identify from the photographs. As pointed out by Roscoe (1952) "The air photo is a window through which the viewer projects his background to determine what is in view".

The relevance of scale is obvious, but it is interesting to consider some of the variables which collectively influence the quality of an aerial photograph. There are the relatively constant, man-controlled variables, such as the properties of the film, the method of printing, film-filter combination used, the shutter and camera efficiency, vibration of the aerial camera itself and the movement of the camera relative to the object on the ground. Also the focal length of the lens, the amount of lens distortion (increased with an increase in lens angle) and the components of the interior and exterior orientation and finally, the variable natural factors, including the apparent reflectivity of an object due to its position relative to the angle of the sun, due to haze and atmospheric refraction, (Welander 1962).

(iv) The Procurement of the Aerial Photography

The specifications required by a group of aerial photographs are dictated by the aims of the study for which they are to be used. In many cases, including this one, economy necessitates the use of pre-existing photography as opposed to procuring more. Photography varying in scale from 1:18,000 to 1:21,600 was chosen from the limited range available, because experience in interpreting photography has indicated that had a smaller scale been selected, for example 1:40,000, some of the tonal variations would have been indistinguishable, planning of field work and taking measurements of discrete landforms would have been more difficult and any complete description of the terrain in terms of the desired number of criteria impossible. Had the scale been larger, it is doubtful whether it would have been proportionately more useful because the recurring tonal variations, which are so important to terrain unit identification, would have been more diffuse and more difficult to pick out.

Unfortunately the photography of the County (Figure 1 - 3) was not all taken at the same scale, or at the same season of the year and was by no means uniformly exposed. However, had it been possible to procure new photography, apart from keeping the above factors constant, the only major change in the specifications for the photography would have been to have had it flown in late spring, for this is the only time of the year when topographic details are not obscured by foliage and when there is a large amount of soil moisture to aid in the identification of drainage patterns. In some areas of the County for which photography flown at different seasons was available, specific patterns were much easier to identify on the spring photographs than on the summer ones. This reflects the fact that variation in soil moisture is one of the prime influences on variation in photographic tone.



AIR PHOTO COVERAGE OF DURHAM COUNTY

Map 1 - 3

■ Photography taken 1964; A.S.L. 10,000; 6" Lens.

● Photography taken 1964-6; A.S.L. 9,000; 6" Lens.

▼ Photography taken 1965; A.S.L. 10,800; 6" Lens.

CHAPTER II

REVIEW OF THE LITERATURE PERTAINING TO THE IDENTIFICATION OF TERRAIN UNITS

The concept of subdividing the landscape into units to facilitate the description and mapping thereof, is not new. Kessali, for instance, in 1946 advised geomorphologists to develop an extensive nomenclature for descriptive landform analysis, landform types and landform type areas. In 1950, he advocated more explicitly a search for geomorphic landscapes, or regions of similar and of different associated landform types. He pointed out that " a study of assemblages of geomorphic landscape is the best means of establishing a true geographer's geomorphology".

Kessali's ideas were carried on by his student Hammond, who devised a scheme to describe and map landform type regions in part of southern California, (Hammond 1954). In this and later works he confined himself to the use of small scales as required on world and continental maps and an analysis of configuration without any genetic implications. For North America, Hammond used three criteria in his subdivision of terrain types, namely: local relief, slope and proportion of near level land. These he further divided into a total of eighteen categories which he subsequently regrouped to define eight terrain types, described as: Nearly flat plains; Rolling and irregular plains; Plains with widely spaced hills and mountains; Partially dissected tablelands; Hills, Low mountains; High mountains and ice caps.

This categorisation is essentially similar to that used in 1949 by James in his continental terrain type maps which were intended to provide a physical background to his economic and ecological stidues. Several other methods of mapping terrain using a non-genetic classification have been devised: Finch and Trewartha (1949) published world maps based on a simple fourfold division of plain, plateaux, hill-lands and mountains; and work by Kendall et al., (1951, p. 182-6) has a similar basis.

In 1960 Thrower contributed a landform study of the island of Cyprus, using Hammond's classification but a larger scale of 1:50,000. Then two years later Lewis (1962), using a modified version of the same method, produced a choromorphographic or surface configuration map, of the west-central U.S.

The advantages of using aerial photographs for terrain mapping were not fully realised until the early 1930's, but since then they have been applied with considerable success by researchers in all parts of the world. It must be emphasised, however, that "terrain mapping" and "terrain unit mapping" are not necessarily synonymous; the former usually refers to morphographic maps on which physiographic features are represented by a standardised set of pictorial or geometrical symbols.

The literature pertaining to the use of aerial photographs in "terrain unit identification" per se., is not large in quantity, is not always easily available and varies greatly in quality. It is also usual to find that publications whose title professes to deal with the topic, are instead concerned with some particular geomorphic phenomenon. For example, Sager (1951) and Cabot (1947) in their papers on aerial terrain analysis in the Canadian Arctic describe in detail the geomorphology of the land surface but mention only incidentally that the majority of the data was obtained from aerial photographs, interpreted with the aid of selective field work. There is even failure to explain which information was obtained by field work and which inferred by interpretation from the photographs. Occasionally writers correct this omission but nowhere, to my knowledge, is there any reference to or analysis of, the thought processes and data gathering involved in the period between the first inspection of the photographs and the final production of a description of the geomorphology of the area shown on them.

The unit area method of land classification as developed in 1935 by the Land Classification Section of the Tennessee Valley Authority, represents one of the earliest attempts to use aerial photographs in conjunction with field work, as a means of subdividing a large area of land on the basis of physical conditions, (Hudson 1936). This study employed the fractional code notation for describing terrain units, combining it for the first time with the use of aerial mosaics as base maps. The mosaics were at a scale of 1:12,000 and each of the land units recognised comprised 200 acres or more. The digits in the numerator of the fractional code were concerned with land use and in the denominator with slopes, drainage, erosion, rock exposure, stoniness of the soil and soil type. Field procedures are recorded in detail by Hudson, but may be summarized as follows:

1. Recognition of an essentially homogeneous land unit.
2. Tentative characterisation of the unit recorded on the mosaic.
3. Tentative boundaries of the unit drawn.
4. Boundaries checked, where possible, during subsequent field work.
5. Final characterisation of the unit made in the form of a fractional code.

The contribution of this work towards solving the specific and regional development problems of the Tennessee Valley was considered to have fully justified the original experiment, which proved beyond all doubts the value of using aerial photographs in this type of work.

In the years immediately following the Second World War, there developed in Canada a demand for a rapid inventory of the nothern environments. A survey was required which could reveal the potential mineral wealth of the north, its suitability for civil and military engineering and its basic geology and geomorphology- about which almost nothing was known. Not suprisingly aerial photography was selected as a basis for the surveys and to this end the R.C.A.F., and certain private companies began an intensive campaign to provide complete air photo coverage of nothern Canada. Vertical photographs were taken in the south and trimetrogon photographs in the north. Several research projects were undertaken by Wilson (1958) and Hare(1959,1964) for the Canadian Defence Research Board and by Bird (1967) for the RAND corporation. Whatever the purpose of each survey, whether it was military or geomorphological, the early analyses were concerned primarily with mapping landforms and landform assemblages. Table 2-1 illustrates four of the Arctic Terrain Classifications used in such studies, (Bird 1967,p.272).

The survey of Labrador-Ungava supervised by Hare (1959,1964) is a case in point. The purpose of the study was to prepare maps of ground cover (vegetation and water) but, in order to understand the reasons for the vegetation distribution and hence aid the mapping thereof, it was necessary to map and draw up a classification of "the apparent aerial

Table 2-1. Arctic Terrain Classification

RAND-McGill (1955 modified)	Hare-D.R.B. (1948 modified)
Rock (100%)	Rock plains
Mainly rock (more than 70% rock)	Low hills
Rock & drift (30-70% rock)	Bold hills
Drift & rock (less than 30% rock)	Glacially moulded hill terrain
Drift (no rock outcrops)	Undifferentiated drift plains
Marshes	Drumlinised drift plains
Sand &/or silt	Rippled till plains
Eskers	Drumlin bog
Beaches	Eskers, gravel trains & sand plains
Ices	Incised valleys
	Spillways

Dept. Mines & Technical Surveys.	Geographical Branch. 1955, 1959.
Glacial deposits:	Swamp
Undifferentiated	Crystalline rock
Eskers	Sedimentary rock
Drumlins	Ground moraine
End moraine	Drumlin terrain
Till plain	Outwash
Fluted till plain	Submarine deposits
Sand dunes	Deltaic deposits
Sand plains	Bog, extensive scattered
Badlands	End moraine, major
Terraces, strands & outwash	End moraine, minor
Alluvial fans	Esker
Rock knob terrain	Esker delta
Bare rock	Glacial channel, dry
Undifferentiated	Beaches
Crystalline	Sand dunes
Volcanic	
Sedimentary	

morphology of the peninsula" (Table 2-1, column 2). In order to do this, the following procedure was used.

First, field studies, covering many th ousands of square miles and reconnaissance flights over even greater distances were undertaken to sample ground conditions and establish an air photo interpretation key for each of the main zones observed within the peninsula. Each key comprised a fully interpreted photo, with overlays of vegetation and physiography, ground photographs and a brief explanatory text. Although the keys were basically similar, each one had to be adjusted to the particular characteristics of the zone it covered, for no key drawn up to aid interpretation in a limited area can ever be used without some modification with reference to another. The second stage of the study involved the main programme of laboratory photo interpretation. Using the established keys to interpret both vertical and trimetrogon aerial photographs, maps of terrain units were prepared at the only available base map scale of 1:506,880. With this complete, another series of field studies were initiated to investigate the scientific problems revealed by interpretation. The fourth stage of the study involved the preparation of brief descriptions of each of the terrain types, accompanied by ground and aerial photographs. Finally a further reduction of the maps was made to a scale of 1:1,000,000.

The limitations of this study, as an exercise in describing and mapping terrain units, can be excused on the grounds that this was not Hare's primary objective. Nevertheless they are worth noting. The final maps represent a four-fold reduction of the originals and hence are really sketch maps, useful as regards regional pattern but grossly over-simplified with respect to topographic detail. The requirement of objectivity called for the use of a somewhat elementary physiognomic classification i.e. one which is deliberately neutral as to genesis and evolutionary stage. No attempt was made to ascertain actual altitudes of the ground surface, because it was not vital to the study and would have required a disproportionate increase in the quantity of work to rectify this omission. Finally subsurface geology was ignored. However the work does constitute the only comprehensive mapping of the topography of the Labrador Penninsula and comprises the first use of air photo interpretation for extensive regional reconnaissance to be mapped at small cartographic scales.

Robitaille (1956) in his delimitation of terrain types in the coastal areas of Foxe Penninsula, Baffin Island, dispensed with the production of an accurate map. Instead he outlined his terrain units on transparent overlays superimposed on his 1:38,000 aerial photographs. Each delimited area was then classified by means of a fractional coding system, annotated directly onto the overlays. The variables used by Robitaille in defining his units and represented by the fractional code were: morphology, geology, surface deposits, drainage and trafficability, and each of them was assessed qualitatively whilst in the field.

Included in the study are a large number of ground photographs accompanied by a description and explanatory text designed to illustrate conditions within the area. They also provide in non-technical terms, a key to assist photo-interpreters to analyse and identify areas of similar physical characteristics elsewhere. Unfortunately, the relationship between the text and either the terrain units as defined on the overlays or the six sample regions which he describes as representative of each of the terrain units found within the area, is not explicit.

Baffin Island was also the subject of Sim's (1964) attempt in 1961 to provide a description of terrain conditions, using aerial photographs in conjunction with field work. He was concerned with mapping physiography and representing a glacial chronology of the nothern part of Foxe Basin. The method used was to interpret the aerial photographs and transfer from them to 1:500,000 maps all details pertaining to fluvio-glacial and glacial deposits, drainage and raised shoreline features. Having done this Sim divided the mapped area into five physiographic regions, each of which he described in some detail with respect to extent,altitude and major geomorphological characteristics, although no quantitative details are given. The precise basis for subdivision, the problems of definition and the exact method and extent of field sampling is not mentioned. However, it appears that consideration of surface form was a major determining factor.

Rather more data concerning methodology is supplied by Fraser (1964) in his study on terrain analysis and air photo interpretation of the Boothia Penninsula, N.W.T. He not only analysed over 6000 vertical and trimetrogon aerial photographs but reduced radar profiles flown in an east-west direction across the penninsula. These latter provided data on relative altitude which was not otherwise available. The extent of his field work is not mentioned apart from the fact that it was sufficient to enable a classification of arctic terrain types to be made and was planned with reference to the aerial photographs. However, it is evident, from the ground photographs, the text and reference to geological samples, that it involved sampling over a very extensive area.

The physiographic regions mapped by Fraser were delineated on the basis of a combination of field and air photo evidence, namely: characteristics of relief, drainage, insolation, geology, slope angle, superficial deposits, evidence of glaciation, vegetation and geomorphic history. Then each terrain type was discussed under the following headings: photographic tone and pattern, topographic expression and origin, drainage characteristics, relief and trafficability.

The regions were outlined on the aerial photographs and plotted directly therefrom using Kodatrace templates.

The unpublished work entitled " Soils and Terrain Around Resolute, Cornwallis Island " by Cruickshank (1968) is unusual in two respects. First, it differs markedly from all the other works in this topic in that he conducted detailed laboratory experiments on the soil samples which he collected from a representative selection of the terrain units which he outlined on the aerial photographs. Second, due to circumstance, he had to adopt the unusual procedure of distinguishing the terrain units in the field before looking at the aerial photographs. This fact explains why his criteria for identifying the different terrain units includes such factors as: stone content of soil, wetness of surface layers and quantity of fine earth present, besides the more normal criteria of morphometry, vegetation, surface patterning and sorting of material. No analysis of drainage patterns was attempted, nor of slope angle as this was considered to relate to surface form and pattern, already considered. Even more suprisingly, erosion was ignored. Despite this, the work does present detailed profiles of the different terrain units, a different approach to the problem of terrain unit identification and precise details of field work.

The terrain unit classification drawn up by Cruickshank is given in Table 2-2. The units themselves were delineated directly onto four times enlargements of the original aerial

Table 2-2. Terrain Unit Classification Devised by Cruickshank for Cornwallis Island

Raised Shorelines & Marine deposits & Forms

- Recent shorelines, fresh forms, sub-angular material
- Shoreline of sorted shelly material
- Raised terraces, fresh form, rounded & sorted material
- Highest beaches, shelly & sorted material subject to solifluction

Rock Outcrop & Related Screes

Patterned & Sorted Level Ground

- 4-6 foot polygons, composed of large stones
- 2-5 foot polygons, composed of 50% fines which accumulate at the centres

Seepage Area of Clay

- Fine material, mossy-organic cover, some patterns, little or no sorting except in drainage channels

Hummocky, sloping patterned ground

- Stony but not sorted

Clay mantle on level ground

- Mainly in inland valleys

Clay deposits scattered with superficial stones photographs, which were cut up to ease field handling. This procedure ignored the inevitable photographic distortion and the errors in interpretation which this may produce. Certainly if any quantitative data had to be incorporated into the terrain unit classification, this system would prove inadequate.

An interesting attempt has been made by Dunbar and Greenaway (1956) to subdivide the entire Canadian Arctic Archipelago into physiographic regions on the basis of air photo pattern. The purpose of the study was to provide arctic pilots with a pictorial and descriptive guide to ground conditions as seen from the air. Hence it deals only with surface form and pattern, it does not include any field work and the subdivision is very generalised. This is unfortunate from the geomorphological aspect but is inevitable considering the vast area covered. This study is unique in that it uses non-stereoscopic high oblique trimetrogon photos (from the R.C.A.F. survey) and because no maps were produced apart from small sketches of the physiographic divisions of each of the arctic islands.

The simplest form of terrain unit maps are those drawn up to provide the armed services with maps portraying non-technical data on trafficability and suitability of an area for military engineering. Radforth's work on "Organic Terrain Organisation from the Air"(1955,1958) is an example of this.

It deals with an area largely composed of muskeg in northern Canada and proposes a categorisation of the terrain surface into twelve different types. These he then describes subjectively under the following headings: photographic tone, texture and pattern; vegetation density; the size and shape of predominant objects as viewed from 150 feet; terrain depth range in feet; relative bearing strength; subsurface ice; drainage and terrain roughness. In spite of the fact that the last four items lend themselves easily to quantitative assesment it should be noted that each of them was qualitatively assigned pre-defined values ranging from 0-10.

A similar approach was used by the U.S. Naval Intelligence in their analysis and mapping of the Yuma Desert Area (1959,1963). Their aim was to determine the military trafficability of land units- defined on this basis- for the relatively small area of the Yuma desert and then extrapolate their findings to satellite photographs of desert areas in other continents. This involved detailed field work and analysis of aerial photographs, topographic, soil and geologic maps of the readily accessible Yuma area, which was assumed would contain a sample of all types of terrain encountered in the larger desert areas in Asia and Africa. The fact that this assumption cannot be relied upon greatly reduces the potential accuracy of the work involved. The variables used as a basis for the classification of the terrain into units of varying trafficability are as follows: soil type, vegetation, slope, relief, characteristic plain profile, surface rock, surface roughness and physiography. When all the analyses were complete each criterion of trafficability was mapped separately on a topographic sheet, with a unit being defined as an area where a single characteristic has a constant value within more than 70% of the area. Where this did not occur, the unit would be mapped as an areal complex having two factors co-dominant. Then,finally, a composite map was plotted showing all the characteristics represented by a fractional code system. Written data pertaining to the final map was confined to a clarification of the illustrations of landforms and physiographic types.

All the literature mentioned thus far has been concerned with areas in North America. However, it is by no means the only continent in which the potential of aerial photographs for terrain analysis has been realised. The C.S.I.R.O. in Australia developed, over 12 years ago, one of the most comprehensive methods of gathering air photo and ground data and combining these with map,tabular and diagrammatic data, in an attempt to describe land systems, defined on the basis of a large number of variables. The data obtained in each of the surveys carried out by C.S.I.R.O. was gathered by a team of scientists, including a pedologist, a geomorphologist,a geologist, a botanist and a hydrologist, all working in collaboration. Their task was to map and describe large areas of the country using as their descriptive unit, the land system. This is defined as a group of areas with a recurring pattern of land form, soils and vegetation and relies on the concept that each of the land systems is expressed on the aerial photograph as a distinctive pattern.

Upon receipt of the air photo coverage of the survey area, the team of scientists would spend about a month or an eighth of the time alloted for the survey, in analysing the photographs. The first step would be to delineate areas of distinct air photo patterns, considered to represent land systems. Then the photos would be used to plan field traverses by jeep and helicopter, to validate the tentative land systems and discover just what ground conditions are represented by each of the distinct air photo patterns. During field work checking of land system boundaries would be effected and areas in which interpretation was uncertain would be visited and the situation clarified.

Not until each member of the survey team was satisfied that the land system devised was truly valid for his field of study, would maps be drawn. The maps were prepared from annotated photographs and in their final form each was accompanied by a detailed report of the ground conditions existing within each delimited area. These reports would incorporate aerial and corresponding ground photographs of a representative section of each land system, a three dimensional geomorphic diagram of any particularly characteristic landforms and possibly a geologic cross section if the situation warranted it. Field data for each of the particular sites examined would appear in a tabulated form under such headings as:

geomorphology, drainage characteristics, geology, vegetation, erosion, soil, superficial deposits and characteristic slope angle. Finally a discussion would be presented to deal with any particular problems that were encountered during the study. (Mabbutt et al.,1963, Perry et al.,1956-7)

Of all the literature studied the methodology used by C.S.I.R.O. in their study and presentation of land systems appears on the surface to deal with the problem in the most complete manner. A more detailed examination, however, reveals that it is the uncomplicated nature of the geomorphology rather than the quality of the methodology that gives the impression of completeness.

A very similar methodology has been used by government agencies in West Pakistan(Hodges 1956) and in South Africa on the granitic terrain between Pretoria and Johannesburg, (Brink et al.,1967). The latter study, of the Kyalami land system, relates land facets or units to soil types. Another South African study, by Aitchinson and Grant (1967) presents a Pattern-Unit-Component-Evaluation Land Classification system which is evolved using a four stage hierarchical subdivision. The first stage in the hierarchy is the Province- an area of constant geology on a regional scale. Second, is the terrain component- an area of constant soil or rock profile, on a constant slope with a constant vegetation association. Third, is the terrain pattern- an area delimited by air photo pattern. Fourth, is the terrain unit- an area occupied by a single physiographic feature.

A modified version of the methodology used by C.S.I.R.O. has been employed by the Oxford Military Engineering Experimental Establishment in England. The M.E.X.E. system includes details regarding climate, agriculture, landscape genesis and is sufficiently flexible to deal with areas of complex geomorphology. It has been applied in England and many parts of the Commonwealth.

In India, Ghose et al.,(1966) have made possibly the first attempt to delineate landform units from aerial photos, for that continent. Their particular classification is largely dependent on genesis.

Very few studies pertaining to terrain unit identification have been initiated in humid tropical areas. However, Erb (1968) has carried out such a study in Jamaica. The working procedures used in this instance are as follows: initially a field reconnaissance of the entire island was made, then a stereoscopic inspection effected in order to delineate any recurring air photo patterns and evaluate their significance in the light of information gained from field work, geological and soil maps. Simultaneously, areas exhibiting different drainage patterns were outlined on the photos and conclusions drawn as to the relationship between these areas and the regional geomorphology. In his paper Erb includes many stereo-pairs of photographs, each representing a major terrain type found in Jamaica and each accompanied by a brief description of morphology and genesis. The impression is conveyed that his purpose was to illustrate, by a series of well chosen examples, the effectiveness of air photo interpretation in the field of geomorphology and geology in this particular environment, rather than to depict the geomorphology of the island.

The final item of literature to be considered, anticipates the future. It comprises a short article by Mollard (1968) which illustrates a detailed method of terrain unit subdivision on a single coloured aerial photograph. It is interesting to note that the units are outlined on the basis of tone and pattern variation and a detailed knowledge of ground conditions,in other words, in terms of exactly the same criteria that are used with panchromatic aerial photographs.

CHAPTER III

PROCESSES INVOLVED IN THE RECOGNITION OF TERRAIN UNITS

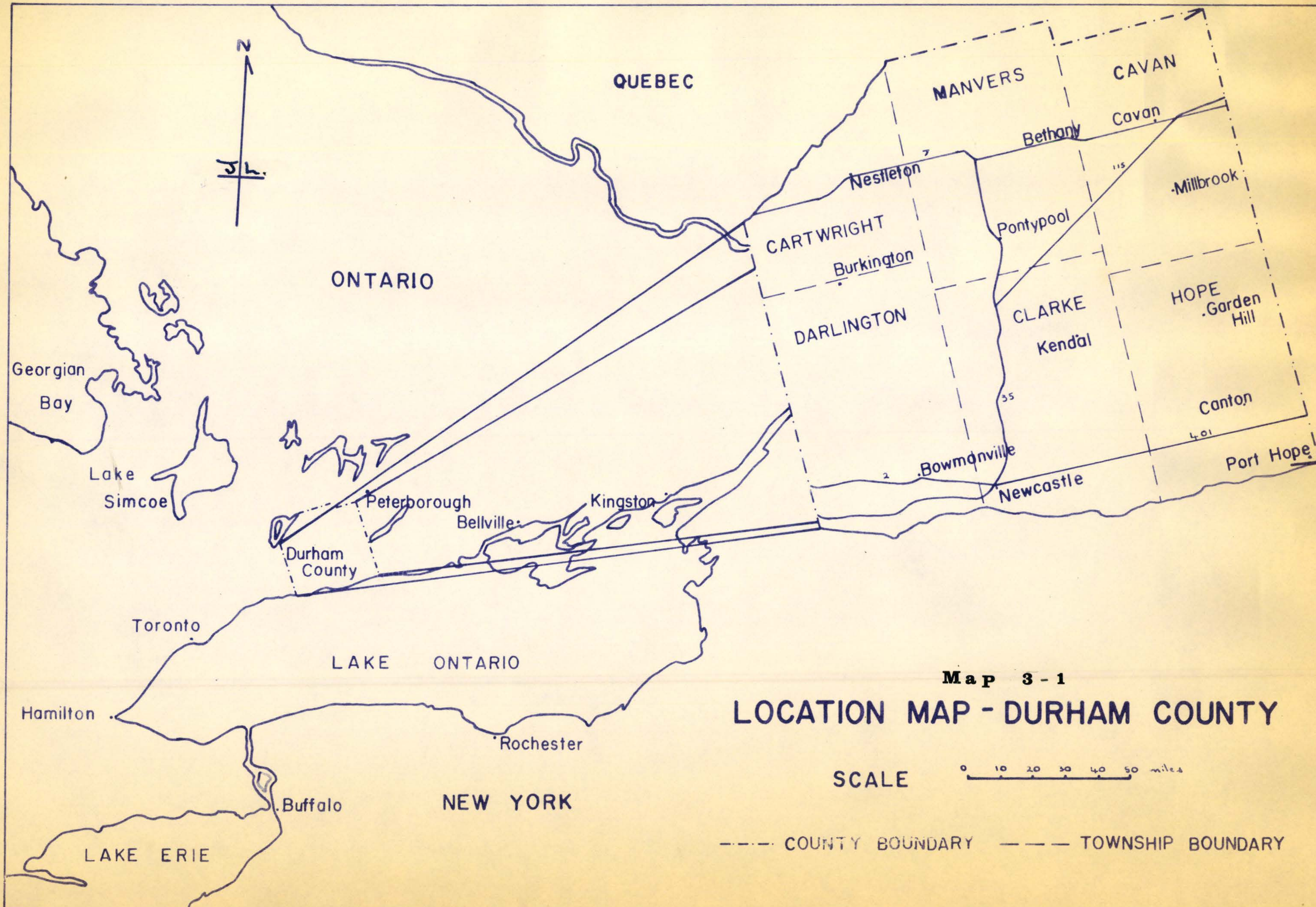
(i) The Assemblage of Data Pertaining to the Study Area

(a) Location

Durham County is located in central Ontario, on the nothern shore of Lake Ontario (Fig.3-1). It is bordered by Ontario, Victoria and Northumberland Counties to the west, north and east,respectively, and covers an area of 629 square miles (Webber et al.,1946,p 9). The water plane of Lake Ontario,at 245 feet above mean sea level, marks the lowest point in the area. The highest point is the crest of the Oak Ridges moraine about three miles north-west of the village of Kendal where the elevation is 1,275 feet.

(b) Glacial History and Physiography

The study area may be divided into five physiographic regions: first, a drumlinised till plain that occupies the nothern half of the area; second, the Schomberg lake deposits which are scattered sporadically across the till plain; third, the Oak Ridges interlobate moraine or kame moraine, that extends in an east-west direction across the centre of the county; fourth, the Iroquois Lake plain; fifth, a deeply eroded drumlinised till plain situated between the Oak Ridges moraine in the north and the Iroquois Lake plain in the south.



Map 3 - 1

LOCATION MAP - DURHAM COUNTY

The superficial deposits were originally mapped by Gravenor (1954,1955,1957), however, the inaccuracy and degree of generalisation of these maps necessitated the production of new ones, from field and air photo evidence, for this thesis. (Figs.3-2 to 3-7).

The superficial deposits are all Pleistocene and Recent in age, and an examination of the pebbles contained therein, well boring data and papers concerned with the subsurface geology of the area, suggests that the underlying bedrock is mainly Trenton and Black River limestone of Ordovician age. The form of the preglacial topography is not known exactly, but studies made by Liberty (1952,1953) and Sandford (1959) in adjacent areas, suggest that the dip of the Ordovician strata reflects the regional slope of the Pre-Cambrian surface, which is south-south-west at a rate of 25 feet per mile (Liberty 1953). Hence the majority of the pre-glacial consequent streams probably headed in the Pre-Cambrian Shield.

The Wisconsin glacial history of this portion of Ontario may be summarised as follows. The continental glacier advanced from a north-easterly direction, covering all of Ontario and extending into Ohio,(Chapman and Putnam 1966). Subsequent retreat of the ice did not involve simply a progressive emergence of the land from the south to north, instead the margins of the wasting glacier assumed a lobate form. A division between two of the resulting lobes extended in an east-west direction across the middle of Durham County. The meltwater

THE PHYSIOGRAPHY OF DARLINGTON TOWNSHIP

KEY

- INTERLOBATE MORAINE
- GROUND MORAINE
- LAKE DEPOSITS
- GRAVEL
- SPILLWAY SANDS & GRAVEL
- MARSH
- IROQUOIS SHORELINE: DEFINITE, INDEFINITE
- FORMER COASTAL LAGOON OF LK IROQUOIS
- RIVER
- ROAD
- RAILWAY
- VI CONCESSION NUMBERS

SCALE 1:50,000

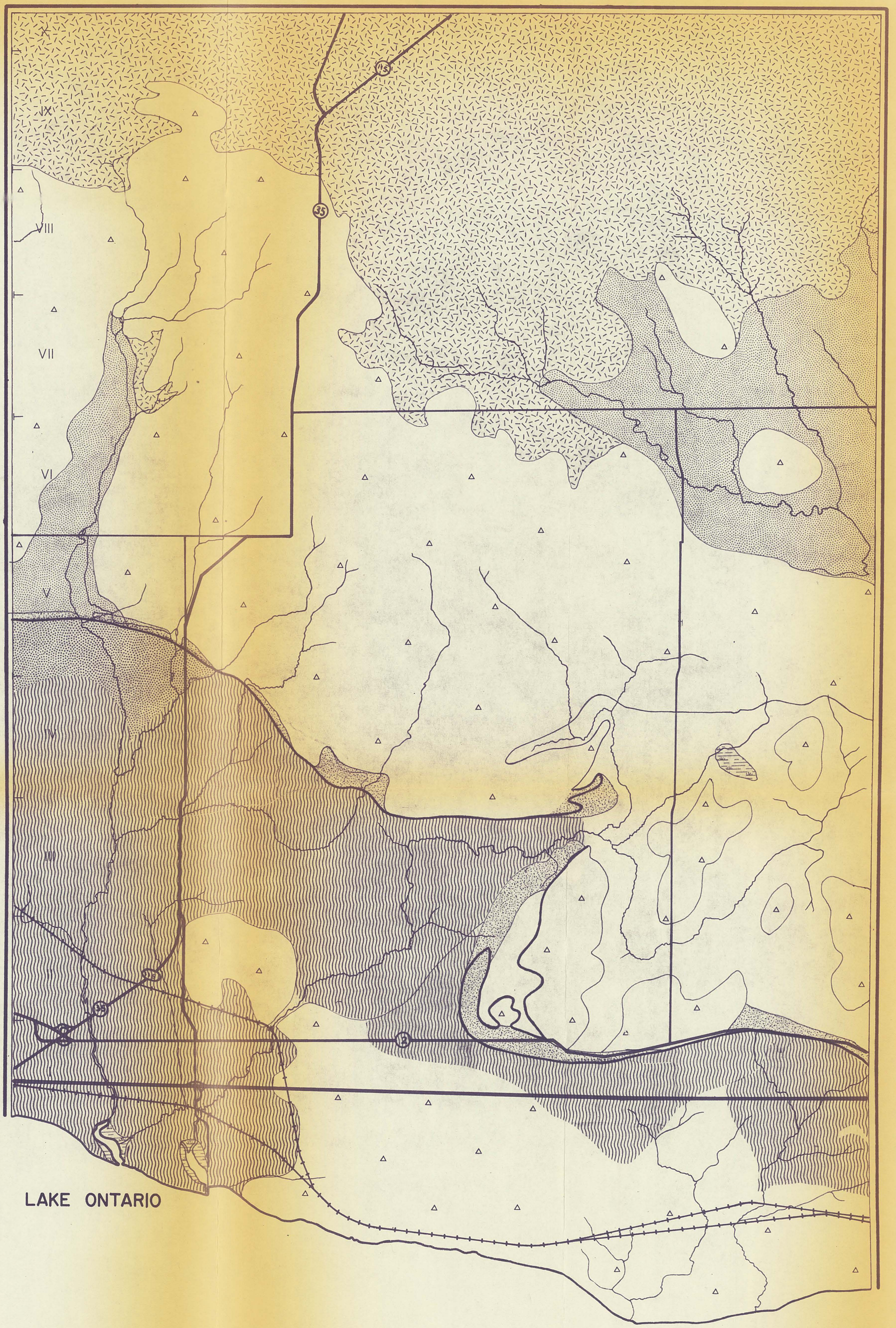
N

THE PHYSIOGRAPHY OF CLARKE TOWNSHIP

KEY

- INTERLOBATE MORAINE
- GROUND MORAINE
- LAKE DEPOSITS
- GRAVEL
- SPILLWAY SANDS & GRAVELS
- MARSH
- LAKE IROQUOIS SHORELINE
- FORMER COASTAL LAGOON OF LK IROQUOIS
- RIVER
- ROAD
- RAILWAY
- VI CONCESSION NUMBERS

SCALE 1:50,000



THE PHYSIOGRAPHY OF HOPE TOWNSHIP

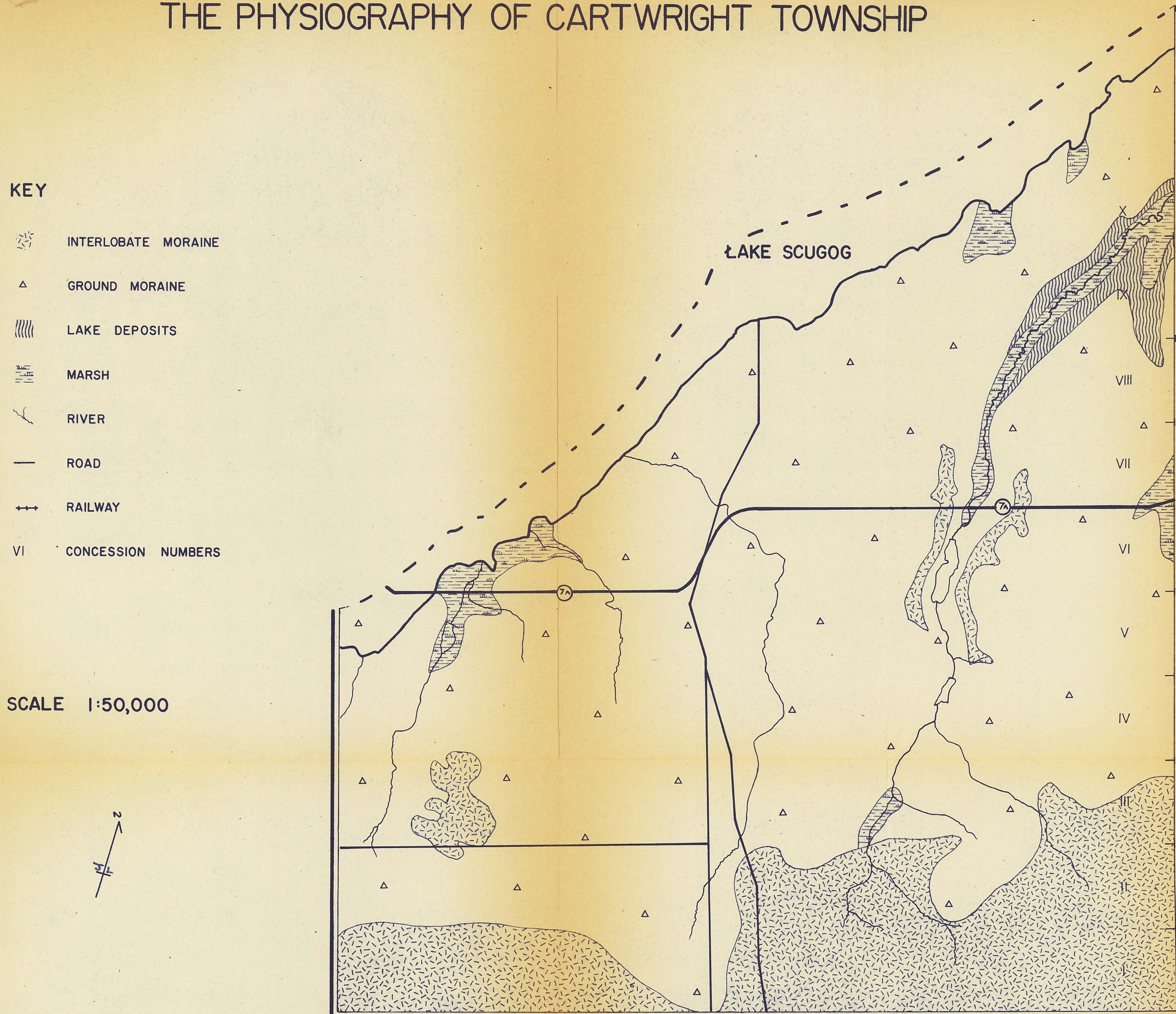
KEY

- INTERLOBATE MORAINE
- △ GROUND MORAINE
- LAKE DEPOSITS
- GRAVEL
- OUTWASH SANDS & GRAVELS
- SPILLWAY & DELTAIC SANDS & GRAVELS
- MARSH
- IROQUOIS SHORELINE: DEFINITE, INDEFINITE
- FORMER COASTAL LAGOONS OF LK. IROQUOIS
- RIVER
- ROAD
- RAILWAY
- VI CONCESSION NUMBERS

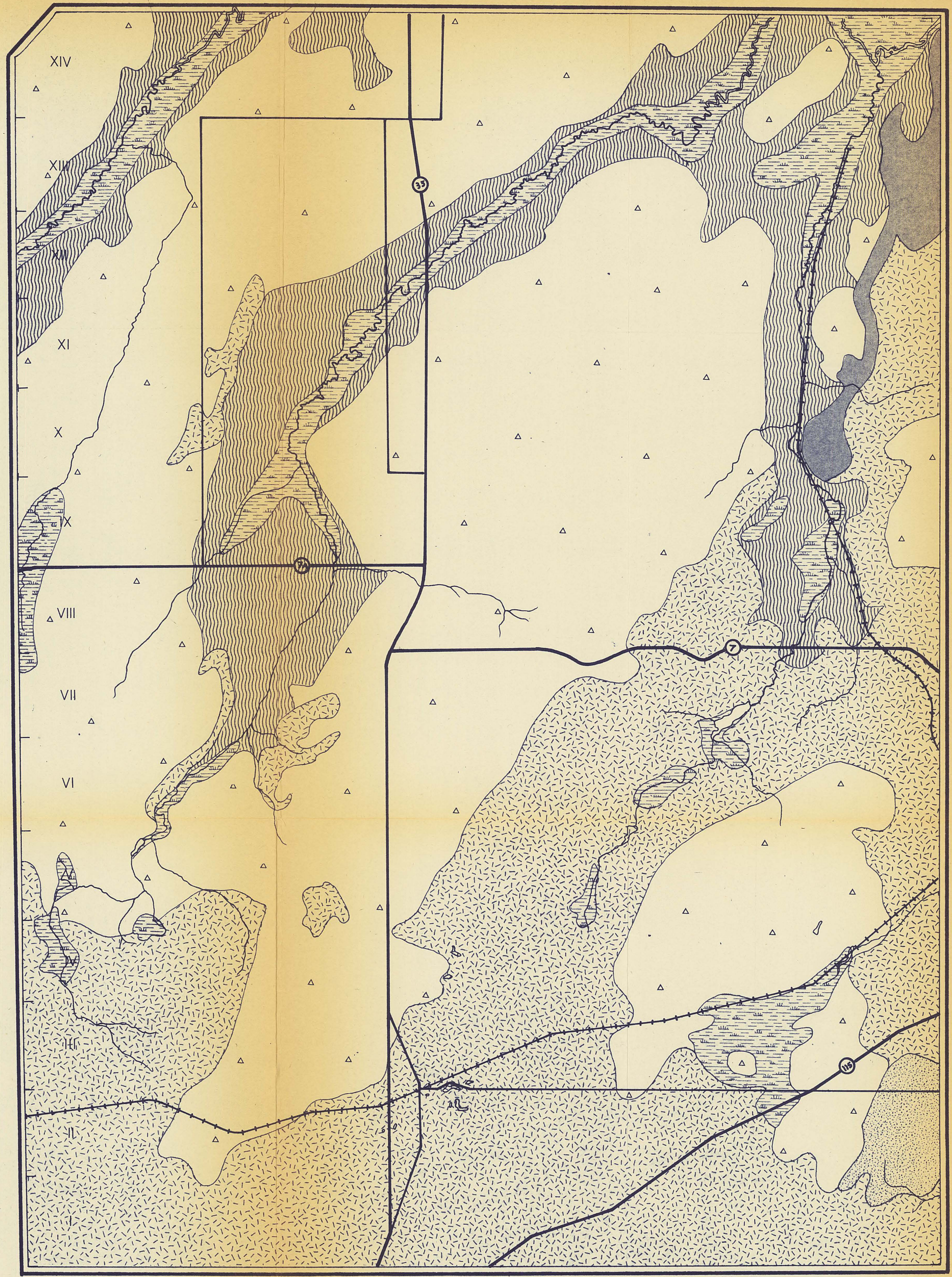
SCALE 1:50,000

N

THE PHYSIOGRAPHY OF CARTWRIGHT TOWNSHIP



THE PHYSIOGRAPHY OF MANVERS TOWNSHIP



KEY

- INTERLOBATE MORAINE
- GROUND MORAINE
- LAKE DEPOSITS
- GRAVEL
- MARSH
- ESKER
- RIVER
- ROAD
- RAILWAY
- VI CONCESSION NUMBERS

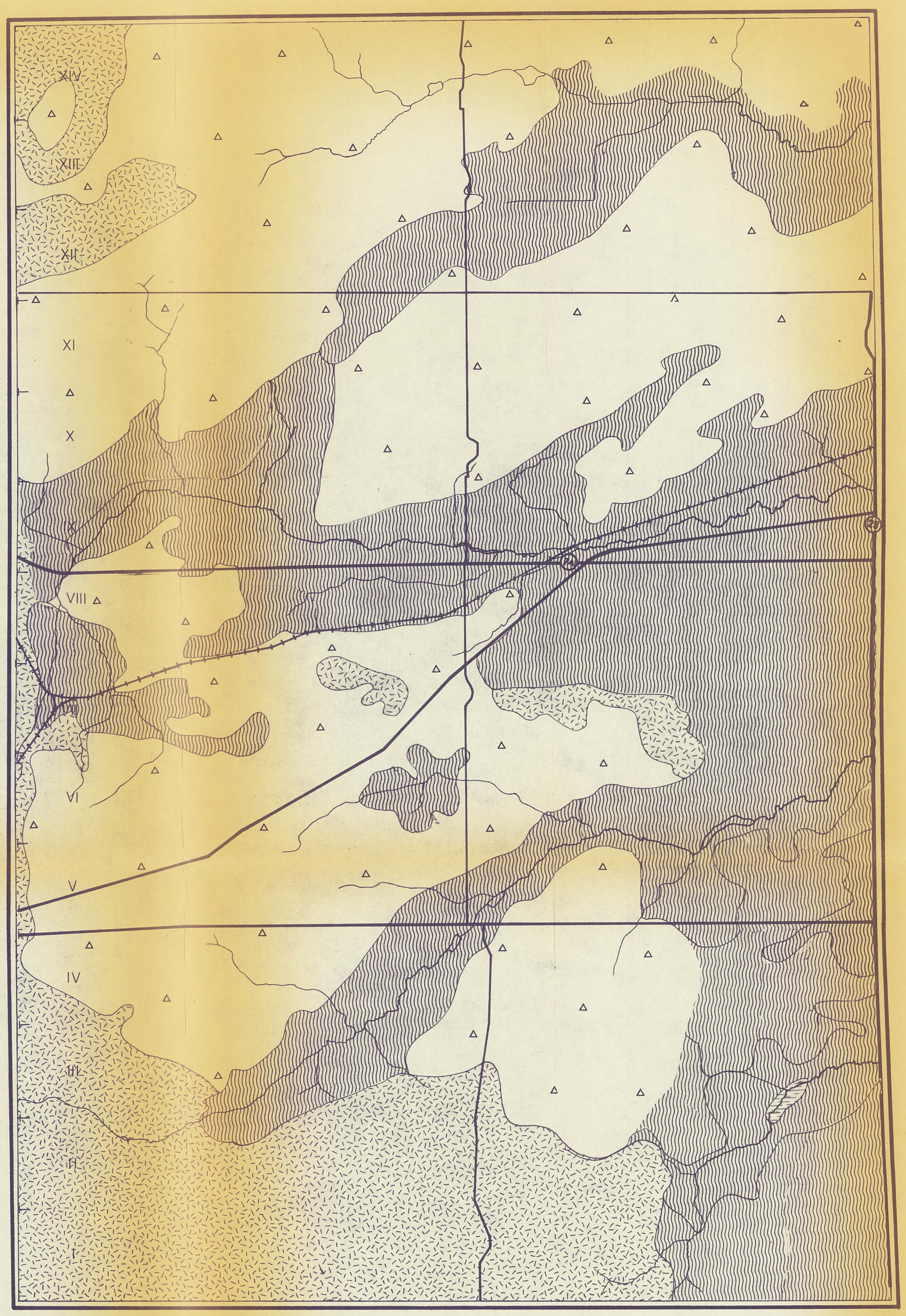
SCALE 1:50,000

THE PHYSIOGRAPHY OF CAVAN TOWNSHIP

KEY

- INTERLOBATE MORAINE
- GROUND MORAINE
- LAKE DEPOSITS
- MARSH
- RIVER
- ROAD
- RAILWAY
- VI CONCESSION NUMBERS

SCALE 1:50,000



from both lobes flowed into the crease between them and then westwards, depositing sand and gravel and initiating the formation of the Oak Ridges interlobate or kame moraine. Apparently these two lobes remained stationary for a long period of time because well borings indicate the deposit to be at least 350 feet deep, though if there is no bedrock within the main mass of the moraine it could be as much as 700 feet deep.

The recession of the two ice lobes continued resulting in the deposition of ground moraine and till alongside the Oak Ridges moraine, also the discharge of meltwater which frequently became impounded initiating the deposition of lacustrine materials. The extent of the retreat is not known, although it is thought to have been quite local prior to a re-advance of the northern lobe. This re-advance approached the Oak Ridges moraine diagonally, overriding it east of Uxbridge, in Ontario County. It destroyed many of the original characteristics of the moraine; mantled its northern and southern flanks with till and deposited several smooth, thin till caps along the crest. The direction of the ice movement during this period can be determined with varying degrees of certainty from eskers, drumlins, and the conformation of the moraines. The elongation of the drumlins afford the best clues and indicates the direction of re-advance of the northern lobe to be 23 degrees west of south, for all but the extreme south-west of the area. Here drumlin elongation is nearly due south indicating that the re-advance of the northerly lobe did not encroach upon this area possibly because of the continuing presence of the Lake Ontario lobe.

There are two further indications that the movement of the ice over the south-west portion of the County was from the south. First, the ground moraine to the south of the Oak Ridges moraine is less stony than that found to the north, reflecting the existence of lake clays in the Lake Ontario basin prior to the last ice advance. Second, amongst the pebbles which do occur, are small amounts of Collingwood shale which outcrops to the south of the Scugog area (Deane 1950).

The Lake Ontario ice lobe ultimately withdrew to the eastern end of the basin thereby precipitating the evolution of Lake Iroquois, and its associated coastal zone. In Durham County this has emerged as a fairly simple linear feature, trending in a direction approximately parallel to that of the present shoreline of Lake Ontario, with the shoreline frequently marked by a low bluff whose basal height ranges from 500 feet in the west to 558 feet in the east. The existence of Lake Iroquois became terminated when the Lake Ontario ice lobe withdrew from the slope at Covey Hill and hence uncovered lower outlets into the Hudson valley, (Chapman et al.,1966,p 44). A still-stand during this retreat is recorded by Coleman (1936) who suggests that it gave rise to the formation of Lake Frontenac and even gives several water plane altitudes for the lake. However, if the lake did exist it can only have been for a short time, because no well-defined Frontenac beaches or shorecliffs were noted by the author in Durham County.

In the time of Lake Iroquois, the margin of the northern ice lobe retreated nearly to the edge of the Shield. As it did so, meltwater became trapped in a series of shallow ponds between the ice front and the Oak Ridges moraine. Due to the confined nature of these lakes - known as Schomberg ponds, (Chapman et al.,1966,p 24)- and to numerous islands, wave action was at a minimum. As a result well developed beach deposits and shore cliffs are absent. It is therefore difficult to determine accurately the position of the old water planes and the outline of the ponds was determined mainly by mapping the distribution of the lacustrine deposits found in them.

(c) Drainage

The Oak Ridges interlobate moraine forms the main drainage divide between the north and south flowing rivers in Durham County. It shows no major breaks in relief but narrows and decreases in elevation at the south-west end of Rice Lake and south of Lake Scugog. Despite its influence on regional drainage, it has itself, as Carmen (1940) pointed out, " a virtual lack of surface drainage". All the water drains vertically through it, moving laterally only when it reaches less pervious beds and reappearing as springs along the the slopes of the moraine. Hence it serves as a source area for many streams which drain the adjacent plains.

The Ganaraska River is by far the largest in the area of study, draining over 100 square miles in the south-eastern part of the County. It is a good example of many streams that rise on the southern flank of the Oak Ridges moraine and discharge into Lake Ontario. It has a gradient of approximately 30 feet per mile and in the spring when the subsoil was still frozen, melting snows on the Oak Ridges moraine used to cause floods in the lower part of the valley, prior to the introduction of flood control measures. The Ganaraska has a further distinction in that it follows the course of a glacial spillway channel, a factor which helps to explain the presence of the large raised delta at the point where the River crosses the former Lake Iroquois shoreline. The gravels which comprise the delta were probably derived from the meltwater stream and its erosion of the Oak Ridges moraine.

Due to the presence of the raised Iroquois shoreline and the emerged lake plain to the south of the drainage divide, the drainage pattern has been considerably modified and on the basis of this modification can be subdivided into two parts. First, the area covered by a low density system of extended consequents- streams which existed at the time of Lake Iroquois and simply extended their courses at the time of emergence. Second, the very high density consequents which rise close to the raised shoreline, follow distinctly linear courses at right angles thereto and cause severe erosion on the coastal plain which they traverse. These variations in drainage density may be partially explained by variations in superficial deposits. The high density streams tend to occur on sandy or silty clay lacustrine materials and the low density streams on deposits of ground moraine and till.

Most of the streams which rise on the northern flank of the Oak Ridges moraine; the East Cross, Pigeon, Fleetwood, Cavanville, Baxter and Squirrel, flow north to join the Trent river system. In general these streams differ in several respects from their southern counterparts. Their gradients tend to be lower and hence flood plains and associated areas of flooded land larger, valleys are shallower and erosion less severe. However, where these streams traverse the junction of the interlobate moraine and the northern area of ground moraine or till, severe stream dissection occurs. In the case of the East Cross, Pigeon, Fleetwood and Baxter streams the overlying till cover has been breached and the friable underlying moraine exposed, producing valleys up to a mile in width and 250 feet in depth. The fact that the present streams are small in relation to the size of the valleys, suggests that they existed prior to the final re-advance of the Lake Simcoe lobe; and the presence of outwash gravels and/or Schomberg lacustrine deposits implies that during the retreat of the ice, the valleys served as areas of accumulation for the outwash deposits from the ice and sands and gravels washed in from the interlobate moraine; and in their lower courses provided ready made basins for pro-glacial lakes. Gravenor (1957,p 14) proposes that the source of the water originally responsible for excavating these valleys, was the Lake Ontario ice lobe which advanced far enough to the north during the penultimate retreat of the Simcoe lobe, to allow the ice front drainage to pour over the northern flank of the Oak Ridges moraine. However, if it is assumed that the valleys were formed after the final retreat of the ice, the only logical explanation for the source of water would be the presence of stagnant ice blocks left on the moraine.

(d) Climate

The climate of southern Ontario has been classified by Putnam and Chapman (1938) as a modified humid continental type. From the temparature and rainfall data shown in Table 3-8, it can be seen that there is little variation of temperature throughout the area, though the proximity of Lake Ontario does cause the climate to be somewhat warmer and more equable in Durham County than in other areas in eastern Ontario or to the immediate north. Precipitation markedly increases inland. The data for Peterborough and Orono are calculated as averages for the past 20 years and for Port Hope for the past 7 years.

(e) Soils

Durham County soils have developed in a relatively cool humid climate, under a forest vegetation- now largely removed- but formerly dominated by broad leaved trees, principally maple and beech. These conditions acting in conjunction with the other variables involved in the soil forming process, can produce a large number of individual conditions that can be recognised in a detailed soil classification.

Table 3-8. Mean Monthly Temperature (°F) for several selected points.

	Period of Record	J	F	M	A	M	J	J	A	S	O	N	D	Year
Port Hope	7	23.6	22.0	30.8	41.2	49.6	61.5	66.8	65.0	58.7	48.6	40.1	26.4	44.2
Orono	20	20.5	19.0	29.8	41.2	52.9	63.7	67.5	65.5	58.4	47.2	37.8	24.4	43.9
Peterborough	20	18.1	16.6	26.6	42.0	53.8	65.0	67.8	65.2	59.7	47.6	32.0	23.1	44.4

Mean Monthly Precipitation (inches) and Snowfall for selected points

	Period of Record	J	F	M	A	M	J	J	A	S	O	N	D	Year
Port Hope	7	3.00	2.33	1.33	2.29	2.03	1.93	2.81	2.86	2.09	2.13	3.90	3.27	29.97
		19.7	12.2	6.1	3.9						0.0	1.25	1.8	
Orono	20	2.52	2.68	1.94	2.31	2.48	2.39	3.44	2.63	2.63	3.03	3.67	3.00	34.84
		15.4	16.8	9.5	3.5							1.9	10.2	
Peterborough	20	1.86	1.98	1.75	2.12	2.26	2.81	3.61	2.37	2.86	2.82	3.01	2.54	26.66
		16.1	15.1	6.0	2.1						2.75	2.6	11.6	

No attempt will be made to provide an exhaustive list of soil types for Durham County, as this has already been dealt with elsewhere (Webber et al.,1946). However, where field data on soil profiles was obtained and found to be characteristic of a particular terrain type the details are included in the appropriate context.

CHAPTER IV

PROCESSES INVOLVED IN THE RECOGNITION OF TERRAIN UNITS

(ii) Analysis of the Aerial Photographs prior to field work

After all the available literature and cartographic data pertaining to the recognition of terrain units and to the area of study have been assembled and carefully studied, the researcher is finally in a position to examine the aerial photographs. An advisable preparatory procedure is to sort the prints into numerical order according to flight line and endeavour, for the duration of the study,to keep them in this order. It is also desirable to lay down, en masse if possible, non-stereoscopic coverage for the entire area and draw up a key showing the positions of the prints relative to one another and their individual positions on a topographic sheet of suitable scale. This will make it easier to locate them at any time.

The initial laying down of all the photographs provides an excellent opportunity for the familiarisation with the photographic representation of the study area and the occurrence of areas of recurring macro- and micro-air photo patterns, which, as will be shown below, are an important element in the recognition of terrain units. The term " air photo pattern " used here and elsewhere in this thesis can be defined as the recurrence of an orderly, spatial arrangement of images having varying tonal densities. For example, an aerial photograph of an orchard where swaths of grass between the trees have been mown for hay, will show the area occupied by a single tree as: a dark toned circular image- representing the tree, within a lighter toned square area of uncut grass all surrounded by a slightly darker toned area of mown grass. This orderly arrangement of images will be repeated for every tree in the orchard and hence an air photo pattern will emerge. This is an extreme or idealistic example of the phenomena normally noted on the aerial photographs.

The forementioned areas of air photo pattern represent various permutations and combinations of landform type, slopes, superficial deposits, soil types, vegetation and drainage patterns. They can only be given meaning and interpreted in terms of such criteria by using a stereoscopic model. This process of interpretation has been defined by Summerson (1954, p 397) as, " the prediction of what cannot actually be seen". Simakova (1964) suggests that interpretation of aerial photographs means the determination and complete classification from an aerial photographic image, of the various objects and phenomena occurring on the earth's surface or composing it. Colwell (1952, p 535, 1954, p 433) defines interpretation as "...the act of examining photographic images of objects for the purpose of identifying objects and deducing their significance ".

Whatever definition is used, the processes involved in interpretation remain the same - however implicit they are in some publications on the subject. According to Stone (1951, p. 755) a procedural or methodological approach to interpretation should be used because, "The establishment of procedure prepares the way for an orderly and complete analysis of complex subjects". Such a systematic approach is especially valuable in the observational phase of the study as it provides a firm basis for the interpretive stage. The interpretive processes recognised by the author during the course of this study are seven in number and may be outlined as follows:

The first step is to acquire a background knowledge of the subjects with which the interpretive study is concerned, in this case, geomorphology, pedology, geology and biogeography: to gain experience in the use of aerial photographs in the study of these sciences and to obtain all the available data, ground photographs, maps, statistics and literature pertaining to the study area.

The second stage requires a systematic examination of all the elements of the patterns appearing on the aerial photographs: that is image shape, size, tone, texture and arrangement. This in turn will lead to recognition of areas having "homogeneous and mutually exclusive" characteristics of pattern and tone, and a tentative sub-division of a large percentage of the study area on this basis. The remainder of the area will either appear to have characteristics which could qualify it for more than one of the recognised patterns, or will not have any identifiable pattern at all. An example of the result of this procedure is illustrated on Photo. 4-1.

The third stage attempts to explain what each of the air photo images and air photo patterns represents and to

Photo. 4-1 An aerial photograph on which areas of characteristic pattern and tone have been outlined.

do this comprehensively requires that several " orders of information " (Hopkins et al.,1955,p 142) be obtained from the photographs. First order information - topography, microrelief, drainage patterns etc., can be observed directly and analysis of this yields second order information such as landform recognition. This in turn provides hypotheses as to the geomorphic origin of the landforms, or third order information, form which fourth order information is deduced concerning such matters as probable composition and texture of the subsurface materials.

The acquisition of all this information involves a stereoscopic examination of the photographs and a careful deductive and inductive evaluation of all the two and three dimensional evidence available from them, in light of common sense and the background knowledge initially acquired by the interpreter. For example, certain features easily identifiable on the aerial photographs, such as raised clifflines and gravel bars, are inductively concluded to have resulted from former submergence of the land. This in turn may lead by deductive reasoning to the specific identification of less easily identifiable features such as beach ridges, sub-aerially weathered and vegetated dune complexes and the extent of currently existing water laid deposits.

However much care and experience is used in the procedures outlined above, interpretation of any aerial photographs will remain incomplete unless it involves a synthesis of laboratory and field work, because, despite claims to the contrary, there will always be areas in which a full interpretation is impossible without field investigation. For as Hare states,(1969,p 42) " an aerial photograph can never give a complete physiographic history, nor can it give an unambiguous description of surface form. In most cases field work is needed before any hypothesis of origin can be accepted; one may speculate about the patterns, but one can never dogmatically assert the manner of their origin ". So stage four of the interpretive process demands the use of the aerial photographs as a tool to plan such field work; to direct attention to anomalous areas where detailed field work is particularly warranted; to suggest hypotheses for field studies; to assist in field sampling and to plan field traverses. Guided by this philosophy and the wish to make the most efficient use of the photographs and bounded by the limitations of time, purpose and facilities, the following preparations were made for this study:

1. Details of the superficial geology as recorded by Gravenor (1957) were recorded on the aerial photographs.
2. If the evidence on the photographs indicated the position of a deposit or its boundary to be at variance with Gravenor's work the location was noted in order that the information might be verified or corrected.
3. All areas in which air photo interpretation of the origin of a particular landform required clarification,were annotated.
4. As previously stated, the basis for this study lies in the

hypothesis that if a terrain unit can be defined on the ground, it will be visible as a specific, homogeneous pattern on an aerial photograph. Hence, having outlined such zones of homogeneous tone and pattern in stage two of the interpretive process, a series of sites were chosen to sample typical areas within each of the zones to determine the land components which produced the air photo pattern. Also to ascertain whether a particular pattern was always associated with a particular set of physical characteristics,i.e. a specific terrain type.

5. When the air photos were initially subdivided on the basis of areas of homogeneous tone and pattern, it was noted that some parts of the photographs remained unclassified; either because they exhibited no easily distinguishable air photo pattern, or because they possessed characteristics of more than one. Within areas included in the first category, sites were chosen at which an attempt could be made to determine - in the field - whether there were any specific physical criteria, e.g. soil type, slope angle, geomorphic origin or form, which could be used instead to delineate terrain units. In fact terrain types X,XIX, and XX were all recognised as a result of this procedure. The relative importance of the specific criteria

used in delineating the terrain types in this way was different in each case, and will thus be noted in the description of the individual terrain types. Areas comprising the second category, were noted on the aerial photographs as requiring detailed field study to subdivide them into two or more terrain units each fulfilling the requirements of the original definition, that of possessing homogeneous and mutually exclusive physical characteristics throughout. For example, some areas that appeared on the basis of field and air photo evidence to be very gently undulating till, were crossed by several valley systems of varying size. The smaller ones were not sufficiently different from the rest of the area in any of the physical criteria that were investigated to produce a change in land use, nor were they large enough to be accurately represented on the 1:50,000 maps on which the terrain units were to be finally drawn, so it was decided to include them in the same terrain type as the till plain. However, the larger valleys could not only be delimited on the final map but exhibited physical characteristics so different from those of the till plain, in terms of drainage conditions, soil type, land use, extent and type of erosion etc., that they were classified as a terrain type in their own right.

6. A series of sites were also selected to sample the boundaries between every combination of terrain types and where necessary to improve the accuracy of their location. The final number, extent and location of the terrain types would not all be known prior to field work so this stage in preparation would have to be completed in the field.
7. Field sites were selected to examine the entire range of drainage conditions existing within each unit.
8. Areas of possible mantle exposure were recorded.
9. The effects of erosion were tentatively classified according to the extent, type and deposit on which it occurred.
10. Land use was ascertained.
11. The position of the Iroquois coastal zone - cliffline, bars, lagoons - was tentatively plotted on the aerial photos to facilitate field checking of the interpretation.
12. The County was partitioned into small regions and routes planned in such a way that each region could be covered - in terms of the above criteria - in a day.

The fifth stage in the interpretive process is the actual field investigation.

(iii) <u>Field Procedure at a Chosen Sample Site</u>

Note: Site location on aerial photographs.

Surface form i.e. valley side or floor, interfluve etc., in plan and profile.

Absolute elevation from 1:50,000 maps.

Relief range of the slope on which the site is located, from maps, or if less than 25 feet, from field observation.

Measurement of characteristic slope angle or a range of measurement of the dominant slope angle. These angles may be defined as pertaining to more than 70% of the land surface within each terrain unit.

Lateral extent of the feature in question.

Micro-relief i.e. ridge and furrow, creep, earth-flow etc.

Drainage conditions - poor, imperfect, well drained, excessively drained - estimated in terms of:

(a) present conditions. Assessed from: rate of flow of rivers; amount of standing water; extent of surface drainage; soil moisture.

(b) conditions known to have occurred at other periods of time, although not apparent at the time of field work. Assessed from: soil type; vegetation; air photo pattern.

Vegetation

Crop land

Rough pasture

Brush

Forest - virgin

secondary growth) Maintainence, if any.
)
plantation (height)) Ground layer.

Soil

Depth

Profile and horizon development

Colour

Texture

Stoniness, shape of constituents

Clay, sand, grit and humus content assessed qualitatively.

Parent Material

Fabric - Composition

Colour

Stoniness, shape of constituents

Arrangement, stratification - contortion

Weathering characteristics

Extent of cementation

Matrix - Composition

Colour

Texture

Extent of erosion and gullying

Type of erosion - Wind

Creep

Slip

Gullying

Riverine

Extent of erosion - None

Patches of soil visible

Large areas of bare ground

All sod removed

Development of gullies

Total destruction of land surface

Where gullying was evident cross sections and plan sections were sketched from measurements. Method and extent of erosion control were also noted.

The annotated photographs were used simultaneously with 1:50,000 topographic sheets whilst in the field. The position of all sample sites visited and the position and direction of all ground photographs were recorded directly on the prints and cross referenced to the main body of field data recorded in a notebook.

(iv) Analysis of the Aerial Photographs After Field Work

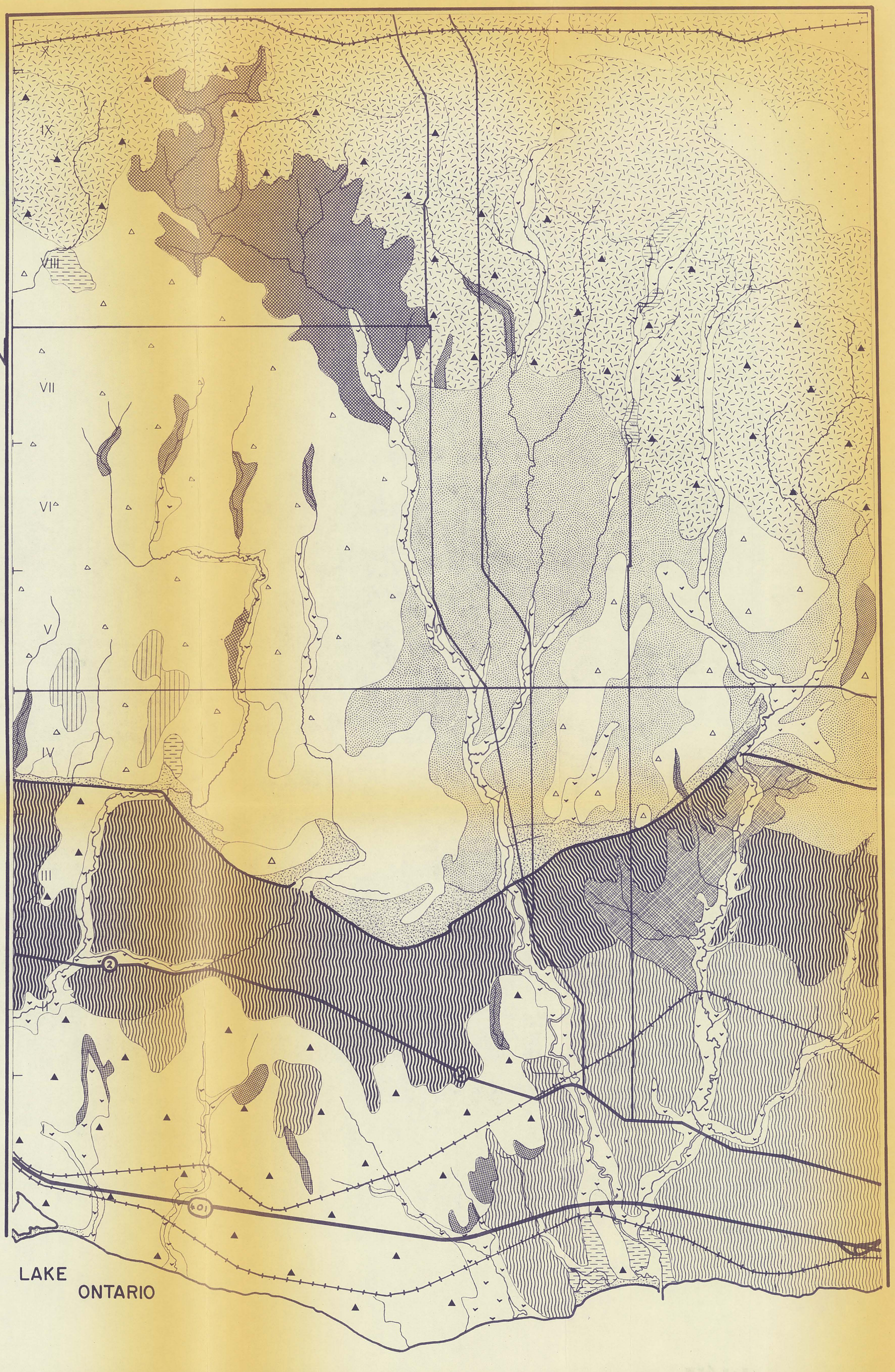
This comprises the sixth stage in the interpretation of any set of aerial photographs. In this particular case it involved the use of photogrammetry to measure the angles of slopes which proved inaccessible in the field and to check recorded angles, not only of parts of the Iroquois cliffline but of valley side slopes and the characteristic slope within a particular terrain unit. This analysis of the aerial photographs also provided an opportunity to extrapolate field information to inaccessible areas, though it was rarely necessary because the only regions that were not fully investigated were the higher, heavily forested parts of the Oak Ridges

As Ray and Fischer (1950, p. 728) so rightly observed, "interpretation is a multistep operation and hence final interpretation of a geomorphological nature may be a synthesis of many lesser but specific interpretations". It is, in fact, the amalgamation of these with all the other background data, that comprises the seventh and final stage in the interpretation of the aerial photographs and hence the definition of terrain units for Durham County (Maps 4-2 to 4-7). This process of amalgamation, which employs Colwell's "convergence of principle" (1952,p 566), is best illustrated with reference to Fig.4-8. Implicit in the use of this principle, is a sort

TERRAIN UNIT MAP OF DARLINGTON TOWNSHIP

KEY - SEE PAGES FOLLOWING THIS SET OF MAPS

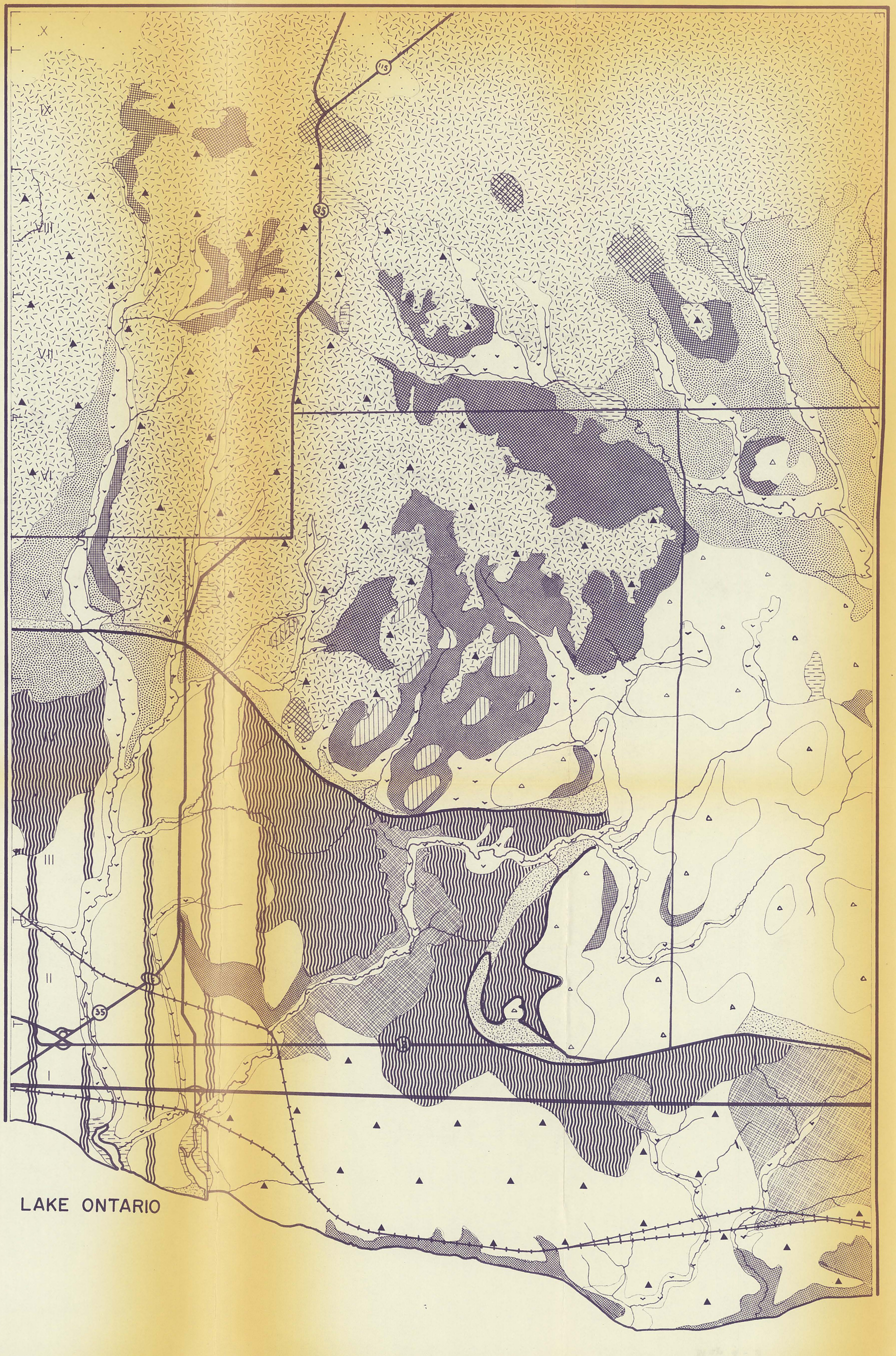
SCALE 1:50,000



TERRAIN UNIT MAP OF CLARKE TOWNSHIP

KEY - SEE PAGES FOLLOWING THIS SET OF MAPS

SCALE 1 : 50,000



63a

TERRAIN UNIT MAP OF HOPE TOWNSHIP

KEY - SEE PAGES FOLLOWING THIS SET OF MAPS

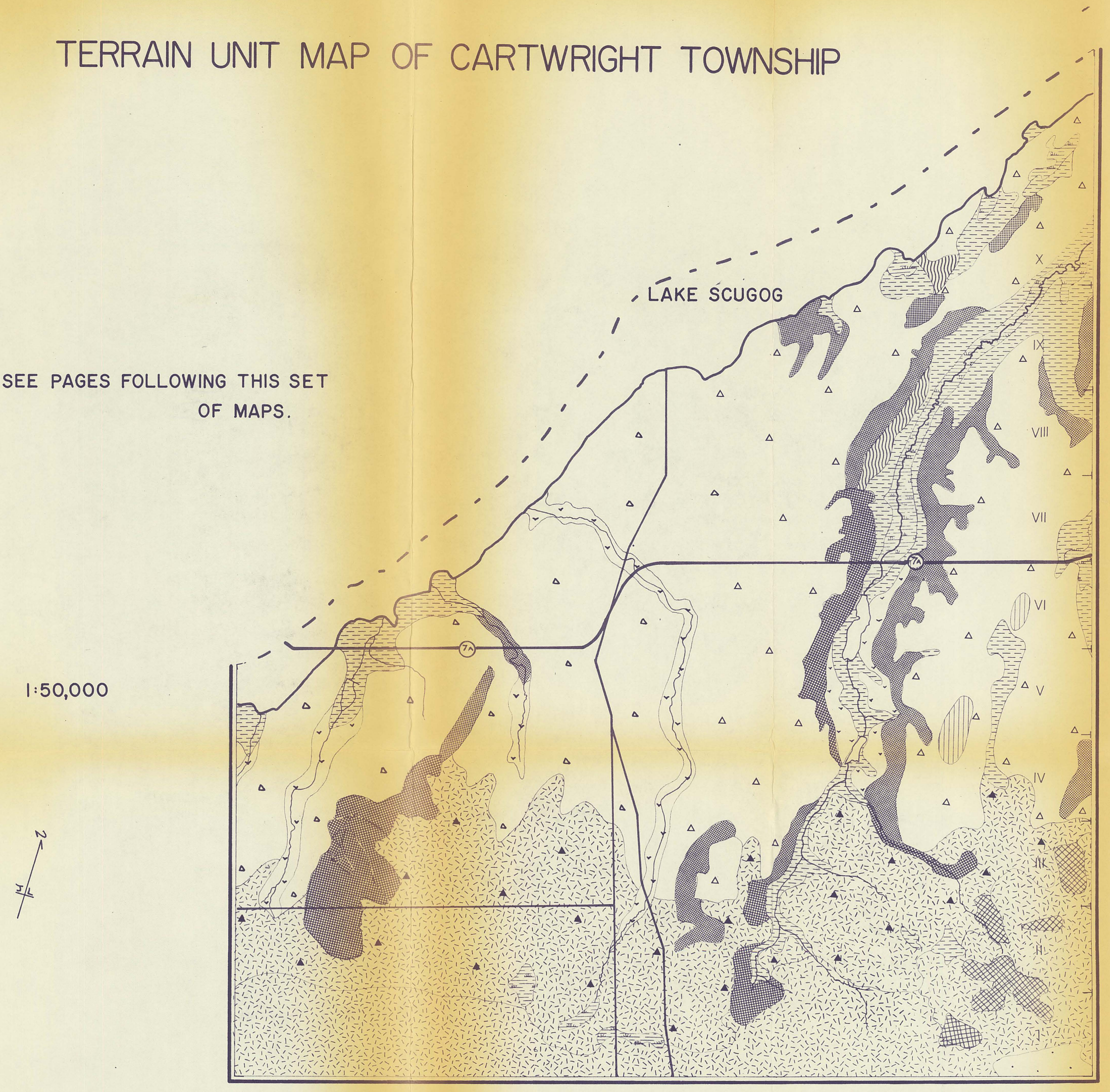
SCALE 1:50,000

LAKE ONTARIO

TERRAIN UNIT MAP OF CARTWRIGHT TOWNSHIP

KEY - SEE PAGES FOLLOWING THIS SET OF MAPS.

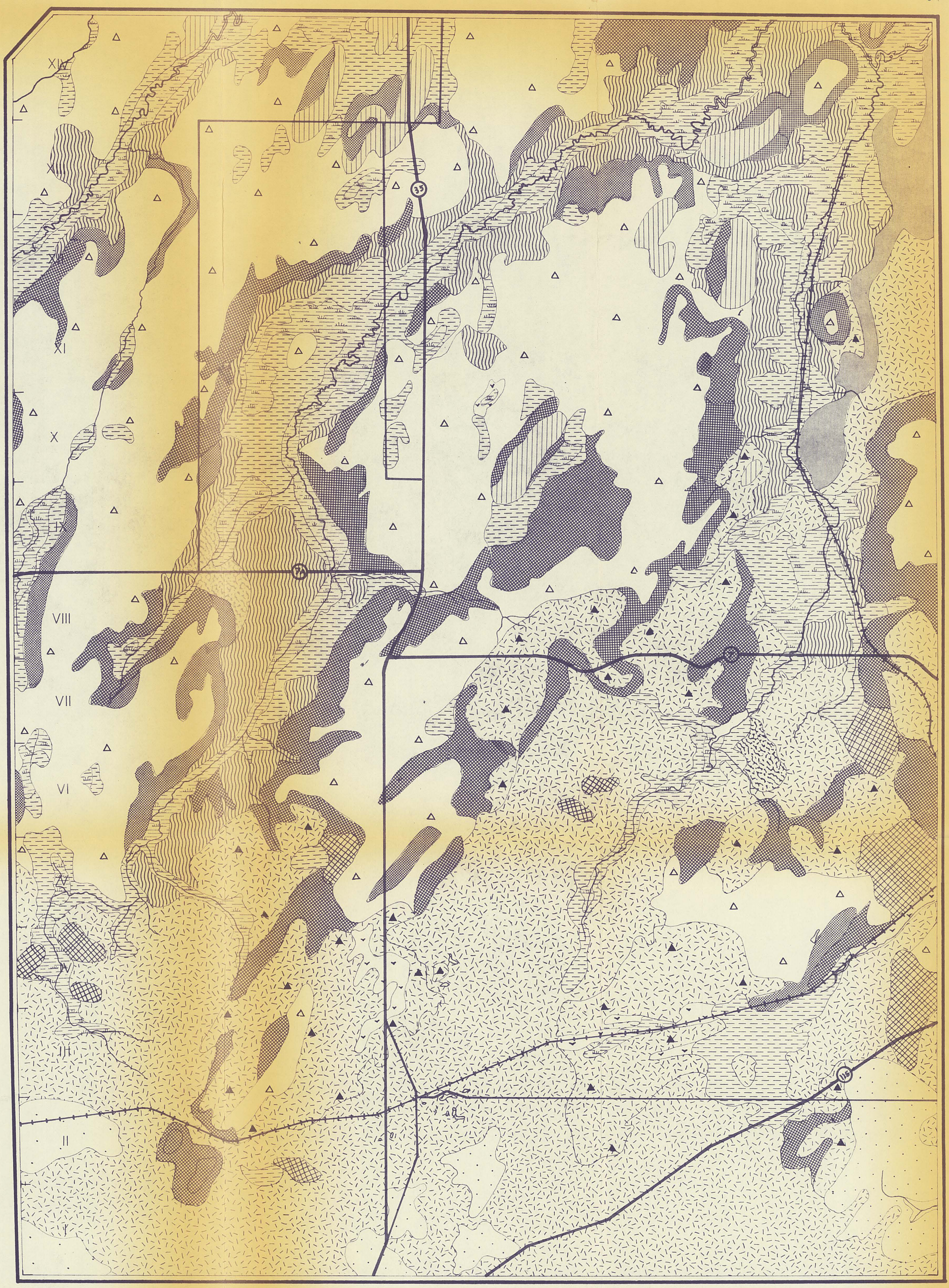
SCALE 1:50,000



TERRAIN UNIT MAP OF MANVERS TOWNSHIP

KEY - SEE PAGES FOLLOWING THIS SET OF MAPS

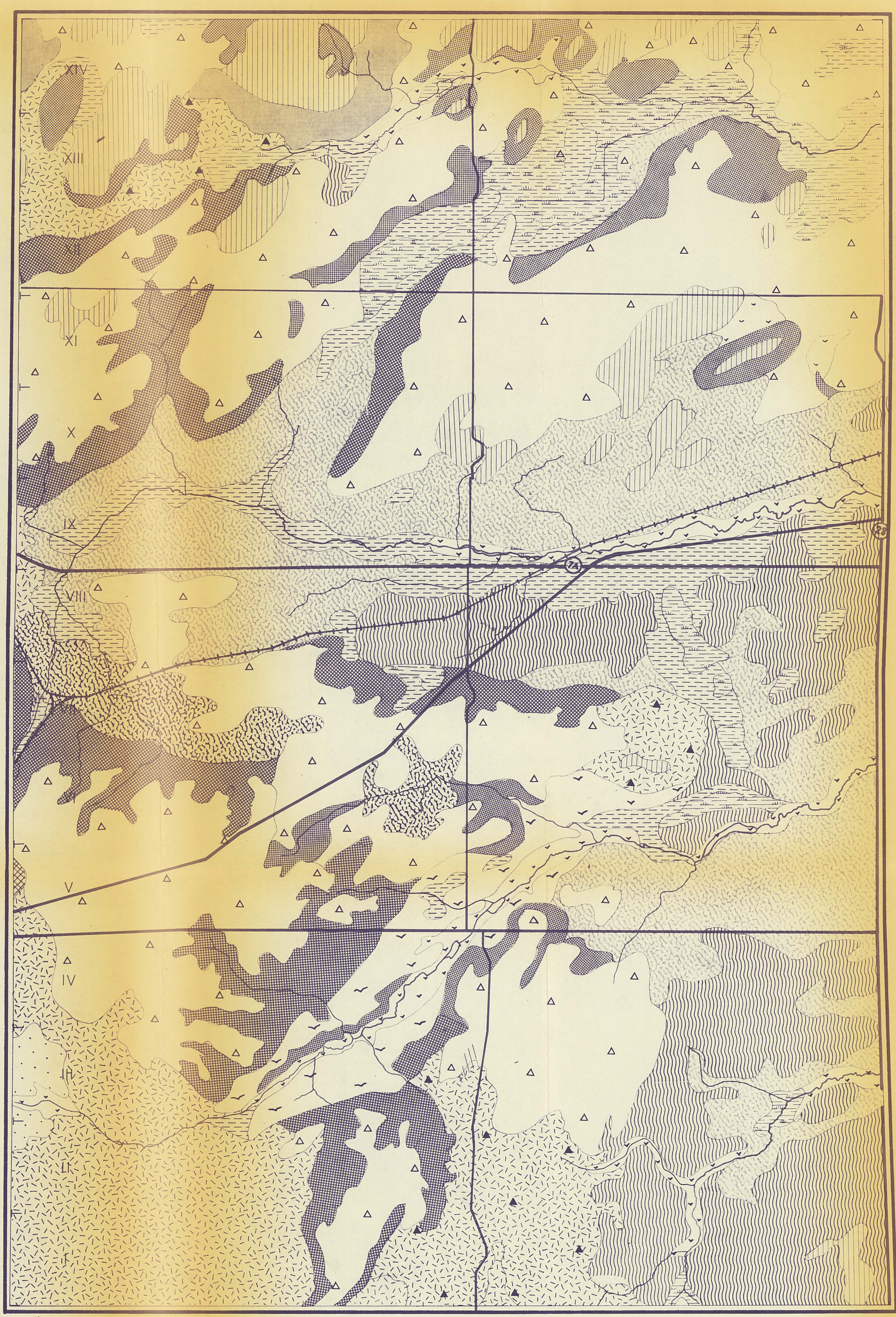
SCALE 1 : 50,000



TERRAIN UNIT MAP OF CAVAN TOWNSHIP

KEY - SEE PAGES FOLLOWING THIS SET OF MAPS

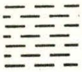
SCALE 1 : 50,000



Key for the Terrain Unit Maps of Durham County

Level Terrain - Organic

I Marshland

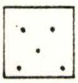


II Muck

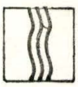
Level Terrain - Mineral

III Alluvial Terraces

IV Extensive Areas of Fluvio-Glacial Sands and Gravels

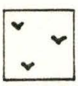


V Deposits of Wind Blown Sand Above 1000'

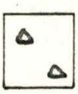
VI Lacustrine Sediments a. silty-clay

VII Lacustrine Sediments b. stony, stratified sands and silts



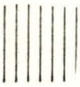
VIII Linear Deposits of Alluvial Origin

Undulating Terrain

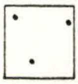


IX Till Plains Above the Level of Former Lacustrine Deposition

X Deposits of Till and Lacustrine Sediments South of the Lake Iroquois Shoreline



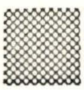
XI Drumlinoid Topography



XII High Level Plateaux Composed of Till Overlain by Sand

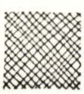
<u>Restricted Areas of Steeply Sloping Terrain</u>

XIII Steep (25-50%) Slopes in Till



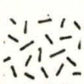
XIV Slopes which Develop at the Junction of Till Deposits with those of Sands, Silts and Gravels

XV Areas of Severe Erosion



XVI Areas of High Density Stream Development Below the Lake Iroquois Shoreline

<u>Irregular, Hummocky Topography</u>



XVII Granular, Areally Extensive Kame-Like Deposits

XVIII Thin Mantles of Till Overlying Sandy Kame Moraine

XIX Esker

XX Kame

XXI Pitted Outwash Deposits

XXII Ablation Till Overlain by Lacustrine Deposits

XXIII Ablation Ridges

Iroquois Coastal Zone

XXIV Cliffline

XXV Gravel Deposits

XXVI Former Coastal Lagoons

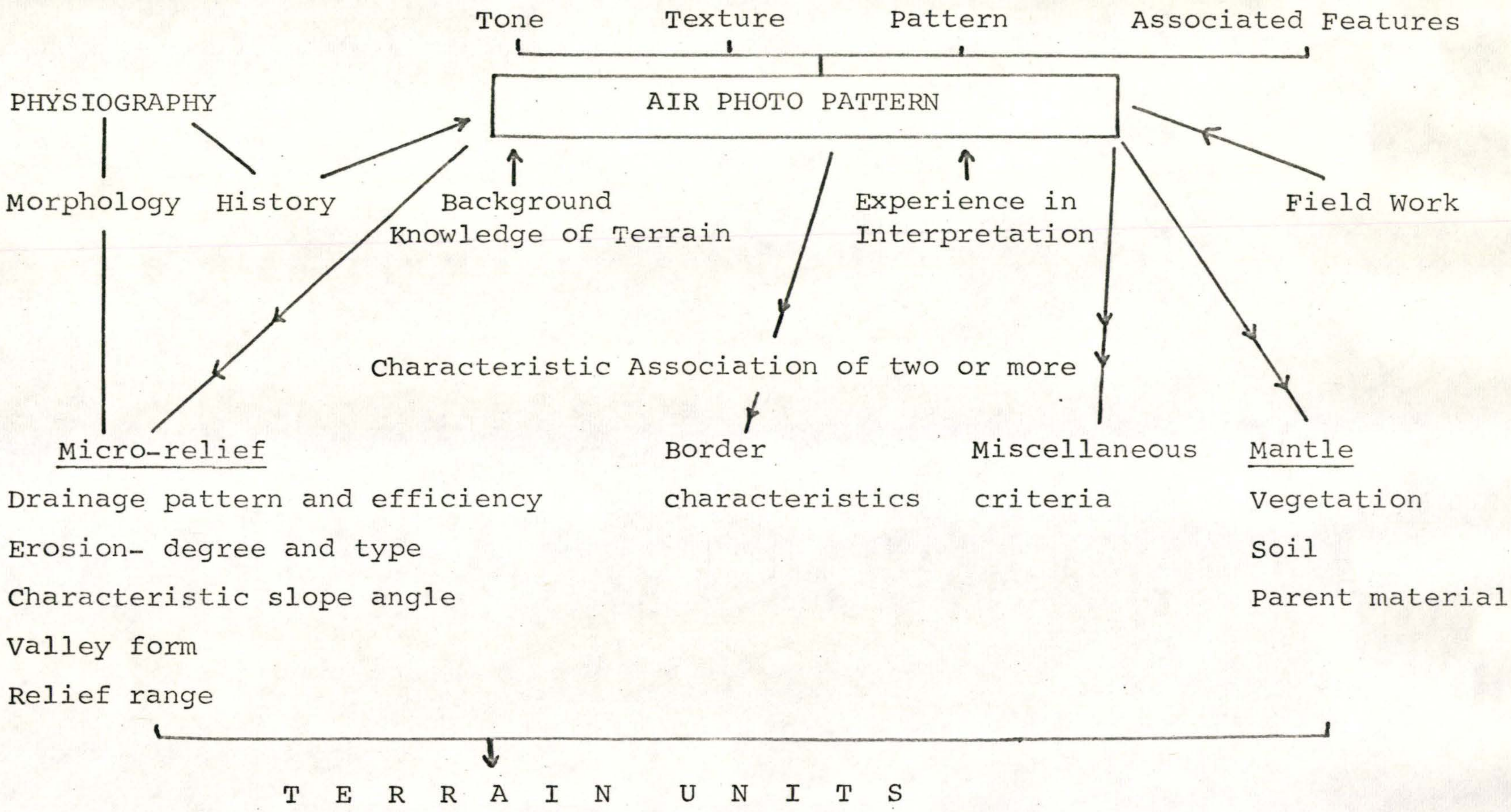
XXVII Dune Formations

River

Road

Railway

VI Concession Numbers



Tone
Texture
Pattern
Associated Features
AIR PHOTO PATTERN
PHYSIOGRAPHY
Morphology
History
Background
Knowledge of Terrain
Experience in
Interpretation
Field Work
Characteristic Association of two or more
Micro-relief
Drainage pattern and efficiency
Erosion- degree and type
Characteristic slope angle
Valley form
Relief range
Border
characteristics
Miscellaneous
criteria
Mantle
Vegetation
Soil
Parent material
T E R R A I N U N I T S

Fig. 4-8.

of mental regression analysis, which subconsciously, or otherwise, involves an assessment of the relative weight or importance of all the geomorphic, pedologic and bio-geographic phenomena and the elements of the air photo pattern, in terms of their contribution to the positive identification of a terrain unit. As an illustration of this last point: a difference in physiography alone may be sufficient to determine between terrain units which may otherwise appear identical.

The seven stages of air photo interpretation, described above, are considered essential to any study aspiring to determine a set of terrain types and map the extent of terrain units, either within a specific location -whether this be in the arctic or the tropics, or for a specific purpose - regardless of whether this is to determine military trafficability, potential recreational land use or to complete an academic exercise. Though in connection with the latter, it should be noted that the relative importance givento the different ground characteristics in the final definition and description of the terrain types will be expected to vary slightly with the purpose of the study.

Having dealt, in general terms, with the procedures involved in the identificaton of terrain units, consideration will now be given to the specific problems encountered during the implementation of these procedures.

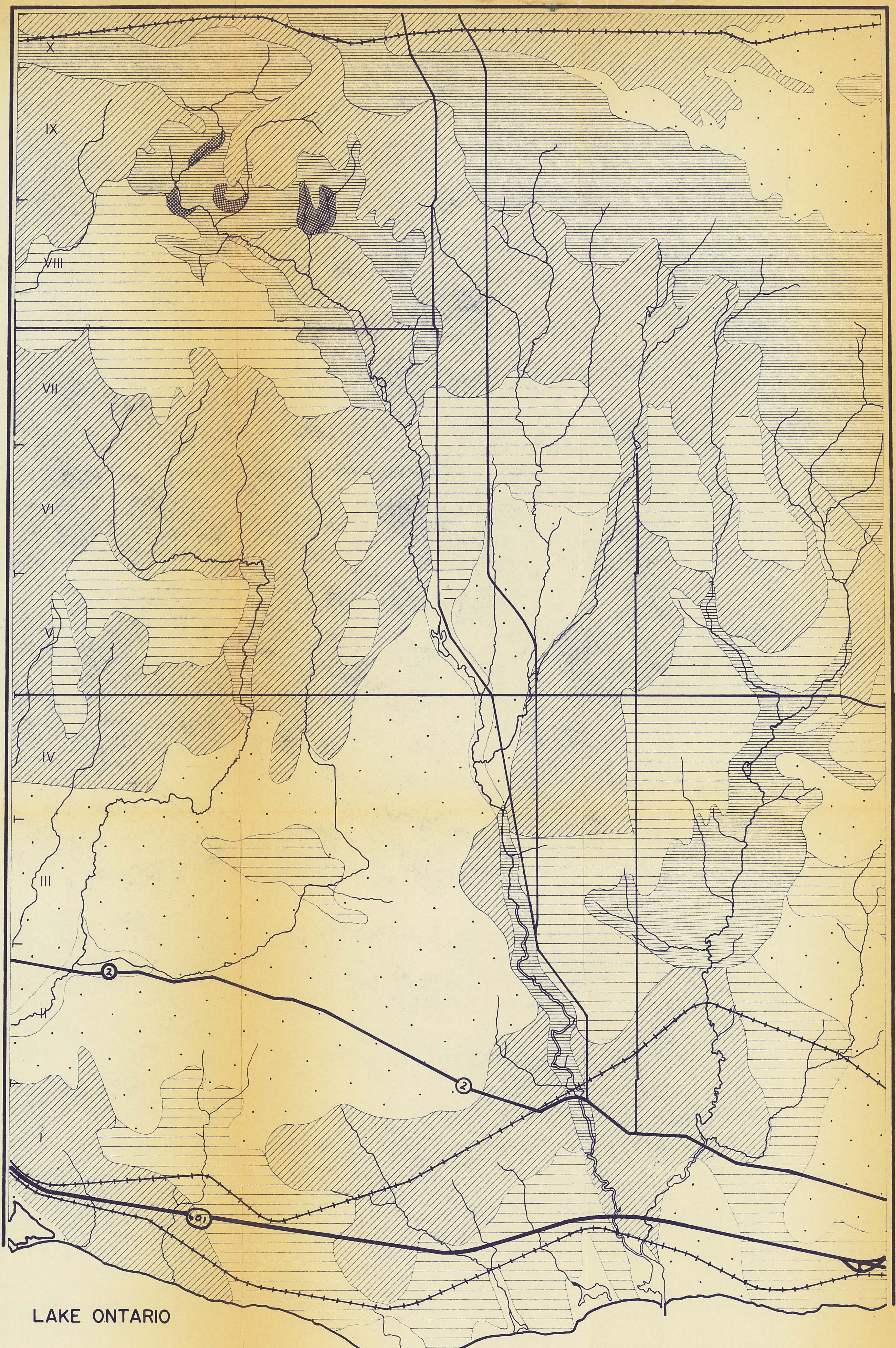
(v) An Assessment of the Value of Air Photo Pattern as a Guide to the Definition of Terrain Units

Air photo pattern can be defined as the " orderly, spatial arrangement of ecologic, topographic or vegetative features, in a two dimensional plain ",(Ray 1960,p 10). Further elucidation of the phenomena is provided by Rib (1967) who reveals the key to the link between terrain unit identification and air photo pattern, when he states that the pattern is " a repetitive expression of the topography of the earth's surface, including relief and slope, that reflects the geomorphic processes involved in its development as well as the parent material of which it is composed ". On a micro scale this can comprise a recurrence of an orderly, spatial arrangement of images having varying tonal densities within a discrete area, or on a larger scale the repetition of such discrete areas of pattern across the mosaic. It was the latter which were initially noted in the analysis of the air photo mosaic and which subsequently assumed importance when they were found, during the course of field work, to be characteristic of particular terrain types.

Within a specific terrain type the natural phenomena responsible for the recurring tonal variations, which constitute the characteristic air photo pattern, can be sub-divided into six groups. These are the topographic expression of the land surface; the position of various facets of the land surface relative to the sun; micro-relief features; variations in drainage conditions; drainage pattern and vegetation. The topographic expression of the land surface can produce very distinctive air photo patterns if the formations comprising the topography recur and their physical parameters remain approximately constant. These parameters include slope angles; horizontal and vertical dimensions i.e. distances between streams, valleys, depressions, crests; breadths of such features as lakes, level divides and bedrock exposures; length of various linear features, e.g. ridges; and the relief range of valleys of different orders. Observations made by Hussey (1962) during the 1955-1961 field seasons, substantiated the hypothesis that slope angle is a significant factor in determining the type of ground, and hence, air photo pattern, which regionally characterises terrain. Although in that particular study, arctic terrain was being considered, a similar conclusion was reached by the author, with respect to the topography of Durham County. This becomes evident from a comparison between the slope zone maps (Maps 4-9 to 4-14) and the terrain unit maps (Maps 4-2 to 4-7) which were derived independantly.

Micro-relief features individually have little effect

AN AVERAGE SLOPE MAP OF DARLINGTON TOWNSHIP



KEY

- more than 45% slope
- 25 - 45%
- 15 - 25%
- 7·5 - 15%
- 2·5 - 7·5%
- 0 - 2·5%
- RIVER
- ROAD
- RAILWAY
- CONCESSION NUMBERS

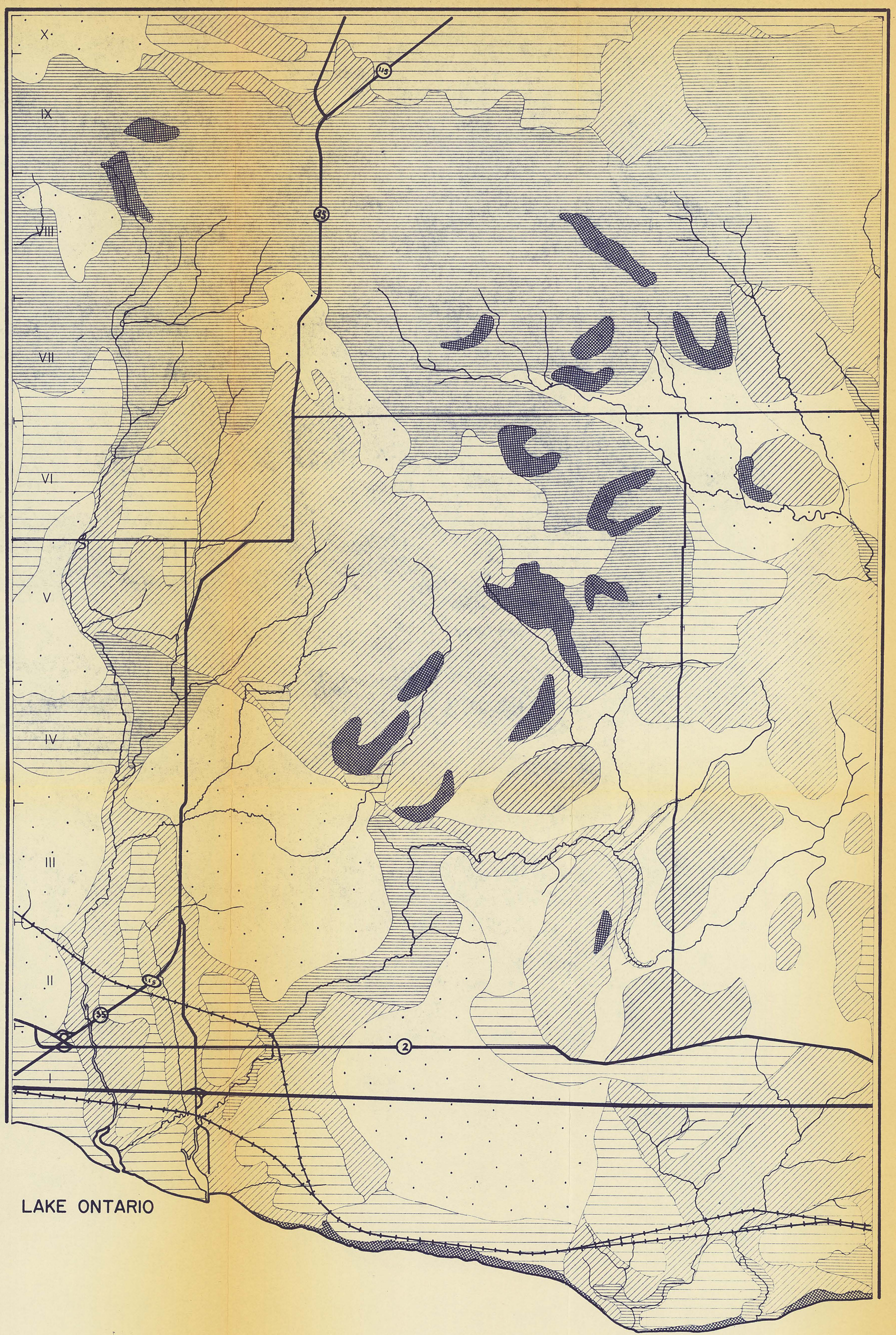
SCALE 1:50,000

AN AVERAGE SLOPE MAP OF CLARKE TOWNSHIP

KEY

- more than 45% slope
- 25 - 45%
- 15 - 25%
- 7·5 - 15%
- 2·5 - 7·5%
- 0 - 2·5%
- RIVER
- ROAD
- RAILWAY
- VI CONCESSION NUMBERS

SCALE 1:50,000

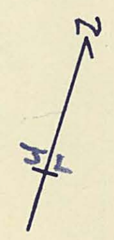


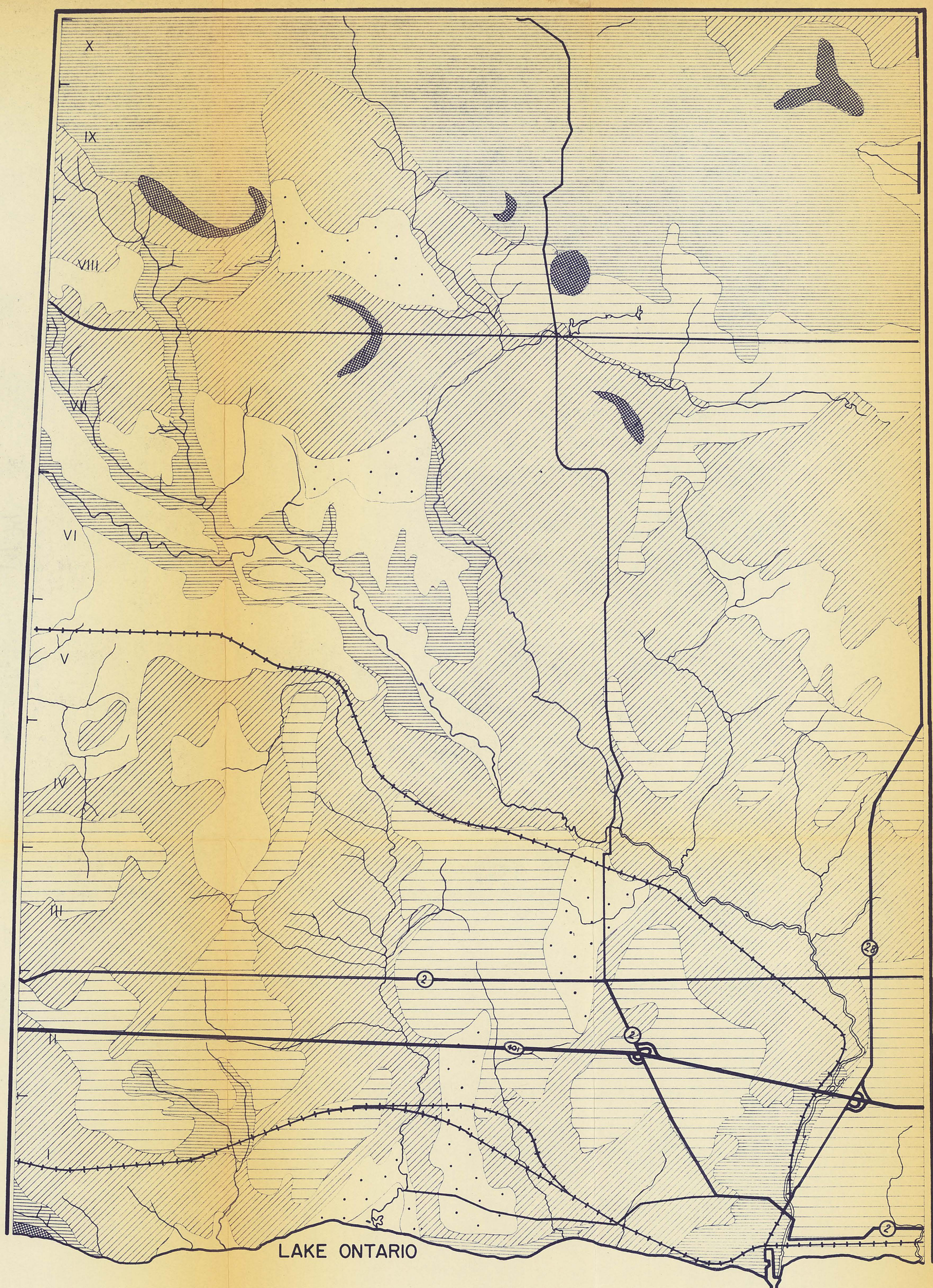
AN AVERAGE SLOPE MAP OF HOPE TOWNSHIP

KEY

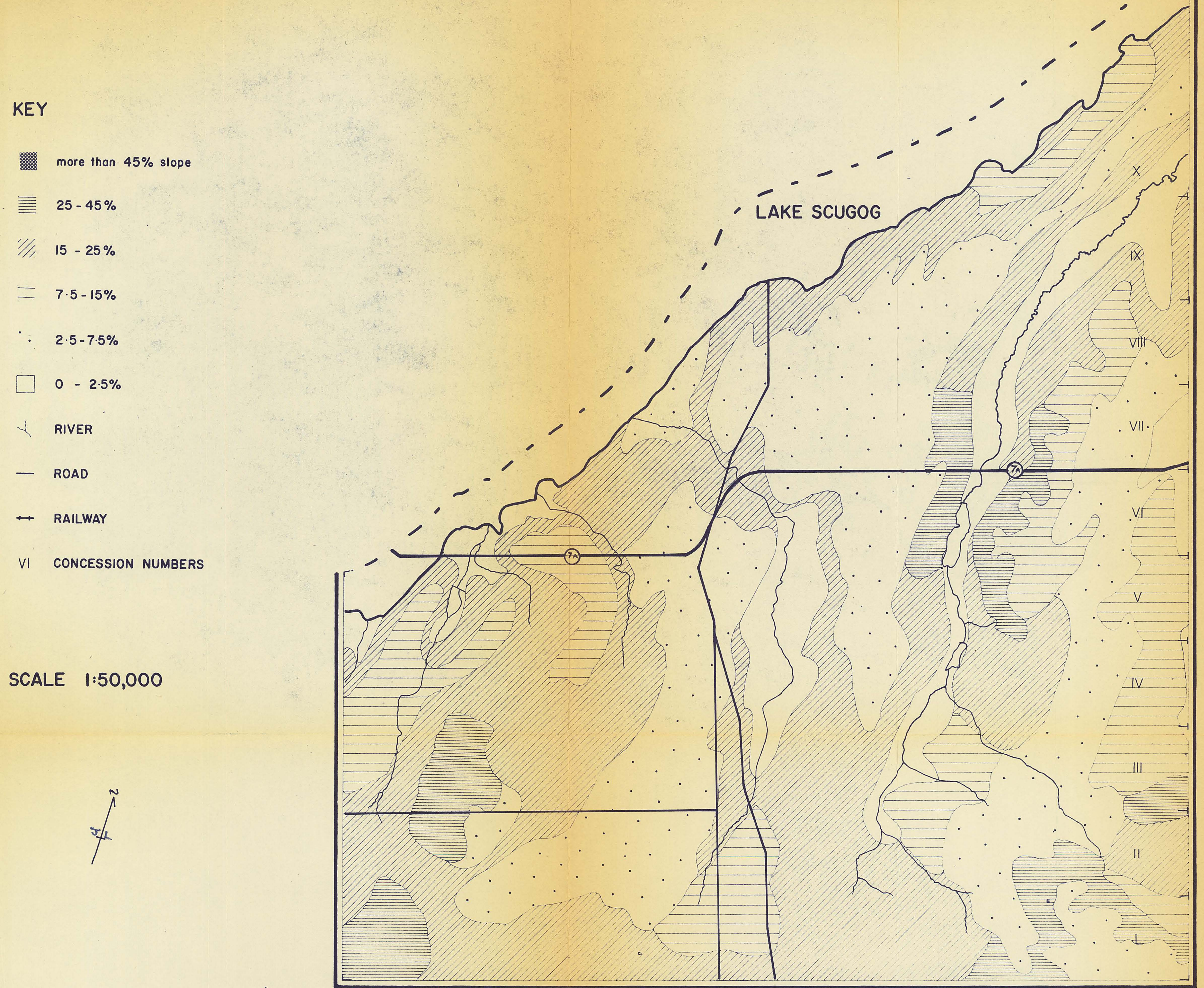
- more than 45% slope
- 25 - 45%
- 15 - 25%
- 7·5 - 15%
- 2·5 - 7·5%
- 0 - 2·5%
- RIVER
- ROAD
- RAILWAY
- VI CONCESSION NUMBERS

SCALE 1:50,000

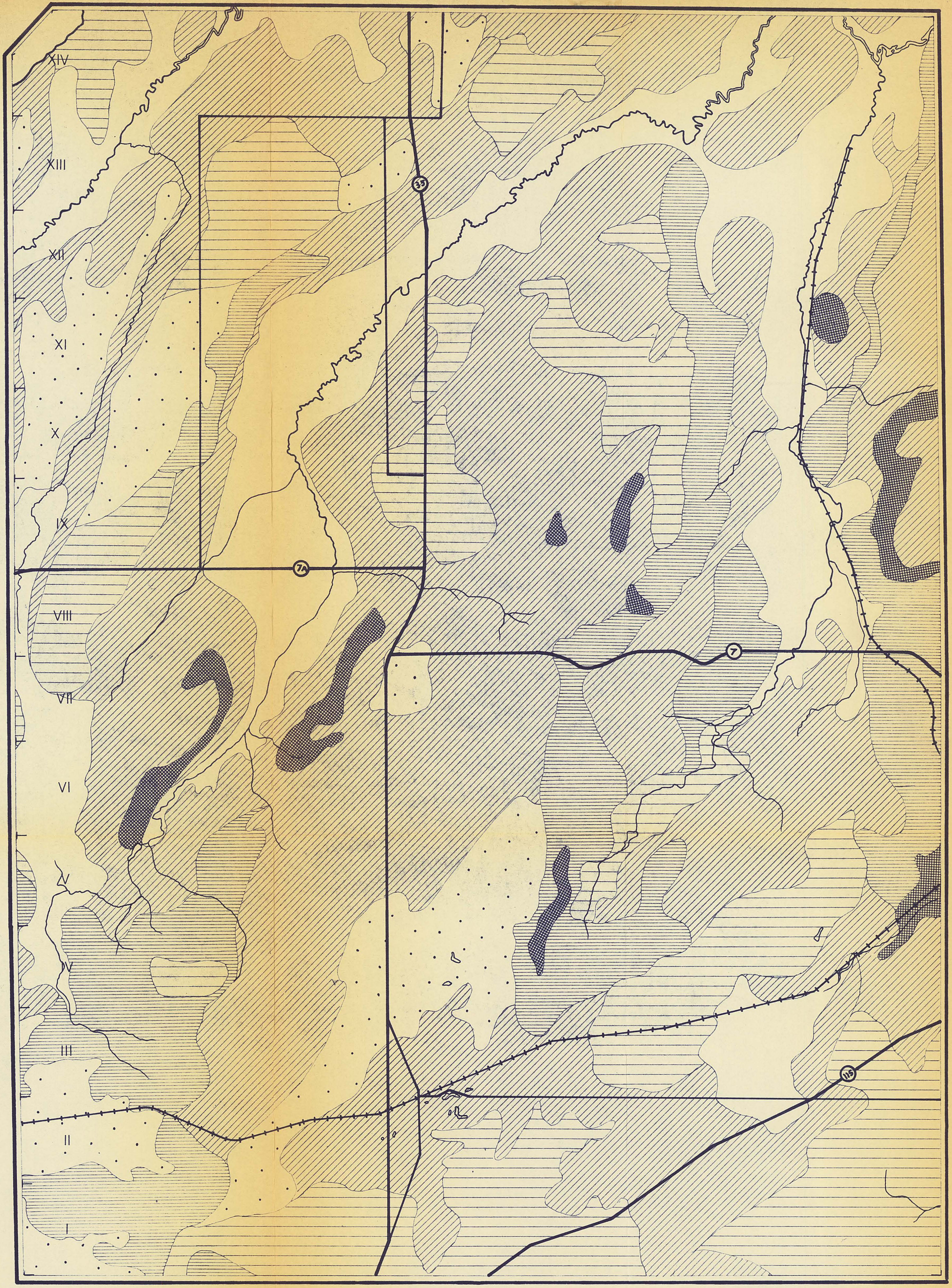




AN AVERAGE SLOPE MAP OF CARTWRIGHT TOWNSHIP



AN AVERAGE SLOPE MAP OF MANVERS TOWNSHIP



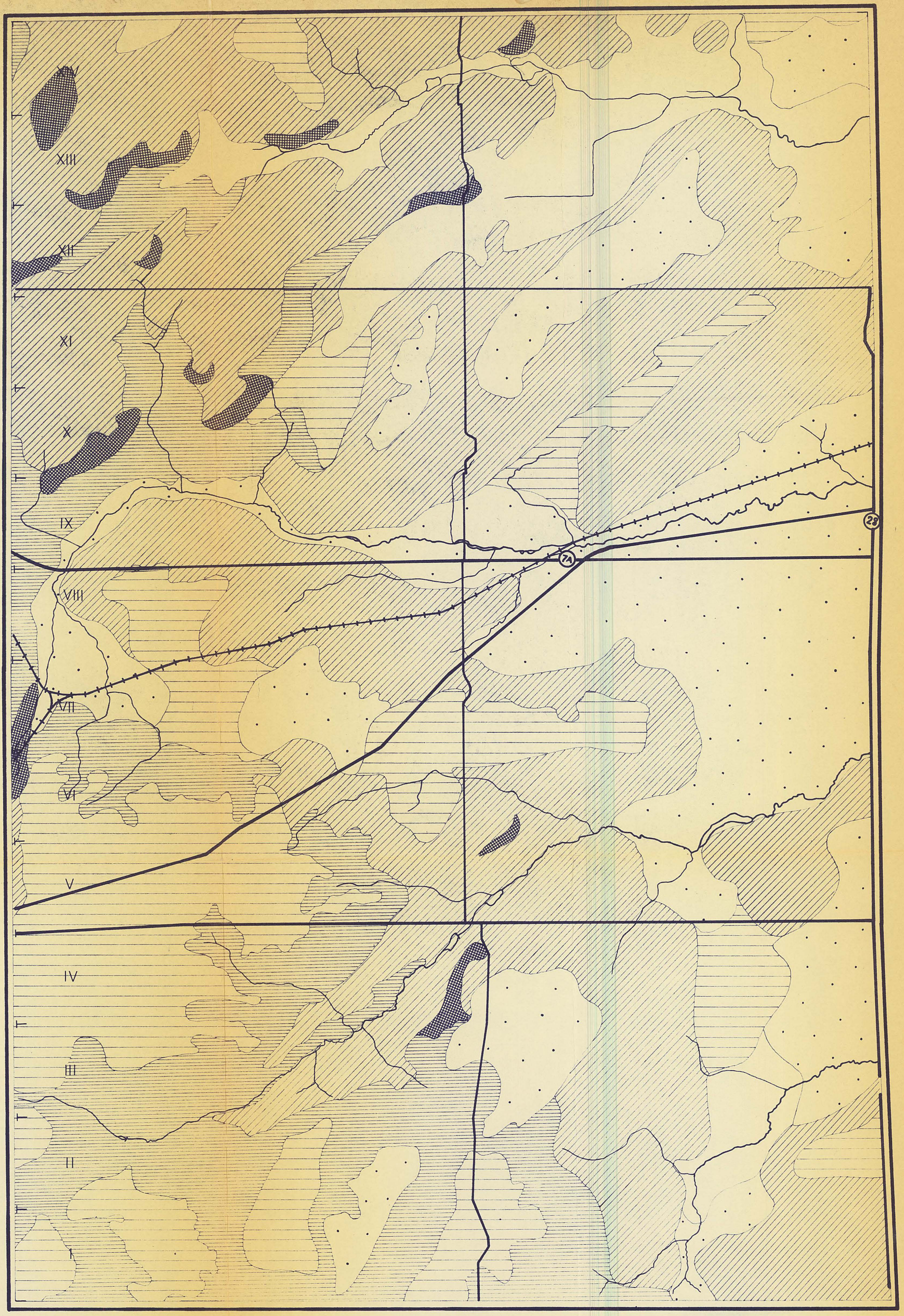
KEY

- more than 45% slope
- 25 - 45%
- 15 - 25%
- 7·5-15%
- 2·5-7·5%
- 0 - 2·5%
- RIVER
- ROAD
- RAILWAY
- VI CONCESSION NUMBERS

SCALE 1:50,000

N

AN AVERAGE SLOPE MAP OF CAVAN TOWNSHIP



KEY

- more than 45% slope
- 25 - 45 %
- 15 - 25 %
- 7·5 - 15 %
- 2·5 - 7·5 %
- 0 - 2·5 %
- RIVER
- ROAD
- RAILWAY
- VI CONCESSION NUMBERS

SCALE 1:50,000

N

on photographic pattern but the repeated occurrence of ridges due to soil creep and the sporadic removal of turf by erosion most certainly will.

Variations in drainage conditions have the greatest influence on air photo pattern in areas where relief range is slight, for example in areas covered by lacustrine deposits, photo interpretation applied to such areas will yield data primarily concerned with soil and superficial deposits, as illustrated below. Belcher during a study of soil conditions from aerial photographs (1948, p 486) ascertained that light tones are generally associated with well drained soils, while clays, due to their water retention capacity, appear dark. Mottling observed on soils in Indiana by Frost (1946, p 122) was attributed to the presence of clay pockets derived from the weathering of gravel. Such patterns were found to represent lower areas of wet plastic clays in contrast to adjoining lighter toned patches of higher, dryer, silty soils. But as pointed out by Gwynne (1942), although there is usually a relationship between air photo tone and drainage conditions, it is quite possible that a light photo tone may simply indicate lack of soil moisture rather than good drainage, or be the result of topographic position.

Two-dimensional drainage patterns, vary in their usefulness as indicators of terrain conditions, depending on whether they are influenced by man induced field patterns or are governed by them. In the first case, an analysis of drainage density and pattern can be very valuable in distinguishing between terrain types. For as Smith (1950) has shown, it is possible to determine a logarithmic relationship between drainage density and a mathematical expression of the dissection or texture of the earth's surface. In this thesis, recognition of drainage patterns proved to be the most useful element in the identification from aerial photographs, of the 'extensive deposits of fluvio-glacial sands and gravels', because the light toned, feathery, filament-like, dendritic photo pattern was quite unique to and ubiquitous throughout the terrain type.

Finally differential growth of cultivated and natural vegetation (including forest) can also contribute to tonal variations of the image and produce patterns which may indirectly be used to indicate ground conditions.

From the above, it may be inferred that once the ground characteristics of the different air photo patterns are known, they can be used to provide a reasonably good basis for the sub-division of the area into terrain types. Further justification for this is provided by Goldstein and Rosenfeld (1964) who affirm that the photographic representation of a given terrain type will generally have a characteristic spatial distribution of detail (or of contrast) and may in addition be marked by the frequent occurrence of elements of a particular shape and that these features will tend to be similar in all samples of its image, thus facilitating discrimination between terrain types. The attainment of this conclusion inspired Rosenfeld (1962) to use automatic visual measurement of pattern or photographic texture in an attempt to automate the recognition of basic terrain types from aerial photographs. The experiment was a success within the limited range of the terrain types used.

Despite the evidence presented above, which attests to the value of using air photo pattern as a guide to the definition of terrain units, it should be remembered that when the photo-mosaics, used in this study, were initially sub-divided into areas exhibiting unique air photo patterns, some zones remained unclassified. This was because, within these areas, air photo pattern without supplementary field data proved inadequate as a means of delineating terrain units. In other words, as Rosenfeld's experiment implies, although it is a very valuable tool in the delimiting of terrain units, alone air photo pattern can only be used to distinguish between a limited range of terrain types.

(vi) <u>A Consideration of the Problem of Scale</u>

The problem of scale, viewed in connection with photographic interpretation, is two-fold, for it concerns both the scale of the photography and the scale or degree of detail of the final work. The former has already been considered but it should be noted that it is this which determines the importance of pattern as an interpretive medium, for as scale decreases the ability to discern individual forms decreases and the reliance on pattern as an indicator of form increases. The scale of the photographs, used in this study, permitted both the examination of individual relief forms and the recognition of areal patterns to aid in a more general description of the area.

Before any attempt could be made to delineate these areal patterns and define terrain units, some decision had to be made regarding the absolute minimum size that would be feasible to classify as a unit in its own right; a size feasible in terms of the final scale of mapping, the purpose of the study and the size of the County, which had to be covered in a limited time. Where should the line be drawn between grouping and not grouping tonal variations together to produce an air photo pattern which may represent a terrain unit? The ultimate decision requires that an individual terrain unit must be large enough to be represented on the 1:50,000 base maps, as an area distinguished by one of a set of predefined symbols. It must also possess some ground characteristics that are sufficiently different from those of its surroundings to make it significant in terms of morphology or change in land use. To clarify these requirements some examples are cited below.

The initial analysis of the aerial photographs revealed large areas of undulating till and ground moraine deposits which occurred above the level of lacustrine deposition in the northern townships of Durham County. Subsequent field and air photo analysis suggested that such areas could be sub-divided into two terrain types: 'drumlinoid topography' and 'gently undulating till plains', on the basis of geomorphic origin and form, slope angle and soil development. Further investigation showed that within the area of drumlinoid topography interdrumlin swales were frequently occupied by muck deposits, which have been classified as a separate terrain type. However, because the majority of these deposits were too small to be represented on the 1:50,000 maps and occurred with regularity throughout the terrain type, it was decided to include them as another characteristic thereof. It was also noted that the slopes of many drumlins were traversed at regular intervals by non-branching, turf covered gullies, which abruptly started and terminated just below and above the convex and concave breaks of slope respectively. These gullies, though quite visible on the aerial photographs, were also too small to be individually represented on the base maps, however, as a group they could have been. In fact, they were not, for two reasons: first, the presence of these phenomena on a drumlin slope did not give rise to any apparent change in drumlin form, land use, soil type, vegetation, drainage or extent and type of erosion; second, in the light of this, it was not considered practical to attempt to outline these numerous and rather small areas when the total area under study is so much larger. However, on slopes where the occurrence of such gullies has res ulted in extensive erosion, removal of vegetation and top soil, alteration of slope form and a change in land use, a separate classification, that of 'steep slopes in till' has been applied.

The above example illustrates the point that within this system of terrain types devised for Durham County, there is unlimited potential for further sub-division of the terrain into smaller units, if the study of a smaller area at a larger scale warrented it.

No attempt has been made to define units of comparable areal extent. Rather they have been defined to incorporate homogeneity of pattern and geomorphic parameters, large enough to include wide stretches of moraine and small enough to pick out river valleys.

(vii) A Consideration of the Problems of Boundary Definition

The problem of boundary definition has relevance not only to this study but to all fields of geography because many geographical elements alter gradually, not abruptly from place to place and therefore the location of boundaries is governed by subjective judgement. The terrain, vegetation and soil characteristics at a particular place are always unique. Consequently observation sites can be grouped only on the basis of similarity not identity, but this introduces the question of how to measure similarity. Compared to this, the problem of defining terrain units, in terms of many more variables, is even more complex and can be approximated only through a synthesis of single elements measured separately. This presupposes that decisions have been made regarding which variables should be used and how they should be combined.

In fact the boundaries of several terrain types are delimited simply by noting a change in one variable, for example, muck deposits are distinguished from marshland according to the level of the water table; eskers are distinguished from their surroundings on the basis of geomorphic form; valley flood plains are distinguishable from steep slopes in till by virtue of their form, location and origin; et cetera. In most cases, however, the precise junction between terrain types A and B is virtually impossible to locate either on the ground or from the aerial photographs. So in order to deal with these situations in a way that is considered quite adequate in this context, a method of arriving at an approximate boundary has been evolved.

First, a boundary is drawn to include all areas which definitely exhibit characteristics of terrain type A; then the same is done for all adjacent areas which definitely exhibit characteristics of terrain type B and finally the ultimate boundary line is drawn half-way between these two limits.

The precise terrain differences across each unit boundary and the special problems involved in distinguishing between particular pairs of terrain types will be dealt with below, in the descriptions of the physical characteristics of the terrain types themselves.

(viii) The Mapping and Description of Terrain Units

The units were originally outlined on the aerial photographs themselves; thence the boundaries were transferred by eye to 1:50,000 topographic sheets and then traced onto the final manuscript.

After the terrain units had been mapped, a suitable method of fully describing them and providing some sort of key, by which any other person might recognise them, had to be devised. Colwell (1953) has defined an air photo interpretation key as, "reference material, designed to facilitate rapid and accurate identification of an object from an analysis of its air photo image." In other words, keys are usually the means by which data obtained from a terrain unit classification, compiled with the aid of aerial photographs, is represented, and they can take many forms depending on the purpose in hand. In this particular case the key is designed to provide, with reference to specific site examples, an accurate, if subjective, description of ground conditions within the individual terrain types. In each case the description will indicate the topography and geomorphic history; type of superficial deposit; characteristic slope angle and relief range; drainage conditions; extent and type of erosion and the means by which it is being combated, if any; soil types; land use and vegetation.

The fractional code and tabular method of presenting this data was rejected in favour of a written report because more detail could thereby be included and observations would not be limited to a specific number of categorised groups. However, there is a limit to the extent to which any written report can accurately represent terrain conditions and this is why so many ground photographs have been included. As has been previously stated, individual terrain types are usually represented on the aerial photographs by a characteristic air photo pattern. Each pattern is therefore illustrated using an aerial photograph itself, in view of the limited vocabulary available for describing such patterns. Finally any special difficulties that were encountered in the interpretation of the features within each terrain type will be discussed.

The key to the interpretation of terrain types in Durham County, as laid out below, also comprises a permanent record of the photo interpretation research and experienced gained whilst carrying out this study. Its production, in basic form, was necessary as a memory aid in defining terrain units from air photo pattern for such a large number of photographs and was a bi-product of the original aim of this thesis to determine the extent to which air photo interpretation can serve as a basis for terrain unit mapping, it was not an end in itself.

CHAPTER V

REGIONAL DESCRIPTION OF DURHAM COUNTY IN TERMS OF TERRAIN TYPES

The following has been organised in such a way as to elucidate the relationship between areas of similar surface configuration and to enunciate the specific criteria by which it is possible to differentiate between them.

Level Terrain - Organic

I Marshland

Land so classified was delimited primarily from aerial photographs, due to inaccessibility, Photo 5-1, and represents areas covered by standing water and vegetation - generally forest and scrub - in varying degrees of degeneration. These areas give the appearance of having once been thickly forested and suffered relatively recent flooding, Photo 5-2. They occur most frequently to the north of the Oak Ridges within the flood plains of the northward flowing streams and it is possible that those in the north-western part of the County were inundated by the rise in the water table accompanying the damming of the drainage outlet at Lindsey and the flooding of Lake Scugog.

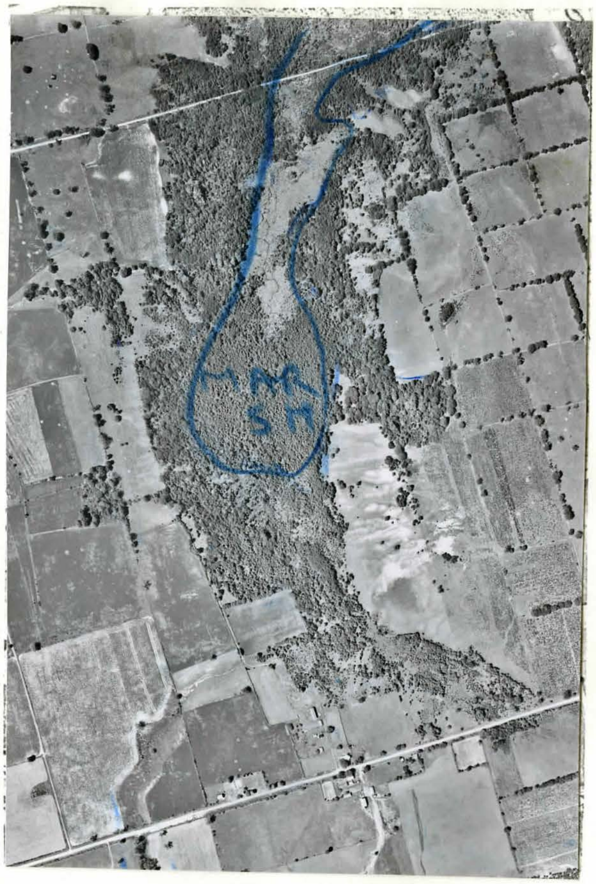


Photo 5-1 Air photo pattern of marshland deposits.

Photo 5-2 Marshland area, showing relatively recent flooding of former forest land.

Little artificial reclamation has been attempted, although some regeneration of vegetation on the edges of the marshland was observed in the field, Photo. 5-3.

II Muck

This terrain type may be distinguished from the above on the basis that for the majority of the year the water table over at least 80% of this area is below the surface of the terrain. Thus defined, muck deposits occur within the former lagoons of the Iroquois coastal zones; in depressions on the gently undulating till plain; and along the slow-moving, low gradient streams flowing northwards from the Oak Ridges into the Trent River system. Drainage is very poor, the water table high and the soil supplanted by a blackish layer of well decomposed organic material ranging in depth from 1-15 feet (Rouse 1961). The land is thus useless for agriculture and is nearly all left as impenetrable woodland, Photo. 5-4, which together with the associated slough areas, Photo. 5-5, may be easily distinguished on the aerial photographs from the pasture land of the flood plains and till, Photo. 5-6. The most commonly occurring trees in these woodlots are tamarack and white cedar, which provides a canopy for a ground layer of numerous grasses and sedges adapted to the high water table.

Photo. 5-3 Local regeneration of Marshland along a raised roadway, by grasses, sedges and bullrushes.

Photo. 5-4 Untended, impenetrable woodland with a ground layer of plants adapted to the high water table- typical of Muck deposits.

Photo. 5-5 Sedges and Shrubs on a river flood plain, typical of Muck deposits.

Photo. 5-6 Air photo pattern of Muck deposits.

Ground and sub-surface survey work by Rouse (1961) in the area of Cavan Bog, to the north of Cavan township, indicates the maximum depth reached by the muck deposits to be 15 feet, though it was found to vary considerably. He also found mineral material occasionally mixed in with the organic material and impervious marl or blue-grey calcareous clays underlying the organic material. This leads to the conclusion that some of the low lying, north trending valleys that became filled with water immediately following the retreat of the ice were subjected to the deposition of clay outwash material. This subsequently impeded drainage and hence muck deposits developed.

Level Terrain - Mineral

III Alluvial Terraces

One such terrace occurs in the upper section of Baxter Creek valley, around Millbrook, where the valley side rises 250 feet above the level of the terrace and the valley itself is over a mile wide. The terrace lies some 20 feet above the present river flood plain, it is almost flat and dissected by streams flowing across it from adjacent higher ground to the river. Elsewhere the soil is sufficiently porous to permit internal seepage and inhibit the development of superficial drainage patterns.

Field investigations revealed that this high level terrace is composed of outwash sands and gravels probably derived from the retreating northern ice lobe and alluvial sands and gravels washed down from the Oak Ridges and trapped in the valley, which, because of its size, is thought to have originated prior to the final readvance of the ice.

Air photo identification of the alluvial terraces that comprise this terrain unit depends largely upon the recognition of geomorphic location and form. However, other characteristics recognisable on the aerial photographs include: a scattering of depressions showing darker tones and mottling, indicating the presence of local clay pockets within the alluvium; also sporadic slumping along the upper slope of the edge of the terrace, seen as white flashes on the photographs ,Photo. 5-7, suggests the removal of sands or other loosely compacted materials from beneath an overlying clay cap.

Soils comprise a stone free, clay loam and on the better drained areas arable farming takes the place of scrubland found elsewhere.

IV <u>Extensive Deposits of Fluvio-Glacial Sands and Gravels</u>

This terrain type is localised in three areas: the raised Ganaraska delta; the northern part of an otherwise pitted outwash plain, on the southern flanks of the Oak Ridges and to the

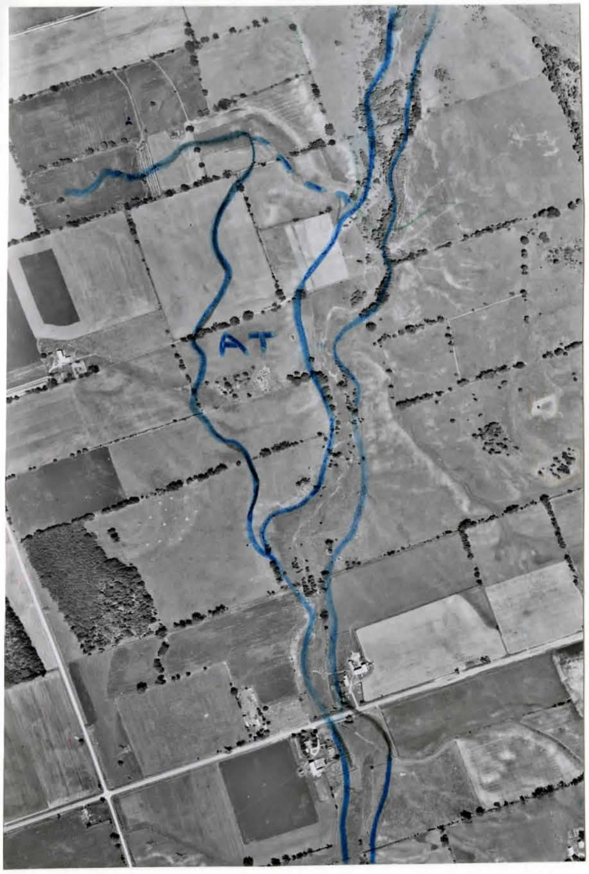


Photo. 5-7 Air photo representation of an alluvial terrace.

east of the Ganaraska delta; and a band of scattered deposits along the Iroquois shoreline between Hampton and Orono. The last two sets of deposits were probably laid down by the meltwater from the Lake Simcoe lobe when it overrode the Oak Ridges to the east of Uxbridge. Compared to this the former area noted could equally well be genetically classified as a deltaic deposit for it was laid down on the shore of Lake Iroquois by the contemporary equivalent of the Ganaraska River, which, like the meltwater streams, drained the sandy Oak Ridges moraine. Thus it is not surprising that the few available exposures show the deposits to consist of a coarse, grey, stratified, calcareous sand.

The topography of this terrain type comprises slopes of less than 3½%, sloping gently southward from the source area and provides an abrupt contrast with the undulating ground and kame moraines immediately to the north, Photo. 5-8. Another factor which makes these areas readily recognisable from the air photos., is their characteristic light toned, feathery, filament-like, dendritic photo pattern, Photo. 5-9. These dendritic patterns invariably trend down slope and field investigation revealed - as was to be expected - that they represent slight increases in soil moisture content, which is being reflected as differences in vegetation growth, Photo. 5-8.

Photo. 5-8 A typical area within terrain unit IV, i.e. extensive deposits of fluvio-glacial sands and gravels. Note the slopes of a ground moraine deposit in the background, and in the foreground tonal variations- which can be observed on the aerial photographs- and in this case are a result of the non-uniform growth of clover.

Photo. 5-9 Air photo representation of terrain type IV.

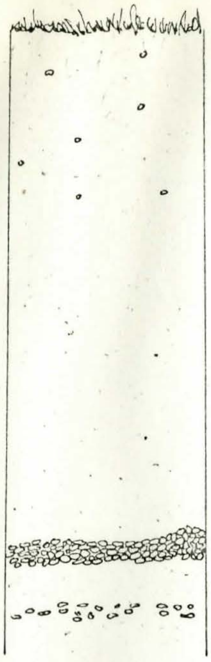
The soils commonly occurring within this terrain type are sandy and stone free and have been classified by Webber and Morwick (1946) as a Brighton sandy loam, a generalised profile of which is shown in figure 5-10. Like the underlying parent material, the soils are sufficiently porous to permit internal drainage, that is apart from the occasional clay pockets which are found on the flatter and more extensive upper reaches of the delta and give rise to muck deposits.

Apart from an insignificant blowing of the ploughed sandy soil, erosion is limited to that induced by streams crossing these fluvio-glacial deposits from the adjacent upland and causing deep incision into the friable, sandy material, which due to the headward erosion of the tributary valleys, is slowly being removed.

The level nature of this terrain type, Photo. 5-8, is well drained, and the fertile soils make it one of the most prosperous agricultural areas and one of the most intensive tobacco growing regions in the County, Photo. 5-11.

V Deposits of Wind Blown Sand above 1000 feet

This terrain type covers a small total acreage and occurs in one or two discrete areas on the Oak Ridges, where it stands out as very flat areas in marked constrast to the adjacent zones of granular, humocky kame moraine. Ground observations confirmed that the soil was very sandy, as suggested by the use of the



Veg - Arable crops e.g. tobacco

A - 12" 7.5 YR 4/2 (Munsell notation) fine, friable sandy loam. A few small pebbles.

B - 15" 7.5 YR 6/6 light brown sandy loam, considerably less humus than A horizon.

C - Stratified, loosely compacted sands & gravels.

Fig. 5-10 Generalised profile of a Brighton sandy loam, the soil type typical of terrain type IV.

Photo. 5-11 Tobacco growing on the fluvio-glacial sands of terrain type IV

land for growing tobacco and the light toned mottlings of whispy appearance noted on the aerial photographs as representing these areas, Photo. 5-12. The occurrence of sand in these locations is probably the result of the deposition of wind-blown sand derived from areas of severe erosion elsewhere on the Oak Ridges, areas similar to those described as terrain type XV. It is unlikely that the sand deposits are deep enough to completely mask the underlying kame moraine. Furthermore, although drainage is good and only very faint, randomly distributed rill marks are apparent from the aerial photographs, the occasional shallow depressions showing darker mottled tones in their lower portions and lighter edges, indicate a sub-surface deposit rather less pervious than sand. This material is most likely to be till which was plastered on during the readvance of one of the ice lobes, for it would effectively mask the underlying hummocky relief, providing a smooth surface for the deposition of the sand.

The soil most frequently found on the composite deposits of this terrain type, is a stone free, grey-brown sandy loam, classified by Weber and Morwick (1946) as a Dundonald sandy loam, Figure 5-13 shows a generalised soil profile. Due to the level nature of the topography and the porosity of the surface, there is little erosion, making this terrain type one of the few areas on the Oak Ridges suitable for farming.

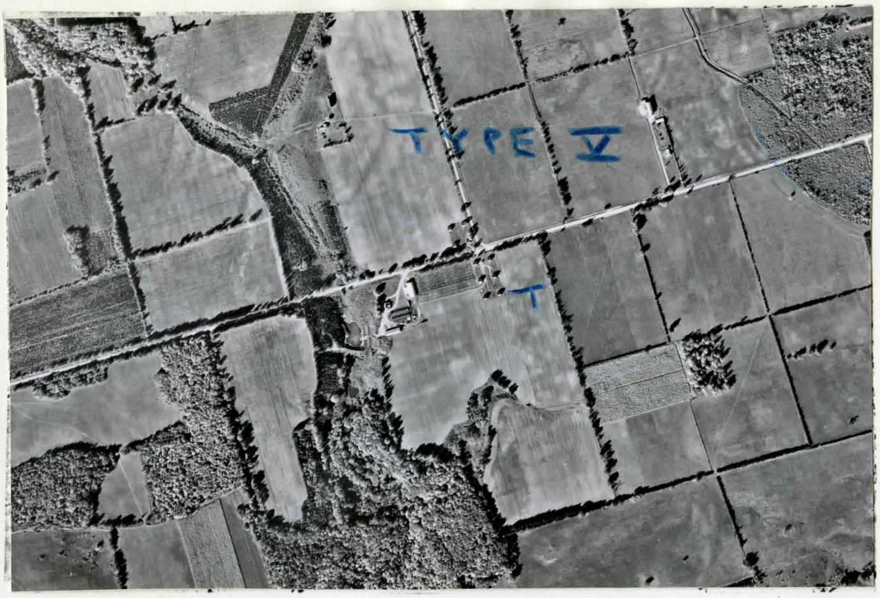
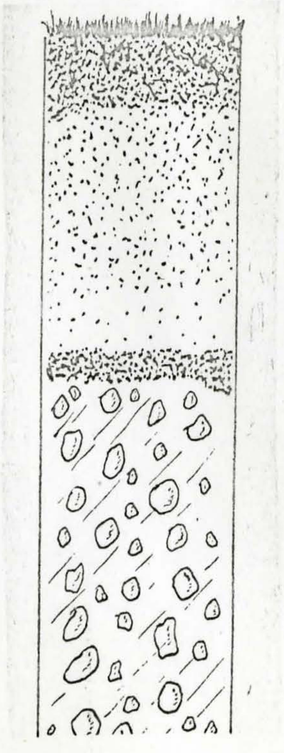


Photo. 5-12 Air photo representation of terrain type V - Deposits of wind blown sand above 1000 feet. Note tobacco kilns (T).



Veg. - Arable crops.

A_1 - 4-6" grey-brown sandy loam approaching single grain structure, low organic content, stonefree.

A_2 - 10-15" light brownish sand, single grain structure.

B - 2-3" brownish loam, soft, friable.

C - Grey, calcareous till with frequent stones and boulders. Till is very compact.

Figure 5-13 A generalised soil profile of the Dundonald sandy loam which is characteristic of terrain unit V.

VI <u>Lacustrine Sediments</u> a. <u>Silty-clay deposits</u>

This terrain type includes sediments laid down in glacial Lake Iroquois as well as those inundated by the Schomberg pondings. However, prior to describing their very similar overall characteristics, the few differences between them will be noted.

The Schomberg deposits are found in a much more restricted environment, that of deep valleys which drain the northern flanks of the Oak Ridges; hence they cover a much smaller area and tend to be shallower - more like a lacustrine veneer over the calcareous till. A characteristic which is occasionally manifested on the ground surface and the aerial photographs as subtle tonal changes - reminiscent of those found representing the 'ablation till overlain by lacustrine deposits', though the relief is usually smaller (Photo. 5-14). The shallower nature of the Schomberg deposits is reflected in increased soil stoniness and a slight variation in soil type. This has been classified by Weber and Morwick (1946) as a Schomberg Clay or Silt loam, a typical profile of which is shown in Figure 5-15.

The topography of the lacustrine plain in general is marked by slopes of 5% and less. It is composed of relatively stonefree silts and clays which tend to be slippery and induce sheeting when wet (Photos. 5-16) and are inclined to be mealy when dry. The deposits are therefore probably silts which have

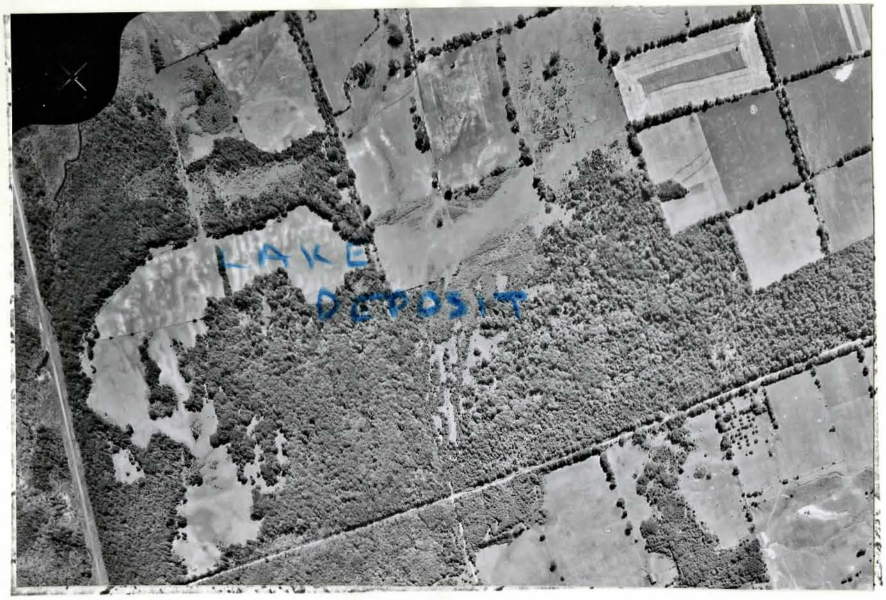
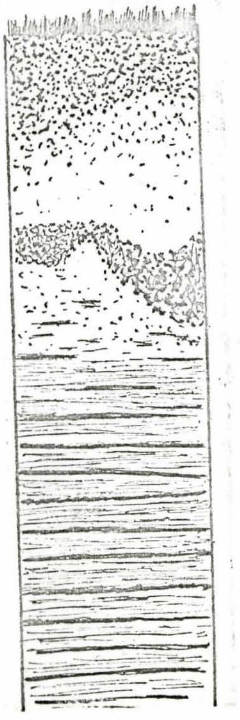


Photo. 5-14 Illustrating the air photo pattern which frequently characterises the Schomberg lake deposits.



Veg. - Rough pasture.

A_1 - 4-6" grey-brown silt or clay loam; nearly stonefree crumb structure.

A_2 - 6-10" greyish silt loam; platy structure.

B - 3-6" brown, sticky clay, blocky structure.

C - Greyish, calcareous varved silts and clays - overlying till at varying depths.

Figure 5-15 A soil profile typical of the Schomberg Clay or Silt loam.

Photos. 5-16 Sheeting of silty clays on areas of lacustrine deposition, after the removal of sod by man and erosion.

been derived from ground rock flour rather than weathered clay minerals. Exposures reveal the deposits to be calcareous, very compact and varved with 2-7" silty grey summer bands and denser brownish grey winter bands usually less than one inch thick.

The soil to which this material gives rise on the Iroquois lake plain is known as the Newcastle loam (Weber and Morwick 1946) a profile of which is shown in Figure 5-17.

Despite the variety of soils developed on the lacustrine deposits, they are usually stonefree and fertility is good, especially on the loams, which are well suited to the growth of market garden products and orchard fruits. Although the small areal extent of the Schomberg loams prevents their optimum use and they usually revert to pasture.

Drainage also is fair to good and in summer the terrain type presents a uniform air photo tone, but after spring rains the clay fraction in the soil causes water accumulation in drainage ditches and swales, making the soil very sticky and giving rise to a unique pattern of tonal variations on the aerial photographs (Photos. 5-18 to 20). Apart from recognition of these patterns, air photo identification of this terrain type depends upon knowledge of its most probable geomorphic location and observation of the gently undulating nature of the topography.

Veg. - Arable crops.

A_1 - 4-7" dark grey clay loam, crumb structure, can be friable when dry.

A_2 - 8-15" brown-grey loam.

B - 4-10" sticky clay; blocky structure.

C - Stonefree, calcareous clay varves.

Figure 5-17 Soil Profile of the Newcastle loam - the most frequently occurring soil type on the silty-clay Iroquois sediments.

Photo. 5-18 Depression showing locally poor drainage on the silty-clay deposits of the level lacustrine plain.

Photos. 5-19,20 Aerial and terrestrial photographs showing tonal variations induced by water-logging on the lacustrine plains. Note the sub-surface clay exposed by deep ploughing above and the pattern of drainage ditches (D) and tile drainage (T) below.

VII Lacustrine Sediments b. Stony, stratified sands and silts

This terrain type is usually found directly to the south of the Iroquois shoreline, and often in areas noted by Gravenor as gravel deposits. However, ground observation has revealed this to be false, the sub-surface material is always stony but its main component is either a stratified sand or silt.

The topography is level to depressional, very similar to that of the surrounding lake plain, but in contrast the soils are poorly drained, very stony, have little horizon development and are practically unused for agriculture, giving rise instead to woodland and scrub (Photo. 5-21). It is therefore very easy to delineate these areas on the aerial photographs by first outlining the very gently undulating, almost level areas of lacustrine deposits and then noting those portions where the drainage is poor, stone piles are dotted over the landscape and scrub or woodland is the predominant vegetation, (Photo. 5-22).

VIII Linear Deposits of Alluvial Origin

A more familiar term for this terrain type would be, river flood plains, that is, they are nearly level, meandering ribbons directly adjacent to streams, and can be readily identified on the aerial photographs due to their location. They are poorly developed on the granular kame-like deposits of the Oak Ridges which are too pervious to permit extensive

Photo. 5-21 Poorly drained, almost level areas of scrubland, typical of terrain type VII. Note the Iroquois cliffline showing soil creep in the background.

Photo. 5-22 Air Photo Pattern typical of terrain type VII. Note scrubland (S), infrequent use of the land for agriculture and numerous stone piles (P).

surface drainage but on the overlying till and on the emerged Iroquois lake plain they vary in extent and generally occur from 15-30 feet below the surrounding topography (Photo. 5-23, 24). On the emerged lake plain, the incision into the till is usually deeper than that into the lacustrine deposits though in both cases secondary incisions occur and for third order streams, may reach a depth of 3½ - 4 feet. Apart from mentioning these differences, no differentiation has been made in the classification, between flood plains developed on different deposits.

The flood plains are poorly drained, subject to flooding and include small pockets of marshland and muck where these are too small to be mapped as individual terrain units. These areas of alluvial deposition are easily distinguishable on the aerial photographs from those of organic terrain, due to differences in drainage condition and land use. On the former there frequently occurs a complex soil derived from varying types of parent material which sometimes incorporates a layering of mineral and organic material induced by yearly depositions. As a result the soils tend to be immature but fertile and well drained enough to provide areas of permanent pasture.

Photo.5-23 Illustrating ground conditions within a Linear Deposit of Alluvial Origin or Valley Flood Plain. Note drainage and secondary incision. Valley sides are composed of till and are subject to creep and local sod removal.

Photo. 5-24 Typical Ground Characteristics of a Valley Flood Plain in Till

Undulating Terrain

IX Till Plains Above the Level of Former Lacustrine Deposition

As a whole , this terrain type comprises a very large proportion of the total area of Durham County, but it exists as a series of discrete entities scattered on the northern and southern flanks of the Oak Ridges and along the crest of the hills themselves. Nowhere does it extend below the limit of former glacio-lacustrine deposition.

The topography is gently undulating with slopes of less than 6%, from which it can be inferred that where the till overlies areas of the Oak Ridges kame moraine, it is deep enough to mask the otherwise hummocky surface of the deposit. Drainage is good to fair even where the till overlies the Oak Ridges moraine on which drainage would otherwise be excessive. First order streams occurring within this terrain type often traverse shallow depressions which are either marshy or exhibit local tonal mottling on the aerial photographs (Photo. 5-25) indicative of locally increased soil moisture and organic content. Otherwise the tones for a similar crop across a unit tend to vary little.

The most frequently occurring soil type is a podsolised loam, grading into a podsolised fine sandy loam near the edges of the deposit. It has been classified by Webber and Morwick (1946) as belonging to the Bondhead series, and a generalised

Photo. 5-25 Air Photo representation of a gently undulating Till plain which occurs above the level of former Lacustrine deposition. Note the uniform tones and occurrence of stone piles.

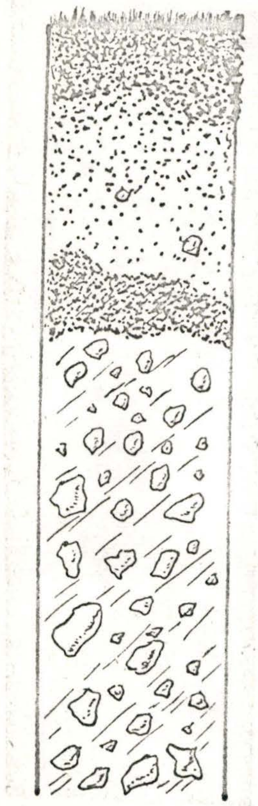
profile is shown in Figure 5-26. The majority of the area is devoted to arable farming and a very small portion is forested. Erosion is mainly riverine, although creep does occur on valley sides, but turf removal is rare.

X Deposits of Till and Lacustrine Sediments South of the Lake Iroquois shoreline

This terrain type includes topography to the south of the Iroquois shoreline that has gently undulating slopes between 10-25% and hence excludes the nearly level lacustrine plains and all the river valleys and areas of intense gullying within it. It is not restricted to a particular deposit and occurs on both emerged till and lacustrine deposits, though more frequently on the former.

As a result of the increase in slope angle, drainage is better than on the lake plains mentioned above, consequently tonal variations, viewed from the ground and the air, tend to be less intense. Other differences between the two terrain types reflect the predominance of till as the sub-soil of this one and they include: increased stoniness of the soil: the more frequent occurrence of borrow pits; greater extent of soil creep and sod removal and the development of steep, deeply eroded clifflines along the shore of Lake Ontario (Photos. 5-27,28). All these factors are visible on the aerial photographs (Photo.

Fig. 5-26 Soil profile of Bondhead loam and sandy loam



Veg - arable crop

A_1 - 10 YR 7/2 (Munsell notation) 4-6" grey brown loam or fine sandy loam, friable crumby structure, few stones, roots throughout entire layer.

A_2 - 8-12" greyish brown sandy loam or loam tending to a weak platy structure.

A_3 - 2" reddy brown, slightly cemented, compacted material.

B - 2-4" brownish loam, weak blocky structure.

C - Grey calcareous till, frequent stones, mainly limestone - sub-angular. When washed out by erosion dries to an extremely hard, white surface.

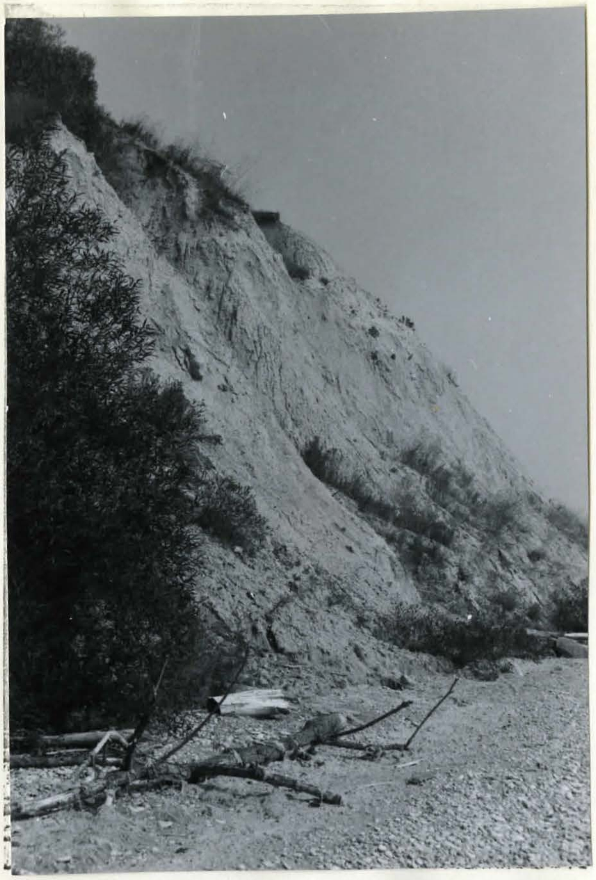


Photo. 5-27,28 The development of steep eroded cliffs, in till, on the shore of Lake Ontario.

Photo. 5-29 Aerial photo of a section of undulating topography south of the Iroquois shoreline. N.B. the deeply eroded cliffline and relatively uniform photo tone. The outlined valley is not included in this terrain type.

Fig. 5-30 A profile of the dark, grey-brown, heavy, sandy loam characteristic of terrain type X.

Veg, - Pasture

A_1 - 4-6" 10 YR 4/2 (Munsell notation) grey-brown loam; crumb structure; relatively stonefree.

A_2 - 10-15" 7.5 YR 5/2 light brown loam; a few stones.

A very distinct horizon.

B - 18" 10 YR 5/4 silty clay loam; blocky structure; many small pebbles with 4" diameter and less.

C - Grey calcareous, stony till.

5-29) and hence supplement the observation of slope angle in the delineation of terrain units.

The soils that develop on this terrain type characteristically comprise a dark grey-brown, heavy, sandy loam (Figure 5-30) and the only apparent differences that occur between the soils underlain by lacustrine deposits as opposed to till, are that they tend to be slightly less stony, more poorly drained and stickier when wet. A high percentage of the land within this terrain type is used for agriculture, especially arable farming and pasture.

XI Drumlinoid Topography

This terrain type is found only above the limit of glacio-lacustrine deposition and then most frequently to the north of the Oak Ridges. It is often associated with the gently undulating till deposits but can easily be distinguished from them by the drumlinoid configuration of the topography. Areas designated as belonging to this terrain type, comprise groups of cigar shaped drumlins orientated approximately 23° west of south and generally distributed in tandem or en échelon. The northern-most ends of the drumlins are usually the bluntest, giving a further indication of the direction of ice movement which gave rise to them. Relief range of such areas often exceeds 100 feet and drumlin slopes average 20-25% (Photo. 5-31).

Photo. 5-31 A drumlin composed of till with poorly drained ground moraine of the inter-drumlin depression in the foreground. Note the stoss end of the drumlin on the right.

The majority of the drumlins examined in the field were composed of a well drained, grey, calcareous, uncemented, stony till. This comprises limestone and pre-Cambrian angular and sub-angular pebbles, cobbles and boulders ranging from ½" to 5 feet in diameter. and coarse gravels. In the borrow pits that were examined no frost shattering of cobbles was noted but many stones exhibited glacial striations (Photo. 5-32). The soils developed on these deposits tend to have little profile development and many stones, (Photo. 5-33) but are well drained and where slopes permit the sandy loam can support arable farming. Elsewhere reforestation and rough grazing are the main land uses (Photo. 5-34).

Together with stone piles there often occur linear, non-branching, turf covered gullies down the sides of drumlins (Photo. 5-35), and these form distinct and easily recognisable linear tonal variations on the aerial photographs (Photo. 5-36). Ground observation has revealed that in some cases where the turf has become broken some attempt has been made to restrict erosion by placing boulders and brush at the head of the gully (Photo. 5-37).

Inter-drumlinoid swales are often poorly drained, showing a mottled appearance on the aerial photographs; and in some cases muck, marshland and even small lakes occur on the less pervious ground moraine upon which the drumlinoid till caps

Photo. 5-32 A glacially striated boulder found in till.

Photo. 5 - 33. A typical soil profile found on the side of a drumlin.
Veg. - Coarse grass and weeds

A_1 - 6" sandy loam. 10 YR 5/3 (Munsell notation) dark grey, brown, moderately stony, crumb structure. Roots throughout this payer.

C - Grey limestone till containing some fragments (Less than 2" diameter) of Pre-Cambrian rock.

On shallower slopes the soil profile is better developed.

Photo. 5-34 Illustrating the use of drumlinoid topography for reforestation and cattle grazing. Note the use of boulders and brush to prevent headward erosion of gullies in the centre and left of the valley.

Photo. 5-35 Linear, non-branching turf covered gullies down the side of a drumlin. Note the erosion and broken turf on the left hand side of the print and the use of stones in an attempt to stop it.

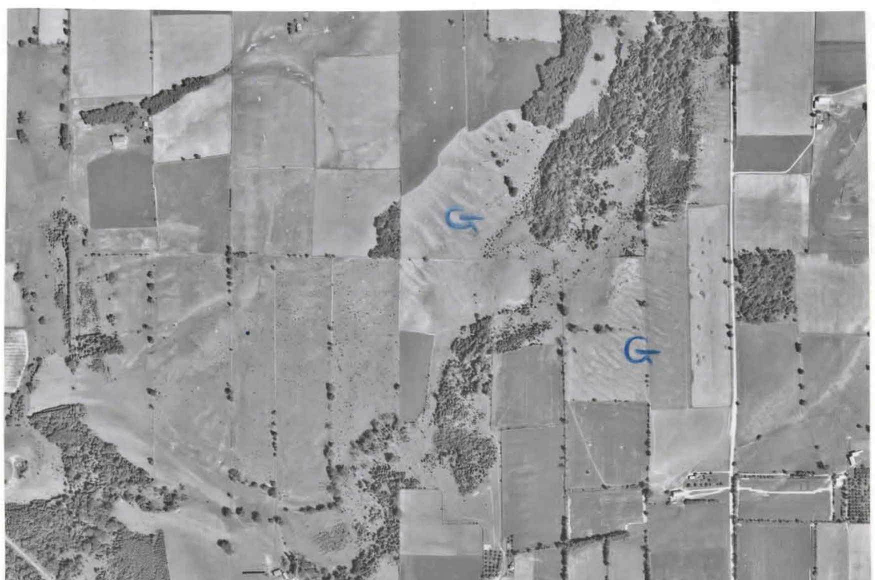


Photo. 5-36 Air photo representation of the linear gullies (G) shown on the ground photograph above.

have been superimposed.

XII High-level Plateaux Composed of Till Overlain by Sand

This terrain type is usually found over 1,000 feet, that is, near the summit of the Oak Ridges as they exist in Durham County. Although similar to terrain type V, 'deposits of wind blown sand above 1,000 feet', it is distinguished from it on the basis of a shallower overburden of sand on the till and the greater local relief range. In fact, the word, plateaux, is used advisedly to accentuate the topographic compar ison between their gently undulating surfaces (slope angles vary from 2.5 - 7.5%) and the extremely hummocky, kame-like nature of the surrounding areas. The soils are sandy as indicated by ground investigation and the fairly light tones and mottled yet whispy appearance of the air photo pattern characteristic of such areas (Photo. 5-37). The good to excellent drainage of the soil and an investigation of borrow pits within the area make it seem unlikely that the sandy deposits are simply a thin mask overlying a level area of till. The porosity of the surface materials, the relatively level nature of the terrain and good farming practices restrict erosion to a minimum (Photo. 5-38). Land use is devoted either to arable farming or plantations of evergreens.

Photos. 5-37,38 Showing typical characteristics of high level plateaux from the air and ground. Note the gently undulating topography and turf removal - exposing sand.

Restricted Areas of Steeply Sloping Terrain

XIII Steep (25-50%) Slopes in Till

This terrain unit is really a later stage in the evolution or erosion of linear drumlin gullies and their counterparts in other regions of the County covered by till. It is found in four different geomorphic locations: along the boundary of till and other deposits; on very steep drumlin sides; and on third and fourth order valley side slopes which are steep enough to involve a change in land use and an increase in non-riverine erosion, Photo. 5-39 (if they enclose a wide flood plain this is classified separately). Finally, this terrain type includes second and third order valleys which fulfil the same requirements as the valley sides mentioned above.

Slope angles vary between 25-50% and soil creep is the most frequently occurring type of erosion. Of course, in some cases secondary incision into the non-branching, turf bottomed gullies that appear on drumlin sides, gives rise to turf removal and over grazing may result in complete turf removal from upper slopes, Photo. 5-40. However, it is the relative lack of exposed soil on these slopes, Photo. 5-41 compared to equally steep slopes on the Oak Ridges moraine, where large scale soil removal occurs, that serves as the chief means of distinguishing between the two types of slope. Another way is to compare the form of the first and second

Photos. 5-39,40 Typical steep slopes in till i.e. slopes are steep enough to involve a change in land use and an increase in non-riverine erosion.

◄Creep on the valley side. Note the fairly well drained flood plain with a secondary incision of 2½ to 3 feet.

▼A very steep drumlin side (upper slope 28.5° lower slope 45°) showing soil creep, complete turf removal, gullying and slumping of the grey, calcareous till.

Photo. 5-41 A long but not very steep slope- exhibiting little erosion found on the edge of a ground moraine deposit - a more typical example of terrain type XIII than Photo 5-38. Lake deposits are in the foreground.

order valleys; for on the more cohesive ground moraine they tend to be U-shaped, having steep upper slopes and rounded valley bottoms, whereas the V-shaped valleys develop on the more granular Oak Ridges moraine.

Drainage on these slopes is excellent but soils are shallow, stony, poorly developed and in some cases non-existent providing exposures of the underlying grey calcareous till. Hence the land is unsuited to agriculture and vegetation restricted to coarse grass and shrubs.

XIV The Slopes which develop at the junction of Till Deposits with those of Sands, Silts or Gravels

In all cases where this terrain type occurs, the till exists as a capping, of varying extent, over a deposit of sands, silts or gravels and as a result tends to protect the underlying, more friable materials from erosion. However at the edges of these local till covers the underlying sands and gravels tend to be removed by seepage and erosion until the till breaks or slumps off. This gives a very distinctive erosion pattern to the slopes where the till and granular deposit junction occurs, and to the sides of the valleys which traverse this junction- a pattern that can easily be recognised on the aerial photographs, Photo. 5-42. As illustrated on Photos. 5-43, 5-44, the more cohesive till tends to form a steep upper slope marked at intervals by light toned flashes of grey, Photo. 5-42 Air photo representation of the slopes (s) which develop at the junction of till and outwash sands & gravels.

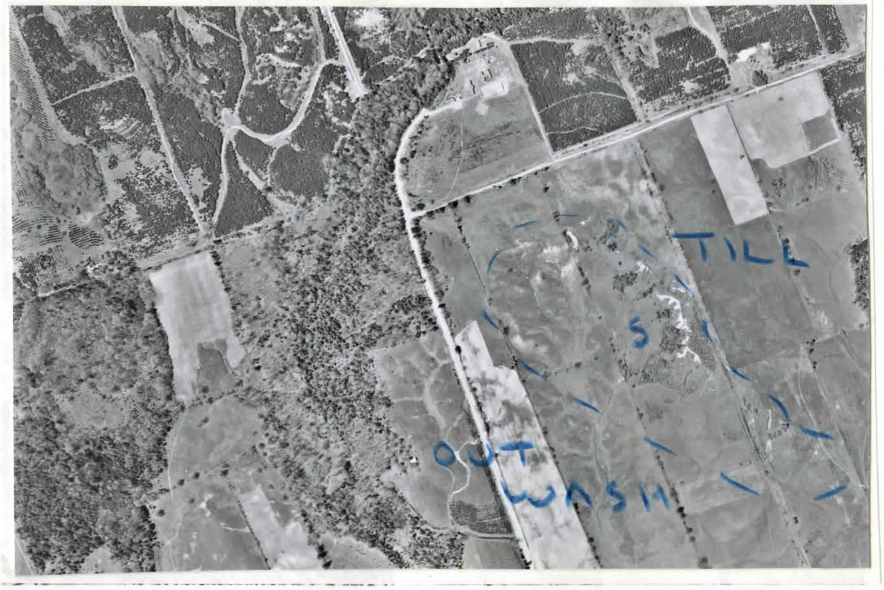


Photo. 5-43 See caption for Photo 5-44.

Photo. 5-44 This scene and the preceeding one, show a slope trending from left to right across the prints, which marks the edge of a capping of ground moraine over the Oak Ridges kame moraine. Note the light toned flashes of eroded, slumped till on the upper slopes.

Photo. 5-45 A close up of an area of slumped till.

stony, calcareous material. This phenomenon occurs most frequently at the junction of till and the sandy Oak Ridges kame deposits but may also be found at the edge of alluvial or lacustrine deposits.

In situations where more gentle slopes mark the till/ granular deposit boundary and the erosion flashes have not developed, the slopes can be distinguished by the occurrence of straight steep- sided unvegetated first-order gullies. These usually start some distance from the top of the slope and occur at intervals across the slope unless erosion is accelerated or has been incident over a long period of time. In this case the gullies will coalesce, ultimately devegetating the slope, Photo. 5-46,47.

When a stream flows from the till across the deposit junction, the individual valley tends to loose its identity in a mass of small sandy hillocks and gullies into which the surface drainage seeps. One such example is the very large re-entry valley of the northerly flowing Fleetwood river,which is responsible for exposing a large section of the Oak Ridges moraine further north than it occurs elsewhere in Durham County.

As a result of severe gradient and erosion the soils within this terrain type are truncated, rendering agriculture impossible and limiting the vegetation to scrub and thin woodland.

Photo. 5-46 An example of the severe erosion that frequently occurs where the edge of a capping of till abuts onto the underlying more friable kame deposits.

Photo. 5-47 A close-up of the site shown above. Note the light toned, stony nature of the till and the clayey fines which have been washed out in the foreground.

XV Areas of severe Erosion

These occur almost exclusively where deforestation and over grazing on the sandy kame or outwash deposits, found locally throughout the Oak Ridges, has intiated creep, sheeting wind erosion and gullying, resulting in 80% or more of the vegetation being removed, Photo. 5-48. Such areas tend to have slopes in excess of 45% and are so severely eroded that not even reforestation by the Dept. of Lands & Forests has been attempted, as it has in many adjacent areas. Soils are completely truncated and the underlying deposits generally pure sand.

Gradually this terrain type which was formerly quite extensive, is being reduced by reforestation and other conservation measures and only very inaccessible areas remain to be so classified. Fortunately, as can be seen on Photo. 5-49 they are very easy to delineate from the aerial photographs, by virtue of their light tones, steep slopes and lack of vegetation.

XVI Areas of High Density Stream Development below the Lake Iroquois shoreline

The drainage systems below the Iroquois shoreline can be subdivided into two types on the basis of genesis, form and area of occurrence. There are first the consequent streams

Photo. 5-48 (above), -49 (left)
Aerial and terrestrial views of an area of severe erosion on the Oak Ridges - terrain unit XV.
Deposits - sandy kame outwash.

which existed at the time of Lake Iroquois and simply extended their courses when the water level fell. These streams have relatively few tributaries, comprise a low density network and are deeply incised from a knick point close to the position of the raised shoreline; although the incisions into the lacustrine deposits tend to be shallower than those into the emerged till. The flood plains of these valleys are clearly defined and the valley side slopes closely related in form to slopes occurring elsewhere within till deposits, so they have been described elsewhere.

The other drainage system is found on the emerged lake plain. In contrast to the above it comprises a very high density drainage network, which developed consequent to the Iroquois shoreline on gently sloping deposits of fine sands, silts and clays. As a result, such areas are now intensely gullied, the soils tend to be truncated, agriculture has largely been abandoned and although complete removal of sod has not occurred the occasional light toned flash of bare sand is noticeable both on the ground and from the air photos (Photo. 5-50). A normal non-eroded profile of the Percy loam, common to this type of deposit (Webber and Morwick 1946) is well drained, fertile and shows moderately good horizon development, Fig. 5-51.

Delimitation of this terrain type from air photos depends

Photo. 5-50 Air photo pattern typical of areas of high density stream development below the Iroquois shoreline (I). Note the light toned flashes of bare sand (S) where erosion has removed the top soil rendering the land useless for agriculture.

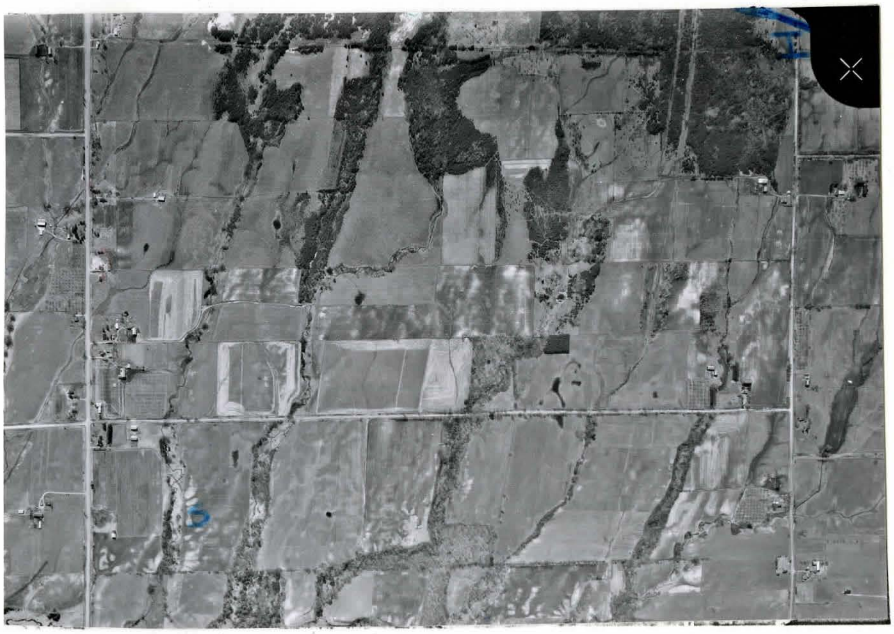


Fig. 5-51 A soil profile of the Percy loam, common to the non eroded areas of terrain type XVI.

Veg. - Pasture

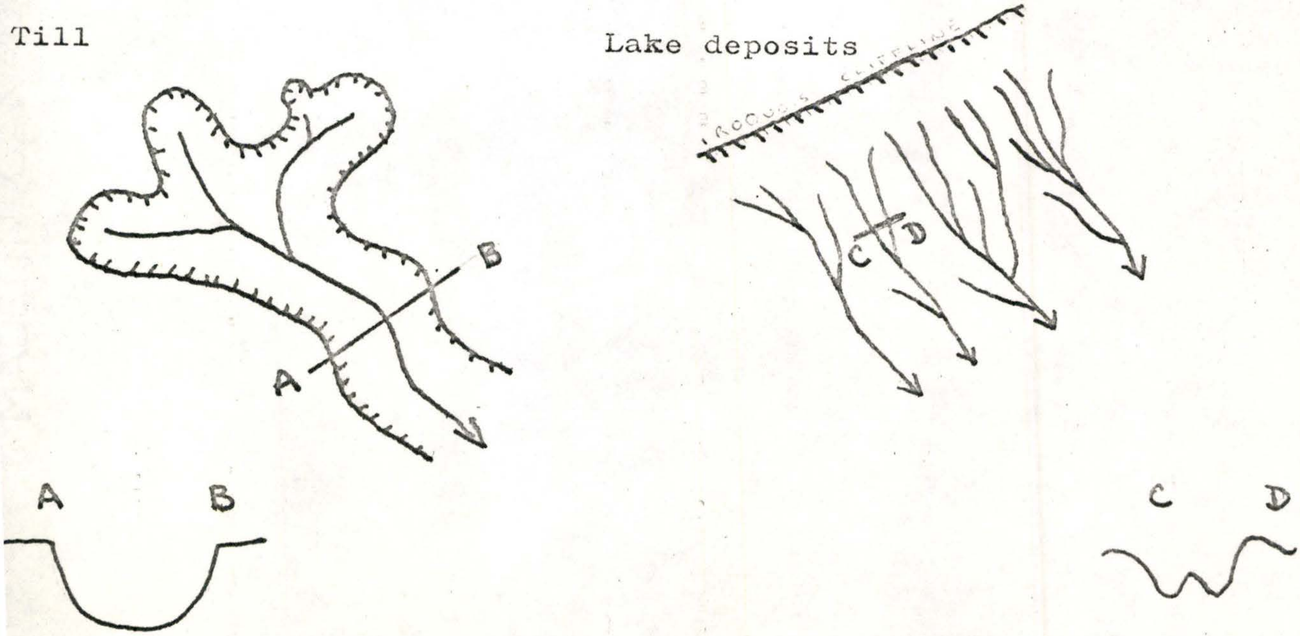
A_1 - 4-6" grey-brown loam or fine sandy loam; crumb structure; generally stone free.

A_2 - 6-8" greyish fine snady loam; weak platy structure.

B - 1-4 " brownish loam; weak nut structure.

C - Greyish calcareous fine sands, silts and clays; may be underlain at varying depths by till.

Fig. 5-52 Plan pattern and valley cross section of gullies developed on two different kinds of deposits.



primarily on the recognition of areas of high density stream incision on the emerged coastal plain, but is facilitated by the fact that the pla n pattern and the valley cross section of these gullies are quite different (Fig. 5-52), from those on the heavier lacustrine sands, silts and clays or the emerged till.

Irregular Hummocky Topography

XVII Granular, Hummocky, Areally extensive Kame-like deposits

This terrain unit exhibits a two fold character. Superficially it resembles an irregular, severely dissected surface covered with a mass of kame-like hillocks of varying sizes. But some of the numerous quarries and borrow pits within the area revealled bedded deposits of pure sand, Photos. 5-53,54, and horizontally stratified deposits of uncemented sands and gravels, suggesting the presence of a buried outwash deposit, probably part of the Oak Ridges interlobate moraine. Furthermore, great variations in texture between adjacent strata inthe deposit (Photo. 5-55) show that large fluctuations occurred in the water velocity during the deposition.

Relief range is very irregualr and characteristic slope angles vary from 22-27%, although slopes are considerably steeper in some areas. The steep gradient, friable sandy soil

Photo. 5-53
Stratified and cross bedded sands in a pit near the crest of Oak Ridges..

Photo. 5-54
Same location as above. Note friable nature & uniformity of deposit and coarse vegetation.

Photo. 5-55
Stratified, uncemented sands & gravels in the Oak Ridges interlobate moraine. Large variation in texture between adj. strata indicates large fluctuations in water velocity during deposition. Pebbles rounded & sub-angular.

coupled with deforestation and over grazing in the late 19th. Century gave rise to severe gullying, creep, total removal of turf, wind erosion and the formation of blow-outs, thus rendering the land useless for agriculture, besides increasing run-off and the danger of flooding in the lower reaches of the rivers draining the southern part of this area, notably the Ganaraska. Subsequent abandonment of the useless land by the settlers and its increasing deterioration by erosion prompted the Dept. of Lands & Forests to buy it and initiate a system of erosion control. This is now well in hand and involves re-forestation (photos. 5-56,57), in badly eroded areas and the introduction of long rotation grasses in areas where farming is still being attempted, though little commercial agriculture is still carried on on this terrain type.

Study of a particular valley system with reference to air and ground photos will best illustrate the ground characteristics of the granular, hummocky kame-like deposit that covers much of the higher parts of the Oak Ridges.

Photos. 5-58 represents an aerial view of the valley system described below. Vegetation comprises scattered shrubs and thin wiry grass which in places fights for existence in ever increasing areas of pure sand (Photo. 5-59) enlarged by creep and wind erosion and evident as areas of very light tone

<u>Photos. 5-56,57</u> Parts of the granular, kame-like deposit on the crest of the Oak Ridges that have been reforested by the Dept. of Lands & Forests in an attempt to prevent erosion.

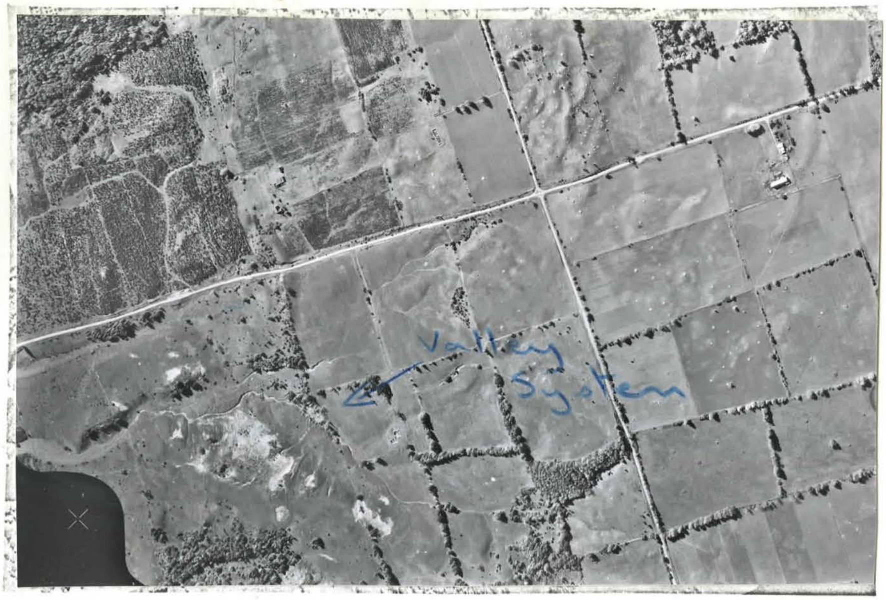


Photo.5-58 Air photo pattern characteristic of valley form within terrain type XVII.

Photo. 5-59 Showing the coarse vegetation and its extensive removal by creep and wind erosion to expose a sandy subsurface - typical of the terrain unit distinguished by a granular, hummocky areally extensive kame-like surface.

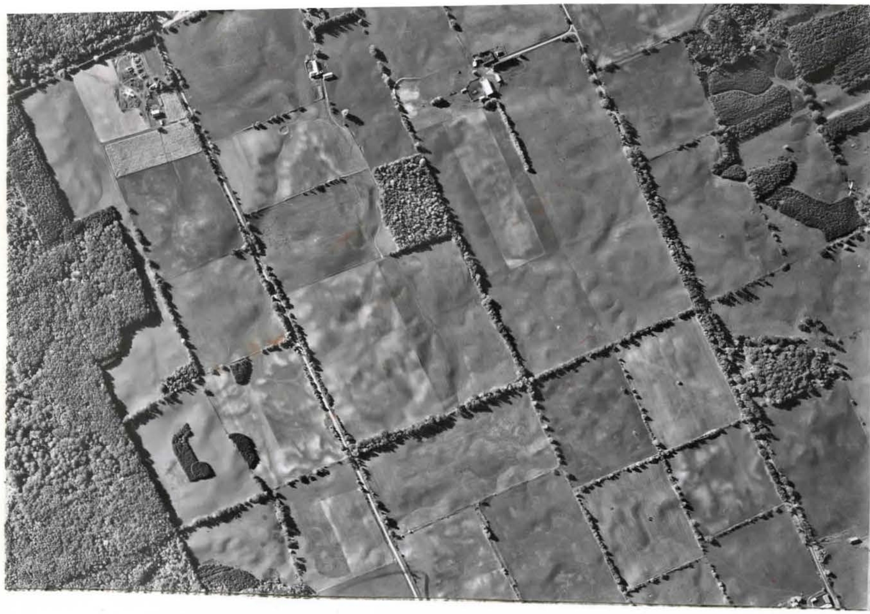
on the aerial photograph. On steeper slopes rills and unvegetated gullies occur sporadically (Photos. 5-60 to 62), and can develop to such an extent as to devegetate an entire hillside The flood plain in this particular valley shows a greater degree of maturity than is usually found in this terrain unit (Photo. 5-62) but it shares a universal characteristic of being completely dry. The exposed stream bed load consists of stone-free, fine sand.

Photos. 5-63 to 65 show aerial and terrestrial views of similar topographic features found elsewhere, and the latter also illustrate the result of over grazing and failure to attempt to arrest erosion.

At first it is difficult to distinguish from the air photos between this terrain type and that classified as' thin mantle of till overlying sandy kame moraine'. However as is exemplified by the accompanying ground photographs, the former tends to be considerably more eroded and better drained. The sandy valley floors also do not show the darker soil mottlings common where there is a layer of calcareous till overlying the sandy kame deposits.

The most frequently occurring soil type is the Pontypool sand (Photo. 5-66). A light grey-brown, podsolised sandy loam.

Photos. 5-60,61,62 Illustrations of the ground characteristics of a valley system typical of the hummocky, kame like terrain unit XVII. Note the various stages of erosion by creep, sheeting & gullying; the occasional surface boulder and the dry sandy stream bed.



Photos. 5-63,64,65. Aerial and terrestrial views of terrain unit XVII. Note the erosion caused by over grazing.

Veg. - Long coarse grass.

A_1 - 6" 10 YR 7/1 (Munsell notation) friable grey-brown sandy loam, coarse single grain structure, loose root mat, stone free.

A_2 - 4" 10 YR 8/3 to 10 YR 6/3. More humic, brown sandy loam, stonefre

B_1 - 1-2" up to ½" diameter gravel, compacted in a grey matrix.

B_2 - 9" 10 YR 7/2 grey sandy loam, lowest extent of root mat.

B_3 - 8" 10 YR 6/3 reddy, coarse sand, stone free.

C - 10 YR 8/3 dark red sand, unstratified.

Photo. 5-66 A soil profile characteristic of terrain unit XVII - Pontypool sandy loam.

Photo. 5-67 A panoramic view of part of terrain unit XVII.

XVIII Thin Mantles of Till overlying Sandy Kame Moraine

This terrain type is transitional between the friable, granular, hummocky, kame deposits found along the crest of the Oak Ridges moraine and the deep, gently undulating deposits of the calcareous till found to the north and south of the moraine. It comprises a thin layer of the latter superimposed upon kame deposits similar to those mentioned above. A layer thick enough to alleviate the very hummocky and irregular nature of the kame moraine, but thin enough for the erosion within first order valleys to expose it. As a result of this erosion small alluvial fans of sand may be found at intervals along valley bottoms. Also where undercutting of the till has occurred by removal of the underlying deposits the result is sometimes apparent as flashes of slumped off till on the upper slopes of the valley side. For the most part however the till is thick enough to prevent large scale erosion.

This terrain type is relatively easy to distinguish from the more level, deeper ground moraine deposits, because besides the difference in relief range,the former exhibit much more mottling and tonal variation. Upper slopes and ridges are fringed with lighter tones indicating the greater content of calcareous material, compared to the darker tones of the lower slopes which represent impeded drainage and increased organic matter in the soil. In fact the appearance of these deposits on the aerial photographs (Photo. 5-68) corresponds much more with Mollard's (1968) and Gravenor's (1960) air photo interpretation key as regards what a till plain should look like than does the photographic pattern exhibited by the unit in this study, which most closely approximates to that description.

It is rather more difficult to draw the line between this terrain type and the friable, granular, hummocky kame deposits that have not been buried or reworked, because the transition is often so gradual. In fact it is easiest first to define areas which definately have kame-like characteristics, then those which show the above traits and finally draw a line halfway between these two limits. The delineation is sometimes aided by observing differences in valley development on the two types of deposits, for the capping of till has the effect of reducing the number of irregular gully systems and coalesing drainage into a series of single channels.

Soils are relatively stone free, sandy and well drained reflecting the influence of a mixture of kame deposits in their parent material. Valley bottoms tend to be swampy, perhaps due to the presence of clay sediments washed out from the till.

Land use tends to be restricted to permanent rough

Photo. 5-68 An air photo pattern characteristic of terrain type XVIII - hummocky kame moraine overlain by a thin mantle of till.

pasture due to inaccessibility and rolling topography.

XIX Esker

There is evidence of only one esker system in Durham County and in view of its unique morphology and genesis, will be considered as a terrain type in its own right. It extends southwards, in a direction approximately parallel to the long axes of the adjacent drumlins, from Victoria County in the north, along the low ground on the eastern side of Fleetwood Creek valley. For most of its length it consists of a slightly sinuous ridge, 425-475 feet wide, generally around 50 feet high but occasionally reaching 80 feet high in a sharp crest (Photo 5-69). The angle of the slope ranges from 15-20%, rather less than the angle of rest of the deposit, but sufficient to induce creep, intermittent gullying and restrict land use to forest and rough grazing. The uncemented fluvio-glacial sands and fine gravels of which the esker is built, appeared poorly bedded in the exposures that were examined, Photos. 5-70,71. Pebble content comprised both limestone and pre-Cambrian specimens less than 3" in diameter although boulders up to 2' in diameter were noted in the borrow pits. No sand lenses were noted but lighter tones and thin turf covering imaged on the air photos indicate the adjacent deposits to be of a granular nature. This is sustantiated by the existence of considerably

Photo. 5-69 An esker ridge, terrain type XIX.

Photo. 5-70 Borrow pit in an esker deposit.

Photo. 5-71 Showing the uncemented, unbedded fluvio-glacial sands and gravels found within the esker. Note rounded and sub-angular pebbles.

better drainage conditions in the immediate vicinity of the esker system compared to the adjacent flood plain of Fleetwood Creek.

The well preserved form of the main esker ridge and the lack of kettle holes makes it unlikely that ice was originally incorporated in the deposits. However the proximity of the small kames, the relatively level course followed by the esker, the recticulate pattern of smaller esker ridges occurring along side the main ridge at one point and the possible existence of crevasse fill ridges 4 miles away suggest that the esker was formed in tunnels near the base of almost dead ice.

At its southern terminus in the Manvers township, Conc X Lot 22, the main esker ridge widens into a jumble of knobs, hollows and short, straight, discontinuous ridges, approximately 15' high (Photo 5-72). It is probable that this marks the location where the water in the esker tunnel discharged into a re-entrant in the ice front.

The soil type to which these fluvio-glacial deposits give rise is similar to that on the granular, hummocky, kame-like terrain found on parts of the Oak Ridges, but it tends to have suffered rather less erosion. It has been classified by Webber and Morwick as the Pontypool gravelly sand, i.e. a light grey - brown coarse sand with large quantities of

Photo. 5-72 Examples of the short straight discontinuous 15 foot high rides that are found at the southern terminus of the esker system.

Photo. 5-73 The irregular surface of a kame deposit terrain type XX.

gravel and cobbles underlain by coarse gravelly sand and some boulders.

Air photo identification of this terrain type - the esker - is based on the recognition of geomorphic form.

XX Kame

This terrain type should not be confused with the areally extensive, granular, hummocky, kame-like deposits considered elsewhere, for it comprises a single, fairly small deposit of ice contact material, which extends southwards from the main body of the deposit in Victoria County, to the north. This part of the kame system is aligned in a direction approximately parallel to the esker previously described and is not too distant from it. Its irregular hummocky surface (Photo. 5-73) attains a height of around 100' above the surrounding till plain and severe gullying, creep and extensive removal of sod by erosion occurs on the steeper slopes. The frequent occurrence of borrow pits permits a very good assessment of the composition of the deposit which grades directly into the surrounding till and is quite different from the kame-like deposits of the Oak Ridges. This deposit is made up of sands,gravels and rounded pebbles which are locally bedded (Photo. 5-74) and in several cases these beds were noted

Photo. 5-74 Stratified sands & gravels in a kame deposit. Beds dip south towards the position of the former ice front.

as dipping towards the south i.e. the former ice front. A typical characteristic of the bedding of these kame deposits was the close proximity of dissimilar fabrics and the slumping and faulting of strata of sandy material towards the edge or ice contact wall of the kame, Photo. 5-75. The pebble fraction of the deposit was mostly of limestone origin, between 1½-6½" diameter, completely unbedded in some sections and revealed no sign of slumping, Photo. 5-76, but in most pits investigated it showed weak cementation which crumbled when hit hard with a hammer but was strong enough to become eroded into pinnacles after the surface sod was removed.

Soil tended to be sandy and stony, lacking horizon development and excessively drained, giving rise to coarse wiry vegetation, unused except for rough grazing and woodland.

As in the case of the esker, identification of this terrain type from the aerial photographs depended primarily on the recognition of geomorphic form.

XXI <u>Pitted Outwash Deposits</u>

This terrain type occurs in only one location in Durham County and that is to the south and the east of an almost level plain of fluvio-glacial deposits, to the east of the Ganaraska delta. Like the latter , the area of pitted outwash was laid down by meltwaters from the Lake Simcoe ice lobe

Photo. 5-75 Slumping and faulting of sandy strata adjacent to the ice contact wall of the kame. Note large variations in deposit texture and cementation of pebbles.

Photo. 5-76 Unbedded weakly cemented kame deposits.

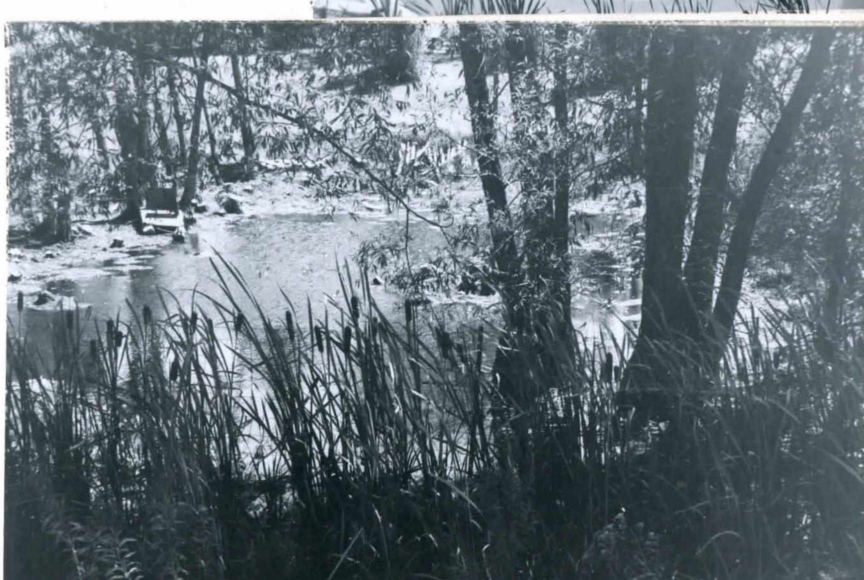
during its northward retreat across the Oak Ridges. The pitted outwash deposits were laid down along with much stagnant ice which subsequently melted producing an irregular topography of knobs, kettle holes and sloughs. Many of the latter are now water and marsh filled, Photo. 5-77 to 79 , and as a result drainage within this area is very poor. Farming is restricted to rough grazing and for the majority of the area even this has not been attempted. The land has remained as scrub and unkempt woodlots. When the terrain type is located on an aerial photograph a very striking characteristic tonal pattern becomes apparent, Photo. 5-80.

XXII Ablation Till Overlain by Lacustrine deposits

This terrain type occurs in north eastern Cavan township within an area which appears, on the basis of air photo evidence, the author's field work and Gravenor's map, to have been inundated by the Schomberg pondings. However, instead of exhibiting the very gently undulating or level surface common to lacustrine deposits this terrain type is composed of an irregular jumble of rimmed kettles,knobs, depressions and linear ridges. A phenomenon which suggests the existence of a composite deposit,e.g. ablation till overlain by a thin veneer of lacustrine deposits. Aveneer which partially masks but does not entirely erase the form of the underlying till.

Photo. 5-77,78,79

Illustrate the landscape typical of terrain unit XXI.



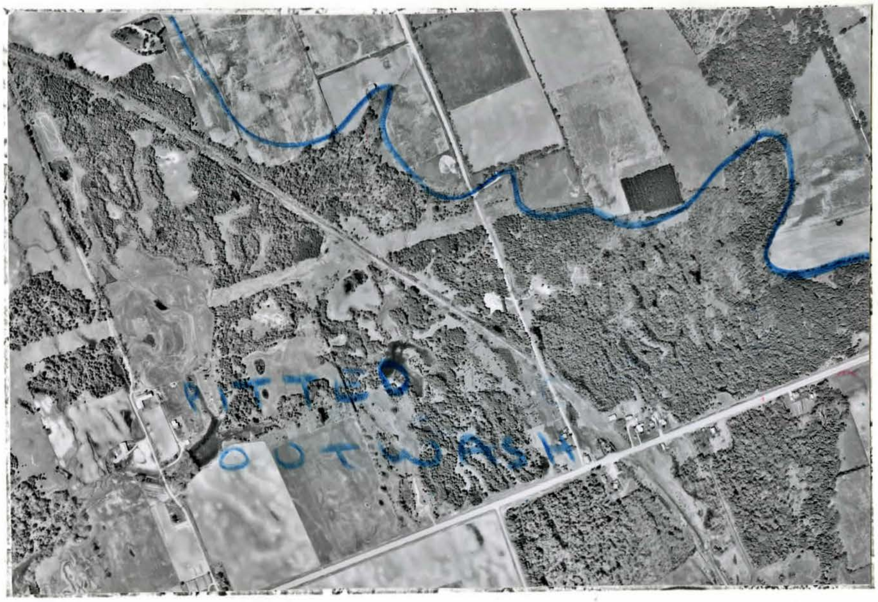


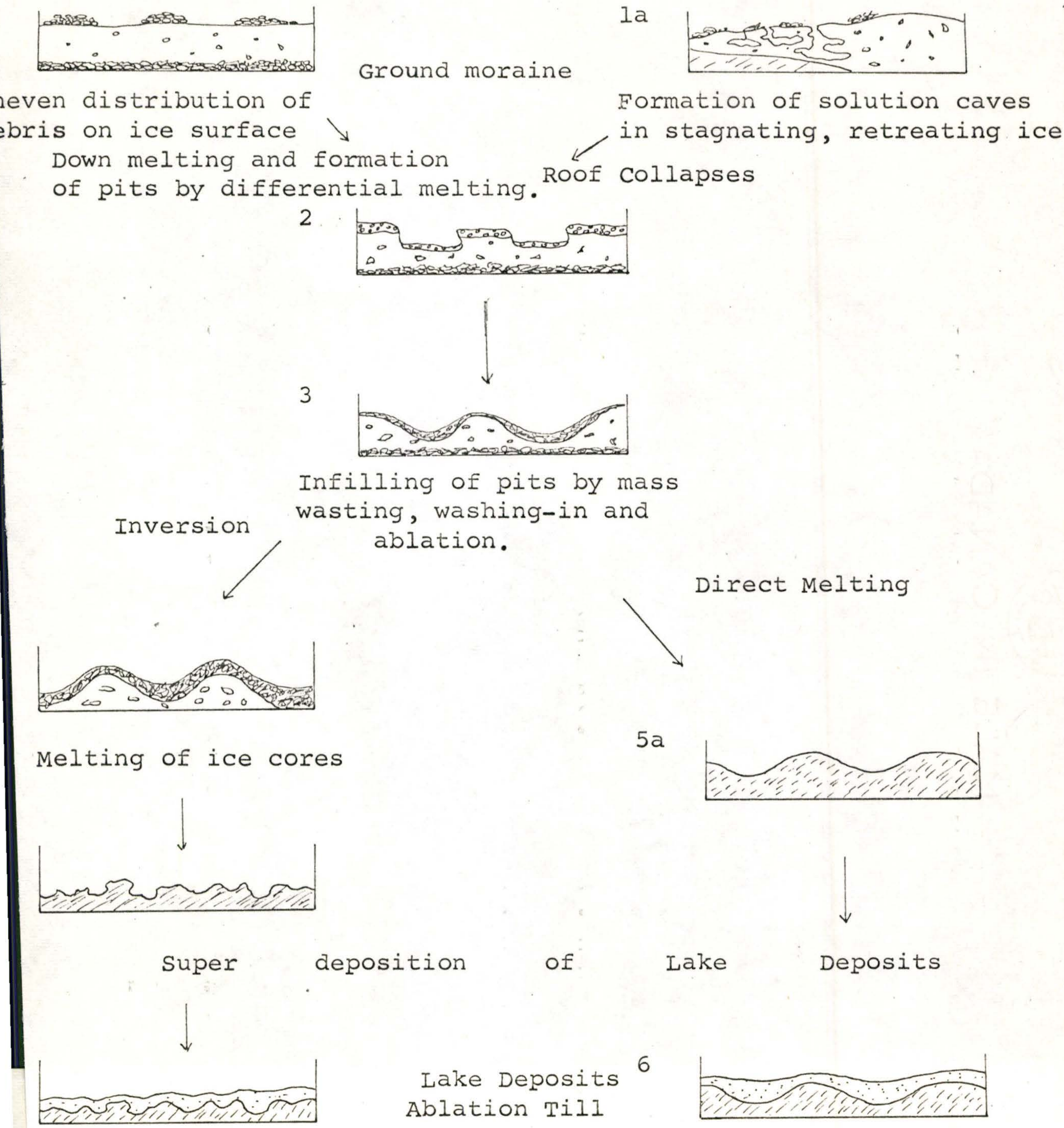
Photo. 5-80 Air photo pattern of pitted outwash deposits.

Four other factors lend support to this hypothesis. The topography is much more subdued than that of unmantled ablation till. Although the drainage in many areas is imperfect, there are very few areas of standing water, such as occurs within kettle holes. This may be due to the more subdued relief but might also be the result of a thin layer of more pervious material overlying the till. Then the tonal variations noted on the air photos as occurring within these areas tend to be less distinct than those observed for areas of disintegration moraine. Finally although the soils are not stony, road side cuttings revealed that in some areas stony calcareous deposits do occur beneath them.

The probable evolution of such a composite deposit is illustrated in Fig. 5-81. It involves the down wasting and stagnation of the northern ice lobe in this area, the subsequent development of knob and kettle topography and the covering of the whole by a thin veneer of lake deposits.

The surface form of this terrain type comprises a system of broad undulations having slopes of 2½-7%. Then superimposed on these are many depressions and ridges. These rarely have a relief of more than 18" to 3' and would probably be difficult to recognise were it not for the deterioration of drainage conditions in the depressions and the resulting

Fig 5-81 Terrain type XXII. Development of Ablation Till Overlain by Lake Deposits, (Adapted from Gravenor, Green & Godfrey, 1960, 11)



changes in vegetation growth, which emphsises both on the air photos and on the ground the influence of the underlying till on the surface topography. For example, on arable land the rimmed kettles appear against the darker toned crops as light toned rings, often slightly elongated down slope and containing crops showing stunted growth. In muck deposits the higher outer rim is marked by shrubs surrounded by sedges and grasses, on woodland the damper depressions tend to be less densely forested, Photos. 5-82 to 84.

There is little or no erosion and drainage is fair to poor. Soils consist mainly of a brown sandy loam grading into a grey sand and finally into a grey coarse calcareous sandy loam, all horizons are relatively stone free. The majority of the land is devoted to unkempt forest and rough grazing but where some attempt has been made at arable farming the poorly drained depressions are not sown, Photo. 5-84.

Where lacustrine deposits are thicker, they completely obliterate the pattern of the underlying till, hence this terrain type tends to be closely associated with the lake deposits proper which are classified separately.

XXIII Ablation Ridges

There are only two small areas of this terrain type in Durham County. They are between Bethany and Millbrook in

Photo. 5-82 Air photo of lacustrine deposit over till.

Photo. 5-83 Differential growth of pasture, reflecting variations in soil moisture content produced by the existence of ablation till beneath the lacustrine deposits.

Photo. 5-84. A depression, similar to many that occur where ablation till is overlain by lacustrine deposits (terrain type XXII). Note the dampness of the depression prevents its use for growing corn.

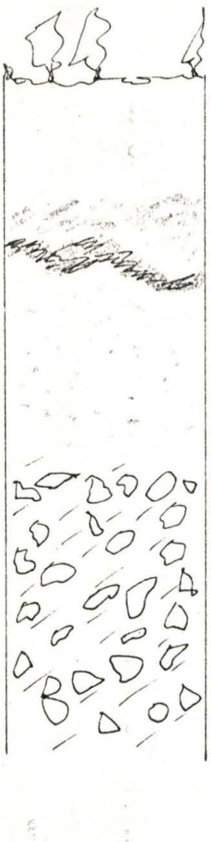
Cavan township. They consist of a series of closely grouped relatively straight ridges, up to ¼ mile in length, from 15-25' high and separated by distances from 50 - 500'. Their composition varies from stony clay till to stratified silts, sands and gravels. The linear inter ridge areas tend to be poorly drained although most of the ridge crests have a light air photo tone, indicative of granular, well drained, probably sandy deposits.

An examination of the soil on one of the ridges revealed a slightly podsolised, sandy loam, (Figure 5-85).

The precise origin of these ridges remains in question partly because of the author's inexperience in recognising such forms both in the field and from air photos, and partly because of the dichotomy of opinion regarding the form of ice block and crevasse fill ridges in the literature, (Deane 1950, Gravenor 1955b, 1957, King 1968). Furthermore the location of ice block ridges as mapped by Gravenor (1955b) does not coincide with ground conditions of the above mentioned ablation ridges. The latter are undoubtedly ice stagnation features and their linearity and uniformity of height suggest the influence of some structural control within the ice, e.g. shear lines or crevasses in the laying down of the deposits.

Due to the hummocky nature of the terrain, the regular

Figure 5-85 Soil profile characteristic of Terrain type XXIII, Ablation Ridges.



Veg. - Forest.

A_1 - 10" 10 YR 7/3 (Munsell notation) sandy loam, stonefree.

A_2 - 3" 10 YR 7/6 sandy loam, stone-free.

B_1 - Undulating hard pan, showing iron mottling.

B_2 - 18" 10 YR 8/2 very fine sand with some iron red patches.

C - Stony deposit, depth uncertain, limestone and granite pebbles less than 8" in diameter.

occurrence of water filled depressions and the podsolised soil with its stony parent material, the land is not used for agriculture. The first two characteristics described in detail above give this terrain type a pattern of tonal variations on the air photos, which is quite unique in Durham County thus making it easier to delineate, Photo. 5-86.

<u>The Iroquois Coastal Zone</u>

A consideration of a raised shoreline or cliffline alone might be considered to have little significance in the context of a discourse on terrain types. However no shoreline can be adequately studied in isolation, without reference to its associated sand, gravel and muck deposits. This in turn introduces the concept of "coastal zone" of wide areal extent.

Within Durham County the Iroquois shoreline was superimposed upon undulating and frequently low lying deposits of unconsolidated till, similar to that which at present borders sections of the northern shoreline of Lake Ontario. It is thus to be expected that the past and present shorelines should show some similarity. The till is easily erodable and condusive to the formation of wide flood plains and marsh filled estuaries. The breakdown of the fabric, which contains more than

Photo. 5-86 Air photo pattern of Ablation ridges,(A)

50% sand and gravel, together with the presence of shallow water offshore and a strong offshore current, initiated in the time of Lake Iroquois, as now, the formation of numerous bay bars, marshy lagoons, offshore hooks, spits and tombola. Hence it was found most convenient for the purposes of this study to sub-divide the " coastal zone" into four terrain types: the cliffline; gravel deposits ; former coastal lagoons; and dune formations, each of which will be described below in terms of location, form, drainage, erosion, soil type and land use. Additional information can be found in the Appendix concerning alternatives to Gravenor's hypothses pertaining to the form and genesis of the former Lake Iroquois shoreline.

XXIV Cliffline

The erodability of the till as a lake shore deposit has been emphsised and this added to the cohesive qualities of its clay content has produced some quite impressive relict cliffs along parts of the Iroquois shoreline, Photo. 5-87, Maps 7-1,2. The basal heights of these cliffs or bluffs ranges from 500' in the west to 558' in the east; and were it not for their genesis which gives them a unique form, they would have been classified as terrain type XIII or XIV.

Some of the features have beach terraces super-imposed upon them, (Photo. 5-88) and in Hope township, Conc. 5 Lot 2,

Photo. 5-87 Part of the raised cliffline which in places marks the former shoreline of Lake Iroquois. It is composed of till.

Photo. 5-88 Wave cut terraces on the raised Iroquois cliffline Slope angle of the terrace is 15° and of the cliff to the right 28.5°. Clarke twp Conc3 lt 20.

Photo. 5-89 Drumlin truncated by the Iroquois shoreline. The beach bar deposits in the foreground which are usually left as scrub, are here producing small grains. Drumlin bluff slope angle is 22°. Hope twp Conc 5 lt 4.

there is a fine example of a truncated drumlin (Photo. 5-89). Where the cliffline or bluff overlooks a former lagoon and has therefore been protected from direct wave action, it has been noticed that there often occurs a series of gullies (Photos. 5-90,91; Maps 7-1,2). They occur as non-branching entities, parallel to the slope and start and terminate quite abruptly, just below and above the convex and concave breaks of slope respectively. The interval between these features tends to be constant for a particular slope and the angle of the gully side is generally 10-12' regardless of slope. In no case that was investigated was the turf on the slope broken, neither did creep occur or water flow.

Drainage on the lakeshore bluffs is excellent but soils are shallow, stony, have little profile development and are in some cases non-existant providing exposures of the underlying grey, calcareous till, Photo. 5-92. Hence land use tends to be restricted to pasture or rough grazing with woodland on the steeper slopes.

XXV Gravel Deposits

Examination of the emerged Iroquois lake plain on aerial photographs and in the field suggests that gravel deposits are not as widespread as has been previously supposed, and that the majority are in the form of bay bars. During the time of Lake

Photos. 5-90,91 Examples of the linear non-branching vegetated gullies (angle of slope 12.5°)which often occurs on the till slopes (angle 10.5°) that border on the former Iroquois coastal lagoons. Clarke twp Conc 3 lt 6.

Iroquois these probably formed parts of the shoreline, enclosing shallow lagoons in much the same way as their successors determine the form of the shoreline of Lake Ontario, (Appendix).

There is a very good example of a tombolo in Hope township (Map 7-2) and several well developed spits - notably in Clarke township Conc. 4 Lot 22 and Conc. 4 Lot 11. Although the original forms of the latter have been obliterated by post-glacial weathering and the only clue to their existence are the tonal changes on the aerial photographs (Photo. 5-93) and changes in soil type.

The internal structure of the gravel deposits varies from site to site as revealed by some of the numerous but mainly abandoned pits in the area. Sometimes the deposits are stratified towards a particular direction, at other sites bedding is horizontal and distinct horizons occur between material of different sizes. Most frequently the bulk of the deposit is composed of a mass of cross and false bedded sands and gravels (Photos. 5-94,95). Waterworn pebbles are included as non-stratified masses in a silty clay matrix (Photo. 5-96). The stones are usually less than four inches in diameter and composed of limestone. Complete rotting of rock within the deposit is rare but when it occurs the subject is usually of pre-Cambrian origin. Frost shattering of pebbles was noted but

Photo. 5-92 Iroquois coastal bluff where the top soil has been removed by erosion revealing the underlying grey, calcareous till. Note the rounded beach cobbles along the base of the slope, the angle of which is 12'.

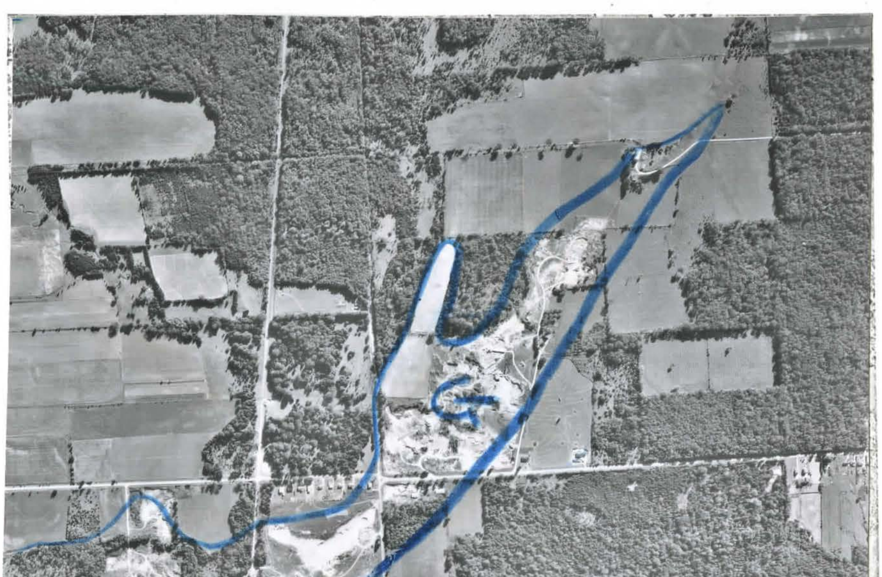


Photo. 5-93 Air photo representation of Iroquois gravel bars (G)

Photo. 5-94 An 8' section through a gravel bar. The pebbles therein are less than 3" in diameter, rounded and show no sign of rotting. Note the cross false bedding.

Photo. 5-95 A section from another gravel pit in a similar geomorphic setting. Hope twp Conc 3 lt26.

this may be an entirely post-glacial phenomenon, (Photo. 5-97).

The soils which develop on these gravel deposits are well drained but exhibit relatively youthful characteristics and a very shallow profile, a typical example of which is that shown in Figure 5-98 and classified by Webber and Morwick (1946) as Brighton gravelly sand. Consequently the land is unsuited to agriculture and vegetation remains as scrubland, (Photo. 5-99).

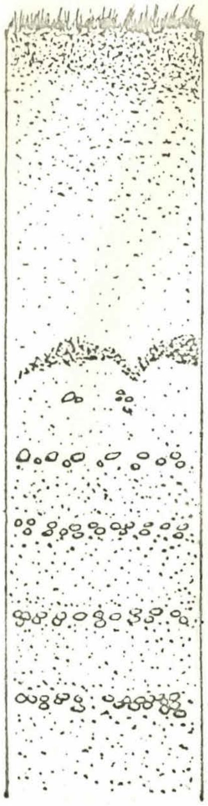
XXVI <u>Former Coastal Lagoons</u>

The maps of the Iroquois coastal zone (Maps 7-1,2) show the wide extent of these lagoons during the time of Lake Iroquois. Subsequent to the post-glacial lowering of the lake surface the enclosing gravel bars were breached by the extended consequent streams and the lagoons drained, however, due to their level to depressional topography and relatively impervious sub-soils many are still very poorly drained and contain marsh (Photo. 5-100) and swampy forest.

The soil composition varies slightly according to drainage conditions but the generalised profile of the Granby sandy loam, shown below (Figure 5-101), is fairly representative of conditions within the terrain type. In a few areas where drainage has been improved arable farming is the major land use.

Photo. 5-96 A section through beach gravels which overlie lake deposits to a depth of approximately 20'; in this case the top 18" of overburden has been removed. Hope twp Conc 2 lt 8.

Photo. 5-97 Shattered rotten and water worn pebbles found in a gravel pit alongside the former Iroquois shore line. Darlington twp Conc 3 lt 22.



Veg. - Coarse wiry grass & scrub.

A_1 - 3-4" sand or sandy loam, low in organic matter, stonefree.

A_2 - 15-20" of coarse yellowish sand, single grain structure.

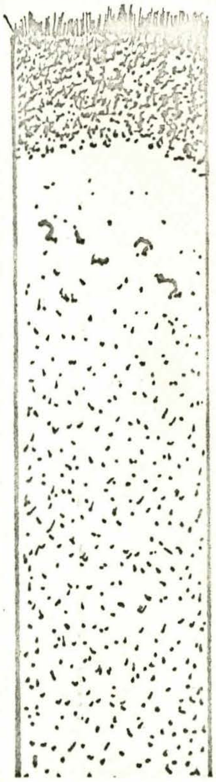
B - 2-4" brownish loam; structure poorly developed; where there is a high sand fraction in the parent material this horizon is more easily distinguished by the colour change than by the textural difference.

C - Grey, calcareous stratified sand and gravel.

Fig. 5-98 A typical profile of the Brighton Gravelly sand which normally overlies the Iroquois gravel deposits

Photo. 5-99 Vegetation representative of that usually found on the Iroquois gravel deposits. Clarke twp Conc 1 lt 8

Photo. 5-100 This view is taken from within an area formerly occupied by one of the coastal lagoons of Lake Iroquois. Note the marsh in the foreground and the confining gravel bar in the background.



Veg. - Water loving trees and shrubs, or, where drainage is improved, arable crops.

A_1 - 6-8" very dark sandy loam; high humus content; soft & porous.

A_2 - 6-10" light grey, coarse sand.

B - 8-12" greyish brown & yellowish brown sand with rusty mottling.

C - Greyish calcareous sands underlain in some cases by gravel or heavy till; occasional strata of silt & clay.

Fig. 5-101 A generalised profile of the Granby sandy loam, the soil type most frequently found within the former lagoons.

XXVII Dune Formations

There is no mention in the literature of any dune formations associated with the coastal zone of Lake Iroquois. However, a careful examination of the aerial photographs showing the area on the Clarke/Hope township boundary to the north of highway 2, suggests the occurrence of such phenomena. Namely, low arcuate ridges, which exhibit light tones on the photographs, are well drained, having an irregular herringbone plan pattern (Photo. 5-102) and from field investigation appear to be composed of fine sand. The orientation of the ridges leads to the conclusion that the prevailing winds instrumental in their formation was easterly; and the manner in which they are scattered across the terrain regardless of surface configuration and the former delineation between land and water, suggests that they are a post-Lake Iroquois phenomena. Their localised occurrence may be due to the proximity of the lower, extremely sandy portion of the formerly submerged delta of the Ganaraska River.

Some of the dunes are forested, some give rise to blow-outs but most produce no change in land use and are cultivated for arable or pasture crops in the same way as the till deposits on which they rest.

Photo. 5-102 showing the air photo pattern exhibited by accurate ridges which are composed of sand and hence presumably dune formations. Coastal lagoon is marked in red.

CHAPTER VI

CONCLUSIONS

The primary objective of this study was to determine the extent to which air photo interpretation could serve as a basis for terrain unit mapping, using Durham County, Ontario, as an example. In order to accomplish this it was necessary to evolve a methodology incorporating the use of aerial photographs, whereby Durham County could be sub-divided into terrain types, and these areas mapped, classified and described.

The methodology has seven stages and these include: First, a collation of all pre-existing data pertaining to the physical characteristics of the area and the identification of terrain units from aerial photographs. Second, a systematic evaluation of all elements of pattern appearing on the aerial photographs, the recognition of areas having "homogeneous and mutually exclusive" characteristics of pattern and tone and the tentative sub-division of the photographs of the study area on this basis. At this stage it proved impossible to categorise the entire area in this manner because parts of it appeared to have characteristics which qualified it for more than one of the recognised patterns or did not appear to exhibit any recognisable pattern at all.

The third stage of the methodology involved an attempt to explain what each of the air photo patterns and images represented by using stereoscopic analysis and available background data. However, conclusions obtained from aerial photographs alone regarding ground conditions can rarely be claimed to be correct, so the next step involved the use of the aerial photographs to plan field work - the fifth stage in the methodology. In the field, checks were made on pre-existing data on geology and soils, sites were chosen to determine exactly what combinations of ground characteristics produced a particular pattern recognised on the aerial photographs; whether a particular pattern was always associated with a particular set of physical characteristics i.e. a specific terrain type; and the extent to which the photographs could be used to delimit terrain types. Also precise ground conditions associated with the boundaries between each combination of terrain types were investigated with the aim of improving the accuracy of their location. Finally, areas on the aerial photographs which had previously remained unclassified because they possessed no distinctive air photo pattern or characteristics of more than one, were sampled to determine whether there were any dominant or co-dominant ground characteristics which could be used instead to delineate terrain types within them.

The sixth stage in the procedure involved using the aerial photographs to extrapolate field evidence to inaccessible areas and photogrammetry to measure angles which were inaccessible in the field and to check field hypotheses regarding characteristic slope angles. The final stage of the methodology involved the use of Colwell's convergence of evidence principle on all the field, air photo and background data obtained during the course of the study, in order to obtain the final sub-division of Durham County into terrain units.

During the evolution of the methodology outlined above, it became apparent that aerial photographs alone could not have been used to define terrain types within the study area. There are several reasons for this, first, without field work it would have been impossible to attach much validity to the interpretation of the aerial photographs. Second, only by doing field work could a complete and accurate description of the ground conditions existing at a particular site, or within a particular terrain type be obtained. Third, without ground work, the reasons for many of the differences in air photo pattern and tone would not have been apparent and therefore their possible significance could not have been assessed in the final delimitation of the terrain types. Finally, analysis of the aerial photographs often proved quite inadequate for precisely locating boundaries between terrain types just as it was for locating boundaries between some types of deposits.

Despite these shortcomings the aerial photographs did prove invaluable as a basis for the mapping of terrain types within Durham County because certain distinctive air photo patterns noted on the photographs were found by field checking to be characteristic of particular terrain types, thus aiding in the delineation thereof. Also the photographs provided clues as to ground conditions, for example, drainage conditions, and after these had been related to reality in one location they could be used to extrapolate field data to other areas. Finally they saved much time in the location of field sample sites and the planning of field traverses.

It is impossible to generalise further about the extent to which aerial photographs have been used in this study, so specific details will be given for each of the terrain types in turn. Marshland was distinguished primarily from the aerial photographs due to its inaccessibility although field work was often necessary as a supplement to air photo evidence in distinguishing between muck and forested areas of alluvial deposits. Recognition from the aerial photographs of geomorphic location and form was sufficient to locate alluvial terraces, linear deposits of alluvial origin, drumlinoid topography and kame and esker deposits, and characteristic air photo patterns provided clues as to the location of areas of fluvio-glacial sands and gravels and the granular, hummocky, areally extensive, kame-like deposits. However, for both, field investigation was often necessary to locate the precise junction between these deposits and those of adjacent areas having similar surface configuration. The level nature of the deposits of wind blown sand over 1,000 feet was very easy to distinguish on the aerial photographs from the adjacent areas of hummocky, kame-like topography on the Oak Ridges but field work was occasionally required to differentiate it from the high level plateaux composed of till overlain by sand, because depth of sand, drainage condition and characteristic slope angle are the only differences. The distinction between silty-clay and stony, stratified sand and clay deposits on the Iroquois Lake plain was apparent on the aerial photographs as changes in land use, drainage conditions and the occurrence of stone piles but field checking was again needed to validate the location of the deposit boundaries.

The extensive till plains above the level of former lacustrine deposition were for the most part easy to distinguish from the aerial photographs due to their uniform tones, gently undulating topography, the sporadic occurrence of poorly drained hollows and characteristic boundary slopes produced where the till overlies more friable sands, silts or gravels. However, careful field work was necessary to loacte the boundary between it and terrain type XVIII - thin mantle of till overlying kame deposits. The undulating deposits of till and lacustrine sediments south of the Iroquois shoreline were distinguished by their location and characteristic slope angles.

Steep slopes in till were delineated mainly from the aerial photographs but field work was occasionally necessary to verify the type of deposit. In contrast to this the slopes which develop at the junction of till with sands, silts or gravels could always be identified with certainty from the aerial photographs, due to their distinctive erosional patterns. Areas of severe erosion on the Oak Ridges and of high density stream development south of the Lake Iroquois shoreline were also both easily delimited from the aerial photographs as a result of their distinctive surface form.

The thin mantles of till overlying sandy kame moraine, was probably one of the most difficult terrain types to define because it occurred in close proximity to both areas of till and the hummocky kame-like deposits. Hence field work again had to be used to validate terrain type boundaries originally delineated on the aerial photographs. Pitted outwash deposits, ablation ridges and ablation till overlain by lacustrine deposits all appeared on the aerial photographs as specific photo patterns which were easy to identify but possessed certain similarities. So, where background knowledge and knowledge of geomorphic location was insufficient to determine what one of the three patterns represented, field work was called for. Finally the initial recognition of all features of the Iroquois shoreline, the cliffline, dunes, gravel deposits and former coastal lagoons deoended almost solely on the use of the aerial photographs, without which the development of an alternative hypothesis as to the form of the Lake Iroquois shoreline (Appendix A) would have been impossible.

The validity of the terrain unit classification is inextricably bound up with, or bounded by, the limitations thereof and these are essentially three-fold: First, those inherent in the nature of the study e.g. the inability to precisely locate terrain type boundaries in all cases. Second, those imposed by the data, e.g. the scale of the photographs. Third, those adopted by the author, e.g. the scale of the mapping and the lack of objectivity.

The first of these limitations is related to the fact that none of the terrain types has a mutually exclusive combination of physical characteristics over one hundred percent of its area. This is because natural phenomena alter gradually, not abruptly from place to place and that the particular combination of phenomena occurring at any site is unique. The attempt to overcome these difficulties by careful field investigation has helped to minimise the effect on the validity of the classification for the County as a whole, but only a much more detailed study at a much larger scale could absolutely validate it for particular localities.

The scale of the photographs limits the ability to map ground details thereon in the same way as the final map scale limits the ability to map all details noted on the photographs. For example, a valley side which is steep enough to induce changes in land use, the predominant type of erosion and soil type, which is easily visible on the photographs, may be too restricted in extent to appear in the final map. This is unfortunate in the local context, but,in terms of the size of the area under consideration is found to be justified.

The low degree of objectivity involved in the subjective decisions inherent in the delineation of units, the choice of boundaries, the final generalisation of the map and the description of the terrain types themselves, was justified within the context of the objectives set forth and the time and facilities available. Also in the light of the belief that an increase in objectivity would not have appreciably altered the number of terrain types, their areal distribution within Durham County or, in fact, the validity of the classification, because the aerial photographs themselves subtly reflect all the changes in variable which appear thereon and could therefore be subjected to objective analysis.

The validity of the air photo interpretation key evolved for the description of the terrain units devised for Durham County, is rather easier to explain and is in fact similar to that for all such keys, namely that it is only valid within the fairly limited physiographic regions within which it was devised; i.e. apart from the situations where it applies to discrete morphological phenomena. For, as Allum (1962) indicates, " one cannot assume that a given combination of climate, deposit and stage of morphological development will produce only one pattern or that if it did, that one's data would be sufficiently precise to locate it." Despite this assurance, the accuracy with which the key may be used to extrapolate to areas having a similar geomorphic history is limited, by the user's own background, as well as that of the key maker, or as Vink (1963) would call it, by his "reference level of interpretation".

The direct applicability of this study to the analysis or solution of problems concerning the physical environment within Durham County, is probably small, because this was not a primary objective. However, it could usefully serve as a basis for, for example, planning agricultural land use; locating borrow pits; planning and evaluating erosion control and reforestation; planning highway development; or even the study of a smaller part of the area in more detail. In the course of such utilisation, the lack of objectivity of the original study would probably prove a severe limitation and for the respective topics additional work would be necessary, such as, detailed soil analysis; study of deposit depth and analysis; mapping of land use at a large scale; accurate surveying and perhaps calculation of differences in drainage density and relief texture to provide a basis for terrain unit subdivision.

Had colour rather than panchromatic photography been used in this study, it is probable that many of the problems of boundary definition would have resolved themselves into shade variations because the human eye is able to distinguish far more shades of colour (20,000) than tones of black and white (200). As a result of this and the fact that good colour reproduction bears a greater resemblance to reality than black and white, there is great potential for the improvement of image and pattern identification in the use of colour photographs and hence corresponding advantages in its application to any study utilising air photo analysis.

Looking to the future, there appears to be great potential in the use of terrain type classifications, as a method of providing rapid , accurate, multi-purpose resource inventories of less densely populated areas of the world and even of extra-terrestrial areas. However until complete automation of air photo analysis and all the subjective decisions involved in the determination of terrain types from photographs, optimum use of this method of surveying will be limited by the vast amount of photographic data involved. Attempts are at present being made to automate the microdensitometer analysis of photographs, for the identification of simple visual patterns (Murray 1961), and in the U.S.S.R. Romanova (1964) has been able to distinguish between two types of unvegetated aeolian deposits using photographs taken under very restricted conditions. However, this is a long way from complete automation, research into which will certainly assume an important place in photo interpretive studies in the future.

APPENDIX A

ALTERNATIVES TO GRAVENOR'S HYPOTHESES PERTAINING TO THE FORM AND GENESIS OF PARTS OF THE IROQUOIS SHORELINE IN DURHAM COUNTY

Prior to the present study the position of the Lake Iroquois shoreline in Durham County had been mapped in detail only by Gravenor (1957). The study was undertaken for the Canadian Geological Survey in 1957 at a scale of 1:126,000, as part of a Physiographic Survey of Durham County. It indicated that the former shoreline was a fairly simple linear feature, trending in a west-north-west to east-south-east direction approximately parallel to the northern shore of Lake Ontario and frquently marked by a low bluff. To the south of the bluff Gravenor recognised the existence of many offshore islands, extensive submerged gravel deposits and gravel bars. He further states that " most of the bars are several hundred feet from the shore " and " served to break wave action", inducing the deposition " of fine sands and silts which are mostly found between the bars and the shore" (Gravenor 1957,p. 33). The only other major depositional formation that he notes as occurring along the Iroquois shoreline is the Ganaraska delta. This he maps as an offshore deposit at a height of 552 feet despite the fact that the height at the base of the cliffline on an "island" to the south of the delta is recorded as being at 532 feet.

A careful examination and correlation of air photo and field evidence of the Iroquois coastal zone was made by the author. This prompted a review of the above observations and hypotheses and suggested what is considered to be a more acceptable alternative (Maps 7-1,7-2). The main differences between the two interpretations lies in the positioning of the shoreline itself, although the height thereof, as calculated by Gravenor, still applies.

Throughout the entire 30 miles of the Iroquois shoreline that exists in Durham County, there is no recognition of a single bay bar in any of the literature. All writers appear to have accepted Gravenor's conclusions that each of the rivers entered Lake Iroquois via short estuaries, across the mouths of most of which occurred a submerged gravel bar. After the emergence of the shoreline, these bars became breached and marsh developed behind them, as indicated in Fig.7-3a below.

As a more plausible alternative to this theory, it is suggested that the bars themselves formed the shoreline (Fig.7-3b). That they enclosed shallow and rather marshy areas of ground limited on the landward side by the low bluffs which form the cliffline.

THE IROQUOIS COASTAL ZONE

DARLINGTON & CLARKE TOWNSHIPS

Map 7-1

THE IROQUOIS COASTAL ZONE

CLARKE & HOPE TOWNSHIPS

Map 7–2

KEY

GRAVEL

MARSH

DELTAIC SANDS & GRAVELS

IROQUOIS SHORELINE - BLUFF SLOPE ANGLE

IROQUOIS SHORELINE INDEFINITE

IROQUOIS CLIFF

IROQ. S - LINE, SEVERE GULLYING

IROQ. S - LINE WITH LINEAR GULLIES

Symbol missing from map

IROQUOIS BLUFF

FORMER COASTAL LAGOON

EDGE OF GANARASKA DELTA

DUNE

INCISED RIVER Vy

ROAD

MAJOR OBSERVATION POINT

TOWN

IV CONCESSION NUMBERS

POSITION OF PHOTOGRAPH

SCALE 1:33,333

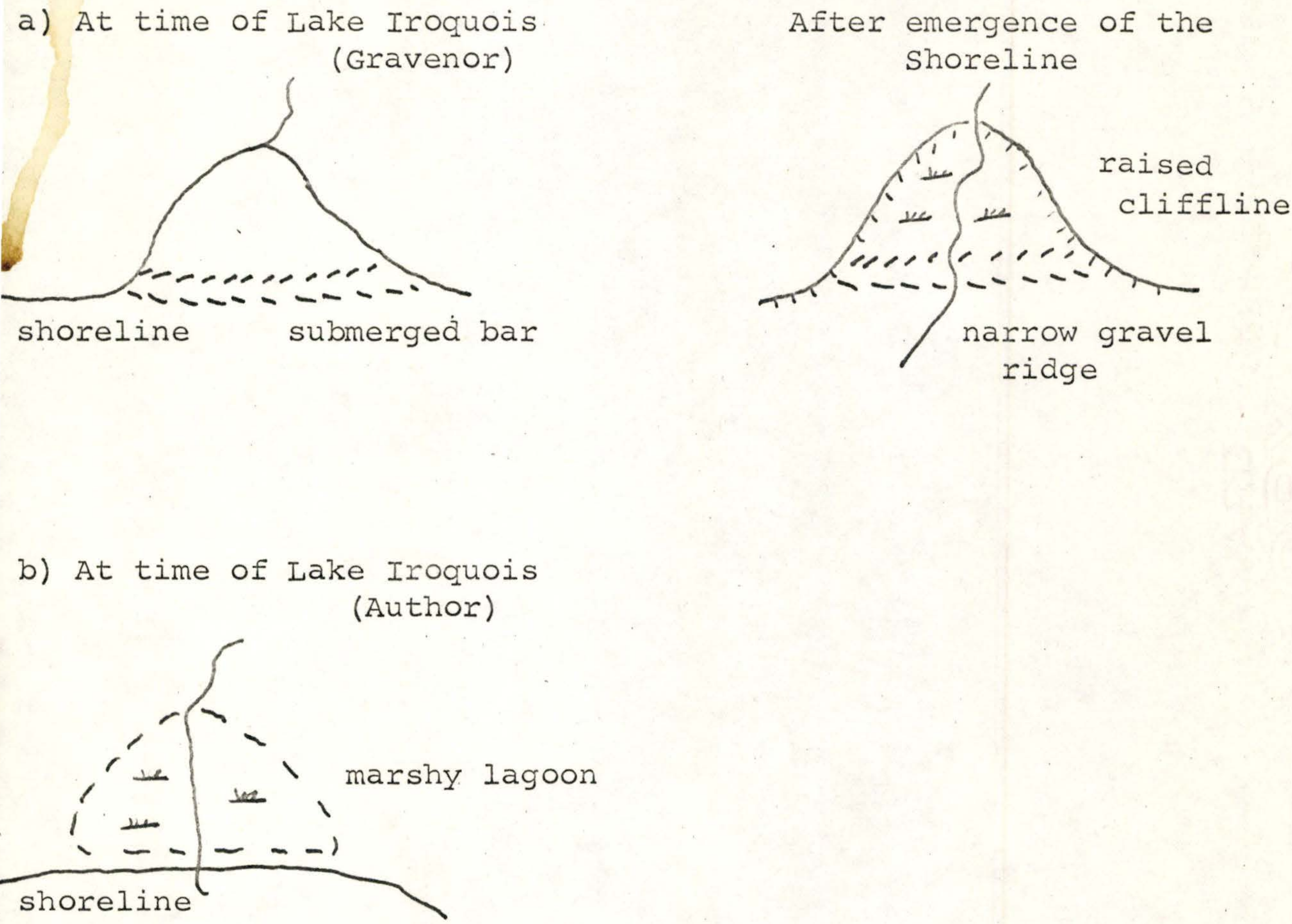


Fig. 7-3 To illustrate the difference between Gravenor's and the author's hypothesis regarding the position of the Iroquois gravel bars at the time of submergence.

Field evidence invariably proves that the height of the bar exceeds the height of the base of the adjacent cliffline. Furthermore, as a result of this interpretation the Iroquois shoreline bears a much closer, if not identical, genetic relationship to the present northern shoreline of Lake Ontario, where nearly every major stream enters the Lake by way of the marshy lagoon, cut off from the lake itself, by a gravel bar in varying degrees of completion. At Oshawa, Farewell Creek enters a marshy lagoon before escaping into the lake via a narrow breach in a gravel bar (Photo. 7-4) and at Wesleyville and west of Bowmanville the bay bars are complete and the enclosed lagoons rapidly silting up.

It is improbable that in nearly identical geomorphic situations bay bars should exist along the shore of Lake Ontario, but only as submerged features along the shore of Lake Iroquois.

In some cases there is evidence of other smaller gravel ridges within the outer bar (Photo. 7-5), for example in Clark township Conc 1 Lot22. This supports Gravenor's hypothesis that the bars were built up from materials tossed up from the lake side causing the bars to migrate towards the shore, but it is not a plausible explanation for the formation of the more extensive gravel deposits which he suggests are offshore features.

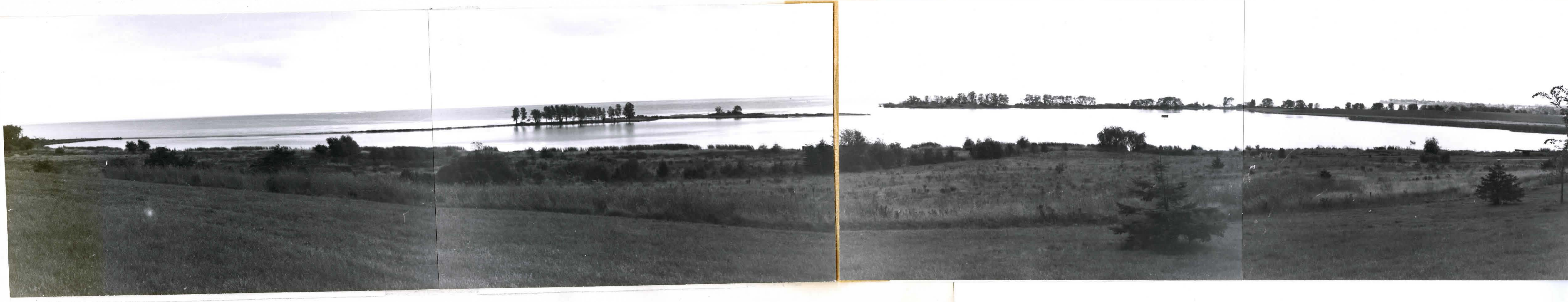


Photo. 7-4 A lagoon enclosed by spits at Farewell Creek, Oshawa, a formation similar to those that probably existed along the shore of glacial Lake Iroquois.

Photo. 7-5 Gravel deposits and a gravel ridge which occur between the Lake Iroquois cliffline and the larger gravel bar which marks the former shoreline. Clarke twp Conc 1 Lt 14.

On his map of the Iroquois shoreline, in the centre of Darlington township, there is shown an offshore island linked by a submerged gravel ridge to undisputed sections of the mainland Iroquois cliff. The exact position of the shoreline between these points appears in doubt, but a considerable area of marsh is acknowledged to the south. Field reconnaissance supports the theory, suggested by the aerial photographs, that the gravel bar exceeds the height of the island cliff and hence that the bar itself marks the true shoreline, which at the time of Lake Iroquois probably enclosed a somewhat marshy lagoon. This hypothesis not only eliminates the uncertainty in delimiting the shoreline behind the gravel bar but gives the feature a more plausible height when it is referred to adjacent portions of the cliffline.

This is precisely the same argument which can be proposed for a similar area of coastal deposits noted by Gravenor in Hope township, Conc 5, Lot1-9. The revised interpretation incorporates three drumlinoid forms, formerly claimed to be islands, as an integral part of a fine tombola approximately 2½ miles long. The gravel ridges of which this feature are made are regular in cross section, varying between 10-15 feet in height and 30-40 yards in width (Photos. 7-6,7-7), and comprise the southern boundary of an area which appears (on the basis of air photo pattern) to have been marshland at some time in the past.

Photo. 7-6, showing a view from the former lake plain towards a gravel tombola, which existed during the time of Lake Iroquois. Angle of slope of the gravel bar is 11.5°. Hope twp Conc 5 Lt 4.

Photo. 7-7, the hill to the right is of drumlinoid form and is linked by the tombola to the left, to the main Iroquois cliffline. Angle of slope of the gravel bar is 27°. Hope twp Conc 5 Lt 5.

Acceptance of the alternative hypothesis proposed above necessitates a modification of the interpretation of the Ganaraska delta and the adjacent island complex. This was done largely on the basis of extrapolating probable shoreline heights from adjacent areas to the east and west where identification was positive and by using air photo evidence. Careful weighing of all the evidence has led to the positioning of the shoreline to the south of the majority of the deltaic deposits of the Ganaraska River, at an altitude of 535 feet, a height much more in keeping with that of the shoreline to the south. Furthermore, drainage patterns, air photo patterns and ground conditions indicate that the delta extends further to the southwest and is 50% larger than the 5 square miles suggested by Gravenor. From a physiographic point of view the delta is an integral part of the coastal zone, but for the purposes of terrain unit identification it is more closely related to areas of different genesis and has been dealt with more fully as terrain type IV above.

The immense, supposedly submerged, gravel bars surrounding Gravenor's "islands" to the southwest of the delta, presumably owe their size, which is disproportionate when compared to that of their diminutive counterparts along the shore, to the abundance of material of morainic origin brought down the Ganaraska and subsequently swept westwards by the offshore current. A detailed study of this area has led the author to the final "altenative hypothesis" presented here, namely that these bars cut off the island-dotted area from the main body of Lake Iroquois, enclosing one vast, swampy lagoon and hence considerably simplifying the coastal outline. The probable outlet of this lagoon followed the present drainage line, to the west but may have been narrower prior to the incision following emergence. Its position along with that of all the other geomorphic features described above, is shown on Maps 7-1,7-2.

FOOTNOTE

The accompanying maps of the Iroquois Lake plain were prepared as follows. Details of the roads and settlements were taken from the National Survey Maps, corrected where necessary and accurately plotted. Details pertaining to the physiography and drainage observed on the aerial photographs were checked in the field before being superimposed on the base map, the transfer being made by eye only. (Rectification was considered unnecessary for these particular prints.) Supplementary data on slope angle, type and extent of erosion, offshore deposits were added from field observations. Slope angles were taken with an abney level and frequently represent the average of a number of readings taken within a local area.

APPENDIX B

The author wishes to bring to the attention of the reader the fact that there appears to be slight discrepancies between the Average Slope Maps, the Physiography Maps and the Terrain Unit Maps for each township within Durham County. This is intentional and does not invalidate any of the maps. The maps depicting Average Slope are, as the name implies generalised; for example, they do not show valley flood plains as areas of near level land unless these are over ¼ mile in width and they completely miss out smaller, more restricted categories of terrain slope noted on the terrain type maps. Similarly the Terrain Unit Maps present a more accurate and detailed picture than the generalised Physiography Maps.

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