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Final Report

A STUDY OF THE LAND TYPE

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PREFACE

There has been interest in land inventory and land classification for many years. Early in this century there was need to appraise public land for purposes of establishing national forests and estimating timber growth and grazing capacity. During the depression years of the early thirties land students, geographers, and planners with the help of the new tool of air photography turned attention to methods for rapid recognition of surface differences on the earth and the units into which they seemed to be combined. Soil scientists were particularly interested in methods to simplify the complexity of mapping individual soil types. In the 1940's the scientists of the Northern Australian Land Survey began the huge task of inventorying their north country employing the "Land System" concept. Since the end of World War II investigators have been working on land analogs for military purposes.

Under these operations and in a sense buried by them lay the idea of the natural land division or the land type developed by the Michigan Land Economic Survey in the 1920's. This is embodied in a scattered literature and in the recollections of the few men now living who used it. The present investigator believed that a study of this early Michigan concept should be made to determine its value as a basis to current investigations and to find out if it had genetic connections with systems now being used. To this end he applied for support to the Army Research Office that had under way various studies in terrain recognition. This support was granted and is gratefully acknowledged.

The purposes of this study are threefold: to delineate the early land type work and to bring together its scattered references; to compare the methodology and results of the early Michigan concepts with more recent work in Australia and England; and to subject an example of land typing made before the times of air photography to modern analytical methods to test its validity. For this last purpose an experimental program was conducted on digital terrain analysis which has been reported (1).

As the study developed changes in its expected findings were apparent. As an example, not much genetic connection was found between one and another way of recognizing and using natural land divisions. Each survey seems to have started anew with its individual purposes, environment, and limitations. In many parts of the world there are "land type" studies; few of them are alike.

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(1) Tobler, W. R., and Davis, C. M., A Digital Terrain Library, Technical Report on Contract No. DA-31-124-ARO-456, U.S. Army Research Office (Durham). Office of Research Administration, The University of Michigan, Ann Arbor, Mich., March, 1968.

Professor Waldo R. Tobler of the Department of Geography of The University of Michigan developed the computer methods of analyzing landform surfaces. Members of the staff of the U.S. Army Research Office in Washington and Durham and the Geography Branch of the Topographic Laboratories at Fort Belvoir have given advice and encouragement during the preparation of this study. Australian friends have contributed much to an understanding of the survey work in that country. I am particularly indebted to Mr. C. S. Christian, Member of the Executive of the C.S.I.R.O. and to Mr. G. Alan Stewart, Chief of the Division of Land Research of the same organization, Dr. J. A. Mabbutt, lately of the C.S.I.R.O. now a member of the School of Geography of the University of New South Wales supplied important information and Mr. R. Geoffrey Downes, chairman of the Soil Conservation Authority of Victoria, sent material on the recent mapping of his organization. Mr. R. Webster of the Soil Science Laboratory of The University of Oxford and Mr. A. O. Barrie of M.E.X.E. kindly sent information about the work of the MEXE-Oxford investigators together with a set of their reports. All of this overseas assistance is gratefully acknowledged and sincerely appreciated.

Patricia Lange, Karen Ewing, Fawsi Asadi, Stephen Gale, are among the graduate students in the Department of Geography who have assisted in various phases of the preparation of this report.

TABLE OF CONTENTS

LIST OF FIGURES

LIST OF FIGURES (Continued)

LIST OF FIGURES (Concluded)

INTRODUCTION

The surface of the earth is an infinitely variable complex. At any particular point location it is composed of a number of lithologic, soil, moisture, biotic, and climatic components each of which in itself may be made up of an association of secondary elements. No two point locations are exactly alike when subjected to fine enough analysis; each is unique.

For many reasons men examine the nature of this complex environment. Important among these is its resource potential for agricultural or pastoral land use; its suitability or its limitations for transport purposes; its content of mineral or other natural resources; its significance for military operations. Geographers in particular devote themselves to study of the spatial arrangment of the environment and of its human attributes; some of them think of their subject as the "significance of the differences and likenesses that exist on the earth's surface."

Although the uniqueness of any point location is evident, uniqueness cannot be used as a beginning of earth surface investigation. For whatever purpose may be in hand it is necessary to develop meaningful categories into which the uniqueness of point locations may be placed for classification; categories within which the differences of uniqueness are unimportant and between which important differences exist. Such categories are therefore generalizations of the facts.

If the surface of the earth is to be investigated in a geographical sense these generalized categories must be mapped to show their character and spatial arrangement. There are two contrasting techniques for doing this: thematic or single feature mapping and composite mapping.

Thematic mapping deals with only one factor at a time. It delineates the pattern of categories of such elements as surface formations, soils, vegetation, or any of the other environmental components, paying only incidental attention to the others. The boundaries are determined by defined criteria; whether or not they correspond with other boundaries is not an immediate matter of concern. If a number of thematic maps of different components of the same area are compared and strong boundary correlation is observed the assumption may be made that the characteristics being mapped are genetically connected. This was the case in the mapping done by the Michigan Land Economic Survey in northern Michigan which led to the concept of the land type. It is possible to carry out multiple thematic mapping in which more than one characteristic is mapped simultaneously by a single mapper. Probably the ultimate in simultaneous mapping was done in the Montford study in which one mapper, or one group, recorded a number of environmental elements together with the land use on a single sheet. In such a technique there is always the inclination as well as the practical necessity of disregarding minor boundary discrepencies, or generalizing, and "splitting the difference" to make a single boundary serve multiple purposes. A thematic map at whatever scale or for whatever purpose is an end result in itself.

In contrast to thematic mapping and the investigation of the surface of the earth in terms of the separate components of the environment is the concept of composite units. This considers the earth surface as being made up of a mosaic of units within which the environment is essentially similar. Because of the variability mentioned above these composites are necessarily generalizations in which the permissiable amount of internal difference is a function of the scale and purposes for which the composites are recognized. Where composite units exist, and they have been demonstrated in several parts of the world, an assumption must be made that some one or some few of the components control the distribution of the others.

From the early 1930's to the present there has been much speculative and theoretical writing about composite units. Most of the treatises set forth some fundamental unit, variously named, as a base. These units are associated into larger ones and these in turn into still larger ones in a hierarchial system that can begin with a soil type and end with the lithosphere. Such speculation appears to have been very attractive to writers as it presents almost unlimited opportunities to propose hierarchial systems and to name the components.

The mapping of composite units however is something much more difficult. It is relatively easy to analyze the environment at one spot location but to ascertain the boundary at which there is enough change in one or more of the composing conditions as to make another composite is a task that requires teamwork by scientists and, for complete coverage, almost as much work as the making of separate thematic maps. Until the time when air photographs became available composite land unit mapping was practically impossible.

This report deals with a study of the land type, one of these composite units, developed in the mapping operations of the Michigan Land Economic Survey in the 1920's. This was a survey for land use purposes done by thematic mapping in the days before the availability of air photographs. There was no intention of mapping composite units and probably the designers of the survey practices had never thought of composite units. It was only when the thematic maps were compared that such units appeared. They were considered so obvious, in this terrain of glacial deposition, as to require no special attention or exposition and were put to work as summary devices, frameworks on which to arrange the specific data of the survey. This is the principal reason why the genesis of composite units in the work of the Michigan survey and of the few students who followed it up has been largely lost in the history of land survey. The main purpose of this report is to put it in its proper place as the initial step in composite recognition.

THE ENVIRONMENT OF NORTHERN MICHIGAN

The purpose of the following description of the environment of a part of northern Michigan is to show that there existed in this area easily recognized "natural divisions of land." These are composed of relatively concordant distributions of surface forms, soils, and natural vegetation. The principal "erratic" or nonconformal distribution was that of drainage.

The concordance or regularity of the landscape forming elements is a result of the youthful nature of the glacial surface deposition that was laid down from the ice only ten to twenty thousand years ago and has been little altered by erosion since disappearance of the glacial melt waters. The surface materials were developed into soils by the relatively rapid process of podsolization and, except for the drainage anomolies, draw their vegetation capacities from the nature of their parent materials.

The principal variant element was the natural vegetation. The area had similar climatic conditions and was practically all forested. The separation of the upland forests into conifers or broadleafs was presumably a matter of the water holding capacities and the acidity content of the parent materials of the soils. This simple relationship however was much complicated by forest succession that apparently proceeded more rapidly on some soils than on others.

The concordance of natural divisions, expounded in the following pages of this section, is characteristic of the whole surface of Michigan. The descriptions and examples used herein are confined principally to the northern half of the Lower Peninsula because in this area the relationships are the most obvious and least complicated and also because this was the area in which the Michigan Land Economic Survey did its first work and where natural land divisions were first recognized.

Although natural land divisions have been noted by numerous investigators and in many parts of the world, it would appear that only in areas of recent glacial deposition is the nature of the surface materials so strong a determinant of the other landscape forming elements. Therefore, it is not remarkable that the workers of the Michigan Land Economic Survey recognized natural land divisions in their earliest operations; what is remarkable is that previous observers had not seen them. Perhaps they did, but no one wrote about it.

In Michigan a line roughly east and west through Saginaw Bay divides the Lower Peninsula into two much different parts. South of this line the soils are for the most part loams of arable quality. After the hardwood forest had been removed in the first half of the 19th century, agriculture spread over the land without serious difficulty and the southern part now constitutes the principal farming area of the state.

North of this line however conditions were much different. The northern part of the peninsula was deeply covered with glacial drift, mostly of sandy composition, deposited as moraines, till plains, and outwashes. The thick ice of the Lake Michigan lobe pushed eastward to meet the thinner ice of the Saginaw lobe which itself was a secondary protuberance of the deep Huron-Erie lobe. A great amount of debris was moved ahead of these lobes and caught between them and then overridden by the ice as it continued to advance toward the south. The elevated, sandy interlobate deposit thus formed is today known as the High Plains (Fig. 1). As the glacier melted the ice lobes retreated in directions opposite to those on which they advanced. The thin ice of the Saginaw lobe retreated northeastward in a halting manner, its stationary positions are marked by chains of weak moraines across the surface of the High Plains (Fig. 2). Around the margins of the High Plains the heavier ice in its pauses and some readvances built more massive moraines.

The moraines are long, narrow, hilly belts distributed in patterns that mark successive ice-front pauses. They are composed of heterogeneous materials, mostly coarse, because the finer particles were washed away by melt water. The margins toward the ice are somewhat sharper than those away from the front that may be masked by outwash. They rise sharply from adjoining outwashes and till plains and are readily recognizable as distinctive landforms.

Till plains were deposited by the glacier in its movement. The ice that was in contact with the earth at the bottom of the glacier accumulated a heavy burden of material varying in texture from boulders to glacial "flour." At some places this was scraped off and left exposed when the ice melted. Till plains have rolling but not rough surfaces and are composed generally of heavier material, boulder clay, because they have not been excessively washed. Sags in the surface may be poorly drained to form ribbon distributions of heavy organic soils. The moisture holding capacity of the soils make till plains the most productive sites for agriculture, but in this northern area of generally sandy soils not all till plains are suitable for cultivation. The distinctive surface configuration and material composition make till plains the second landform of easy recognition.

The spaces between the moraines and till plains are generally covered by outwash. This is fine material carried away from the glacial front by melt water. The heavier particles, sand, were dropped immediately and close to the ice whereas the finer flour stayed in suspension and went down the channels and into the lakes. Like the two preceding landforms, outwashes are readily recognizable from their level surface and sandy composition. They do, however, take two distinctive forms: where the outwash was deposited on deep underlying sands it forms a dry plain; if it is a shallow layer on heavier material such as a till plain it forms a marshy or swampy area containing organic soils.

Fig. 1. The land forms of Michigan (by Erwin Raisz).

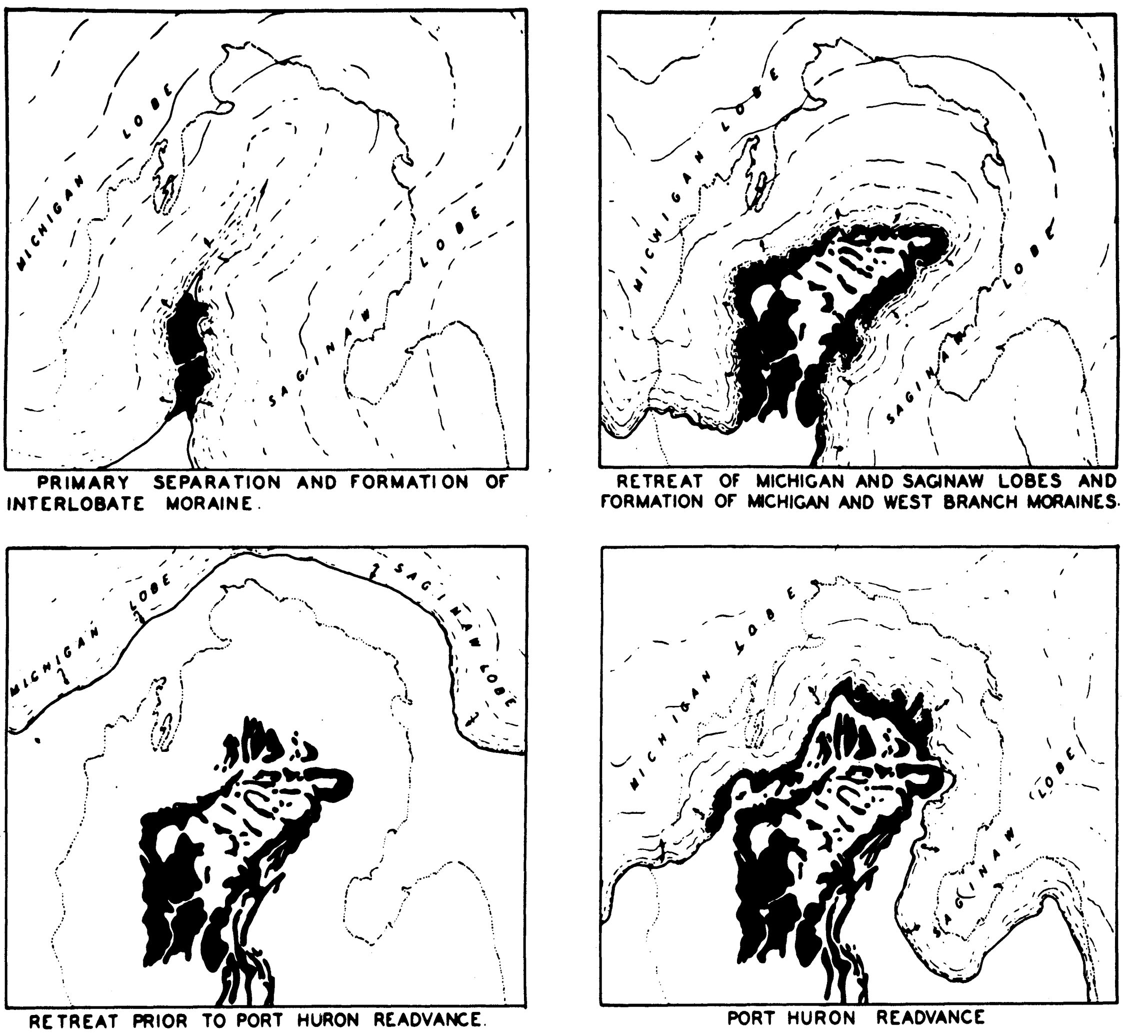

Fig. 2. Moraine formation in the High Plains. From Davis, "The High Plains of Michigan."

A fourth major landform is formed by the sandy or clay lake plains that mark higher water levels around the Great Lakes during the period of glacial melting. These are characterized by level surface, the presence of old shore lines or dunes, and their proximity of present lake shores.

During the first decade of this century Frank Leverett, an able and dedicated glacial geologist associated with the U.S. Geological Survey and The University of Michigan, began his careful mapping of the glacial surface features of the state ultimately to be presented in the monumental Monograph 53 (2).

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(2) Leverett, Frank, and Taylor, Frank B., The Pleistocene of Indiana and Michigan and the History of the Great Lakes, U.S. Geol. Survey, Monograph 53, Washington, 1915.

Although no descriptions of his field methods can now be located both Lovejoy and Schoenmann (3) stated that Leverett worked principally from a horse and buggy in the cutover country. At that time, shortly after the end of logging operations, the landscape must have been much more open than at present. Whether or not this was a factor, Leverett seemed to have no difficulty in mapping the surface forms which he recognized readily. He located section corners from the General Land Office plats and paced off distances along the landform boundaries. There is little doubt that he was an expert field mapper, but the facts remain that even in this early day and with only simple hand instruments he was able to map accurately and rapidly the major glacial landforms. He also established rough elevations from railroad track surveys and such other sources as were easily available to produce a contour map with 100-foot intervals.

Monograph 53 was largely devoted to explanation of the processes of the glacial surface and the composition of the drift. A history of the various glacial stages of the Great Lakes was principally the work of Taylor. The map of surface formations published on 1:750,000 scale was an insert in the report. In 1932 the writer of this report transferred Leverett's 1:750,000 lines to field sheets of approximately 1:125,000 and found in field use that any inaccuracies were no greater than those to be expected in such a transfer. This statement of accuracy is here introduced not principally as a tribute to Leverett's skill as a field worker, but to indicate the ease with which the Michigan landforms can be mapped.

The second element in northern Michigan forming the natural land divisions is the soil. In contrast to landforms which are large and easily recognizable features soils must be mapped to be recognized and were mapped by the Land Economic Survey in great detail. Certain soil boundaries are concordant with landform boundaries, but all are not, and a large amount of generalization of the individual soil types must be made before the essential concordance appears.

There are two general kinds of soils in northern Michigan: the lowland, poorly drained organic soils, and the mineral soils of upland locations. The organic soils owe their origins to drainage conditions and are therefore erratic in the orderly landscape pattern based on the landforms. The glacier destroyed the drainage network of preglacial times and left an uneven surface of porous material that has not yet developed an effective drainage system. The organic soils are located for the most part on outwashes or parts of lake plains and inthe sags of till plains, but they also occur locally on pitted moraines. Because they are products of the drainage, the soil types themselves show little boundary concordance with those of landforms.

(3) Lovejoy and Schoenmann were principal characters in the Michigan Land Economic Survey. See later notes concerning them.

"In a glaciated region like Michigan, where the land surface is <u>youthful</u>, where there has been little or no alteration of the constructional topographic forms, inherited soil characteristics are more closely associated with the subjacent formation than in an old nonglaciated eroded region... It is hardly to be expected that an outwash plain or a moraine or any of the other divisions of the same order would have the same meaning in soil terms throughout the whole State... However when local interpretations are made soil group-relationships may be established, particularly textural groups..." (4).

The upland mineral soils have been formed by podsolization of the relatively coarse materials left by glacial deposition. There were fairly well mixed by glacial action so that differences resulting from their mineral qualities are minimized. Materials originating from the limestone rocks north and west of Lake Michigan are more limey and less acidic than those from the east and south. This difference is not very great but seems to have had critical significance in the original forest cover. As mentioned earlier both the morainic and outwash materials were differentiated by melt water into texture classes and where texture differences are of importance in soil mapping the soil boundaries show concordance.

In alleging such concordance there are several conditions that should be mentioned. Landforms are discrete phenomena with relatively distinct boundaries; soil by comparison is a factor constantly varying from place to place. It is identified by sampling and has indefinite boundaries that in places represent only the mapper's concept of sufficient change to warrant a different type name. Mappers use vegetation, drainage, and landform boundaries as soil boundaries. There had been little work done on the northern soils at the beginning of the operations of the Land Economic Survey in the early 1920's; many of the soil types were identified by Veatch and bear names from the local areas surveyed (5). The purposes of the Survey required detail necessary to evaluate the land quality and mappers worked on a ten acre unit area. The "catena" association suggested nearly a decade later by Milne (6) would perhaps have shown more concordance with landforms. An example of the Survey detail is shown by Fig. 3, a rendering of the soil boundaries as mapped by the Land Economic Survey at 1:63,360 scale for Logan Township in Ogemaw County. Figure 4 shows the same county enlarged from Veatch's generalized Soil Map of

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(4) Veatch, J. O., "Geology in Soil Classification," <u>Pap. Mich. Acad. Science, Arts, and Letters</u>, 5: (1925) 287-296.

(5) These were classified of course under the "old" soil scheme rather than the present or "newer" one currently used by soil mappers.

(6) Discussed later in this report.

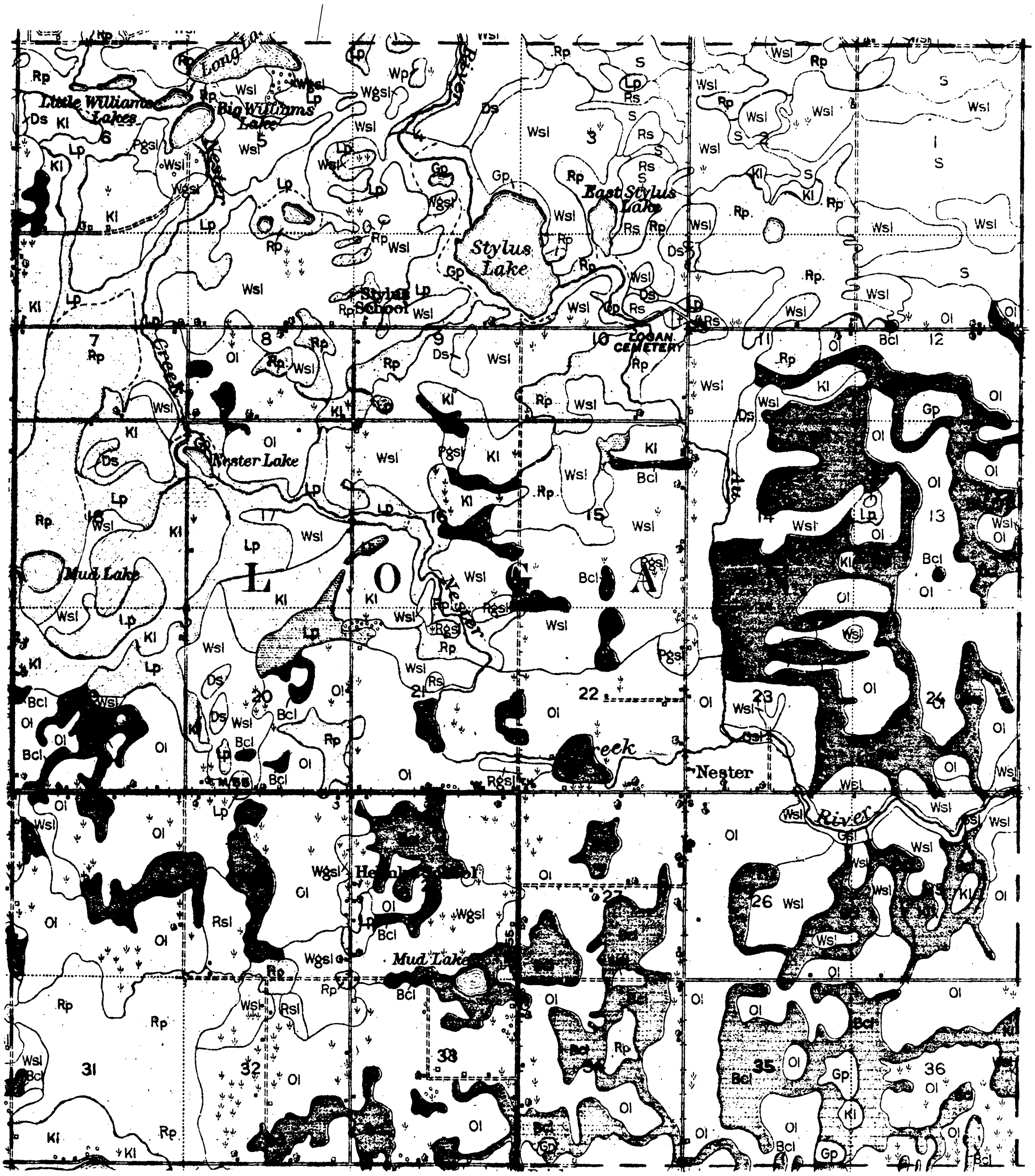

Fig. 3. Soils in a township. Published by the Michigan Land Economic Survey from Soil and Lay of the Land Map of Ogemaw County. Scale: 1:63,360.

Michigan published in 1953 on a scale of 1:750,000. Still greater generalization is necessary for easy recognition of concordance of soil boundaries with landform boundaries. Figure 5 is an enlargement of Kalkaska County from Veatch's map and Fig. 6 is a generalization of that map made by showing organic soils on the outwashes by dashed lines and combining morainic soils of closely related characteristics. At this degree of generalization the concordance with the landforms taken from Helen Martin's surface formation map (Fig. 7) of 1955 is obvious (7).

Within these limitations the soils formed the second of the concordant elements that existed as "natural land divisions."

The distributional relationships of the patterns of original vegetation and of soils in northern Michigan have been so adequately mapped and documented as to require little substantiation. The correlated distributions of these two elements were so obvious to Veatch from his own observations as well as from the early mapping operations of the Land Economic Survey that he produced a map of the original vegetation from soil maps as a part of a 1928 publication (8). Later he carried out a correlation study between soil types and the remnants of original cover in southern Michigan (9) to find that a "dependable but by no means perfect correlation between forest types and the units or types of soil..." Davis, using Veatch's ideas and maps together with other information showed close correlation between the original forest cover and both soils and landforms in the High Plains of northern Michigan (10) (Fig. 8). Veatch points out the simultaneous development of soils and vegetation and states that temperature and moisture conditions are the primary considerations in the development of both.

Under original conditions the concordance of forest cover and soil must have been much more clear than after logging operations. Even in the original conditions there were some inconsistencies: the existence of much (white) pine in dominantly hardwood areas may have indicated a phase of Veatch's idea of "simultaneous development" or of normal forest succession in a static soil situation wherein the pines were relics of an earlier dominance.

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(7) Miss Martin's map is generally based on Leverett with refinements made in succeeding years.

(8) Veatch, J. O., Map of the Original Forest Cover of Michigan, in "Reconstruction of Forest Cover Based on Soil Maps," Quarterly Bulletin 10: 3 (1928) Mich. Agr. Exper. Station, Lansing.

(9) "Soil Maps as a Basis for Mapping Original Forest Cover," Pap. Mich. Acad. Science, Arts, and Letters 15: (1931) 267-273.

(10) Davis, C. M., "The High Plains of Michigan," Pap. Mich. Acad. Arts, Science, and Letters 21: (1935) 303-341.

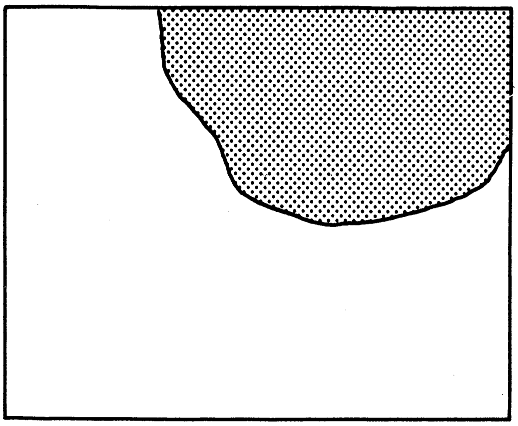


Fig. 4. Soils of Logan Township (see Fig. 3) as generalized on Veatch's map of Soils of Michigan. Published scale 1:750,000; scale of this drawing approximately 1:100,000.

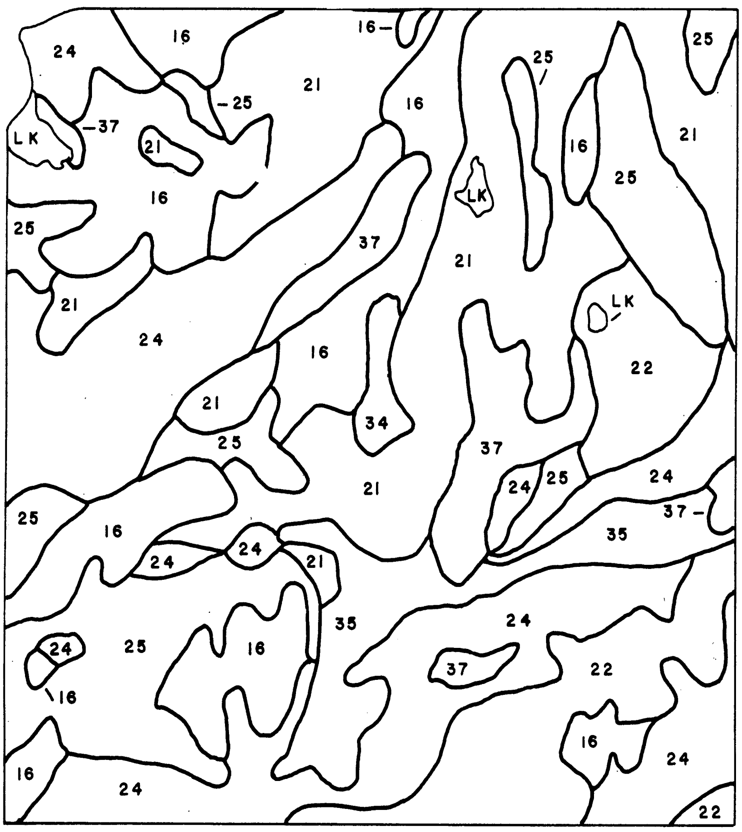


Fig. 5. Soils of Kalkaska County from Veatch's Soil Map of Michigan, 1953.

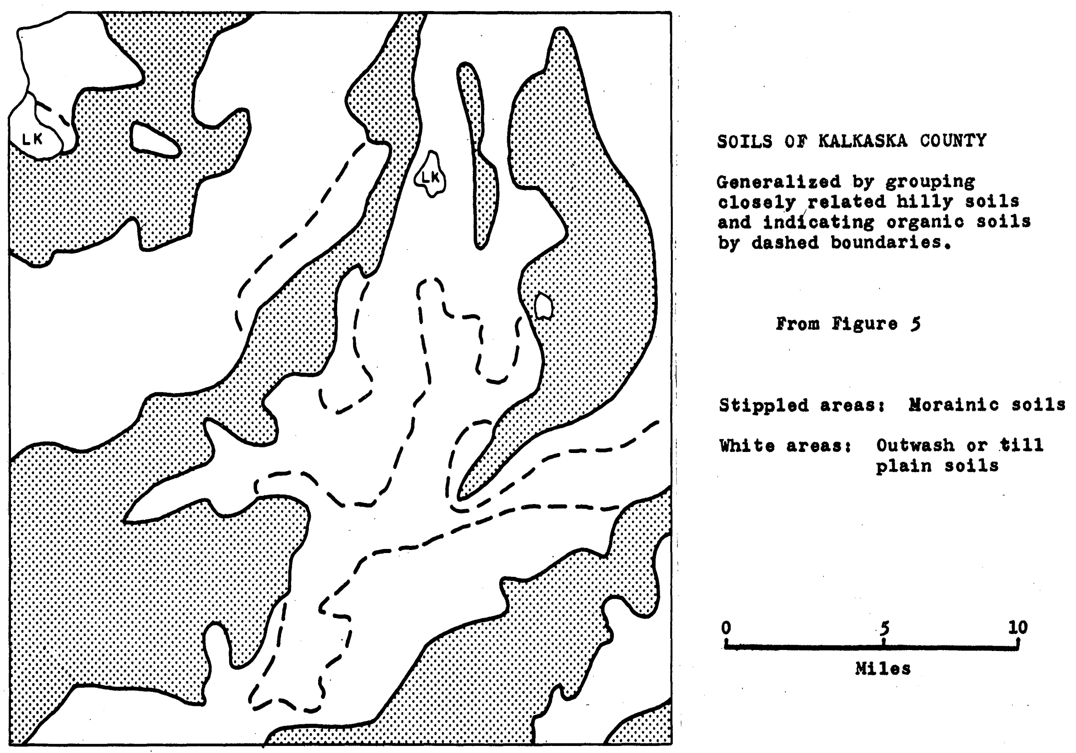


Fig. 6. Soils of Kalkaska County: generalization by combining some morainic soils and indicating wet soils by dashed boundaries (see Fig. 5).

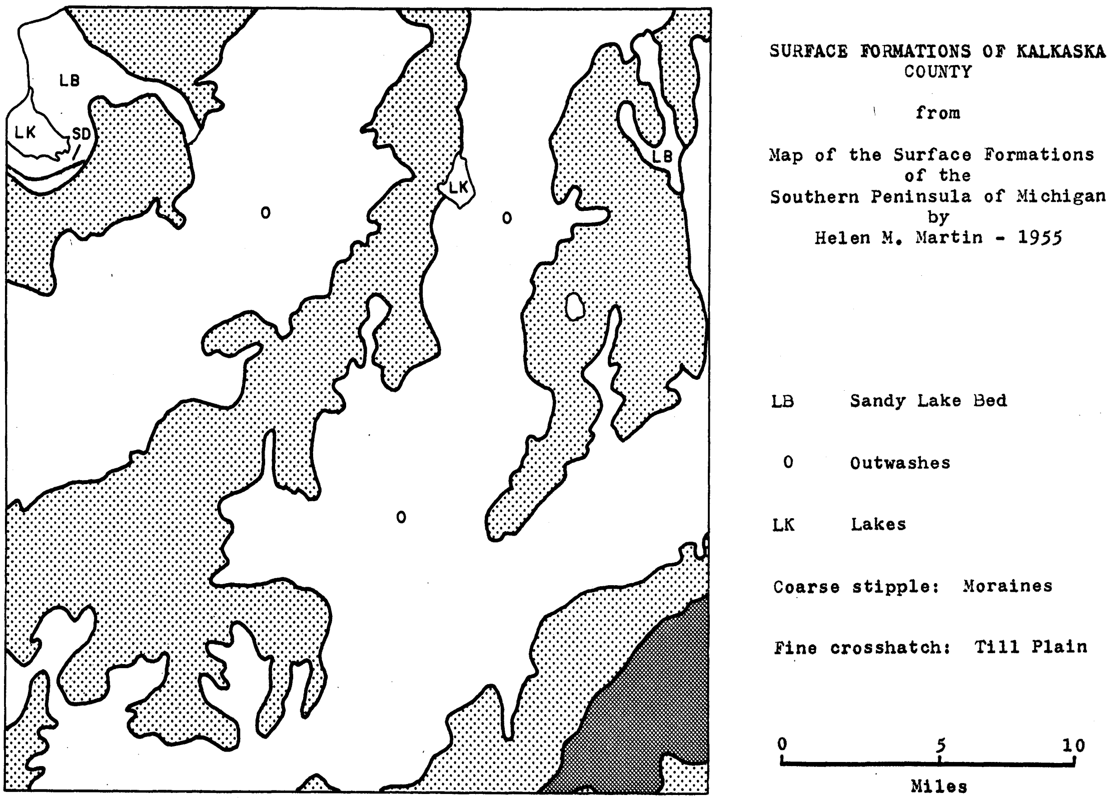
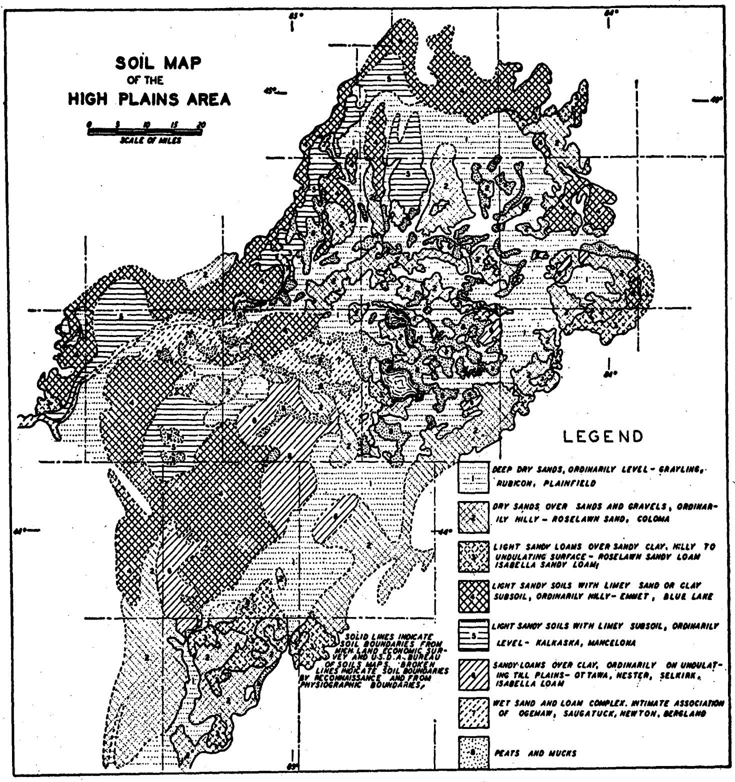
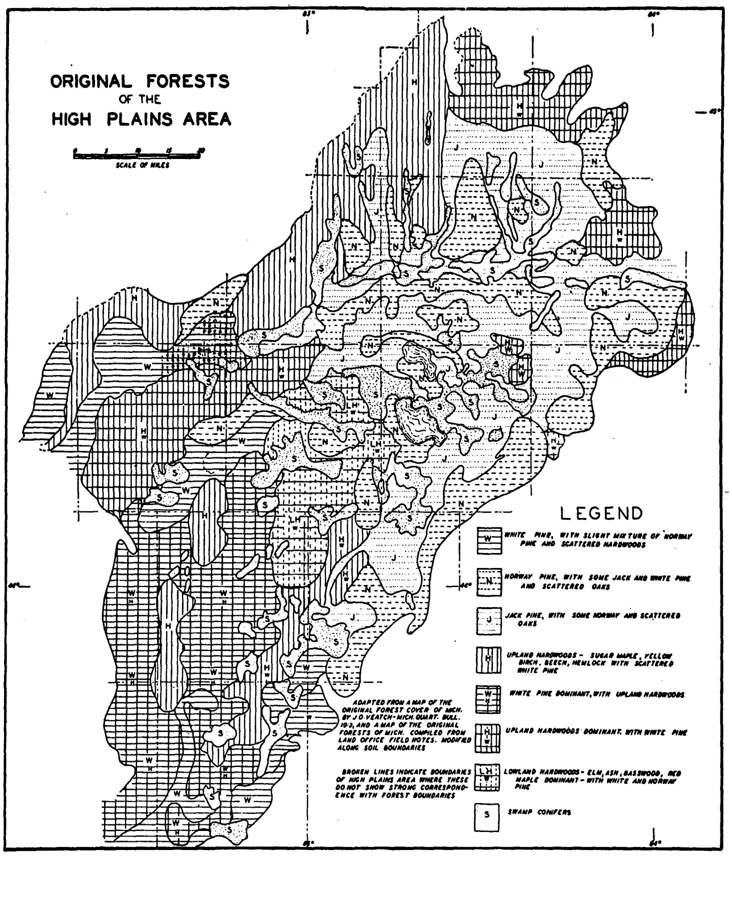


Fig. 7. Surface formations of Kalkaska County from Map of the Surface Formations of the Southern Peninsula of Michigan (by Helen M. Margin, 1955).



(a)



(b)

Fig. 8. Concordant distributions in the High Plains. From Davis, "The High Plains of Michigan."

The lumbering operations radically altered the original forest cover by selective harvesting of the pines; subsequent fires changed ecological conditions as did agricultural clearing (11) but both the distribution of the species valuable to the loggers as well as the distribution of agricultural clearing were based on the soil pattern. Even in the landscapes of the present, the strong concordance of soils and landforms stated in the preceding pages together with natural vegetation still exists, and it follows that:

> In northern Michigan there existed "natural divisions of land" based upon the pattern of the landforms, each being characterized by a relatively distinctive association of landform, soil, and forest cover; the recognition of these as "land types" was both easy and inevitable.

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(11) Davis, _op_. _cit_., p. 317, et seq.

THE LAND ECONOMIC SURVEY

Professor J. O. Veatch put it succinctly when he said in response to a question on the origin of the land type concept in Michigan, "Who knows where ideas come from?" However, it seems clear that this idea was developed during the mapping operations of the Michigan Land Economic Survey during the early years of the decade of the 1920's.

The Survey was a perhaps inevitable consequence of a number of historical and economic circumstances that followed lumbering in the meager environment of northern Michigan which has been described in the preceding part of this report. A knowledge of these circumstances is useful to an understanding of the reason for the establishment of the Survey and its methods of operation.

The northern parts of the state were opened up by lumbermen principally in the first decade after the Civil War. Although there had been a few coastal settlements previous to this time, as well as some lumbering along the lower parts of the principal rivers, the important operations occurred during the last three decades of the 19th century.

The forested areas close to the major streams were harvested by river logging in which the rivers were the principal carriers and major settlements were on the lakes at the river mouths. This did not bring many settlers into the cut-over areas as no transportation system other than the river itself was necessary. However, because it was never profitable to haul logs more than a few miles to the water, the large stands of timber on the interfluves could be reached only by railroads which by the early years of the 1870's had been constructed through the timber lands.

As a means of bringing settlers into the land railroad logging was much different from river logging. The main railroads were principal arteries; many secondary lines of tracks some of temporary nature were constructed by the lumbermen and intended solely for logging purposes. Connected to the railroads was a system of lumbering roads reaching into all parts of the forested area. By way of this road-railroad system settlers could easily get into the cut-over country. Towns along the main railroads and even lumber camps and large sawmills became seeds of settlement.

The lumbermen regarded the pine lands as part of their stock in trade. They had purchased the land for its timber and when this was gone the remainder was a byproduct to be disposed of at a profit if possible, or abandoned if necessary. In this period of the expansion of the frontier there was no public question of this policy of "cut out and get out"—the business of the lumberman was timber, not land, but the land remained. The tax laws of the period did not encourage lumber companies to hold idle land for many years. For the most part it was turned over to land selling organizations which conducted "various intensive real estate selling schemes" some of which from a present point of view seem to have been fraudulent and scandalous. Some of those who bought small parcels sight unseen on low down payments never settled on their lands, but enough did to form a thin scattering of settlement.

Most of the cut-over land, however, was not sold for settlement and could not be long held by the land companies. Even before 1910 there was widespread tax delinquency in the larger holdings and abandonment of the smaller by disillusioned settlers. Under state laws there is a seven-year period between initial tax delinquency and the time when the state acquires title to the land. Such seven-year intervals left much land in a "suspended" status. Developing settlement of the arable parts of the northern country masked statistically the increasing acreage falling into public ownership. The State Land Office held the tax abandoned land for general sale to any interested parties. Small parcels containing harvestable second growth were bought by timber scavengers, logged off, and allowed to revert to tax delinquency. Such sales were commonly made at prices with did not equal the accumulated overdue taxes and sales at more than one dollar per acre were the exception rather than the rule. A legislative investigation in 1909 turned up considerable evidence of unsatisfactory land selling as well as the fact that state land holdings were approaching one million acres. One result of this investigation was the establishment of a Public Domain Commission to deal with the problems of the public land. Into this commission were consolidated the State Land Office, the Forestry Commission, the Game, Fish, and Forest Fire Warden, and hopefully, the Commission on Immigration.

Although the Public Domain Commission was a great improvement over the separate agencies that had been managing the state land, it was handicapped by the lack of any general policy. Even during the lumbering years knowledgable land men had believed that northern Michigan in general was hopeless for close agricultural settlement; "This land," they said, "has raised its crop." But there were values in the land. The Forestry Commission in 1902 had established forest reserves on state land near Higgins and Houghton lakes, a move of doubtful value because the quality of the soils was submarginal not only for agriculture but also for economic timber growth. Hunting, fishing, and other recreational land uses were growing; the State as the owner of native wildlife had the duty of protection and regulation of such resources. Evidence of public recognition of the potential recreational values was apparent in the fact that in the lands acquired through tax abandonment there was almost no water frontage. Without much information as to the values in the State lands the Public Domain Commission was helpless to establish any policies except that of holding the land in hopes that something would develop (12).

In 1919 a group of scientists in the Michigan Academy of Sciences expressed their concern over the great and growing amount of idle stump land in State ownership and the necessity for some plan for its future. The Academy set up a committee to study the situation and to make recommendations. At the 1920 meeting a symposium under the chairmanship of Carl O Sauer was held on the subject of "Michigan's Idle Lands." This produced two papers of far-reaching significance. The first of these was a presentation by Parish S. Lovejoy in which he pointed out that one-third of the state was in "nonproductive, idle land—and virtually bankrupt." This area, he said, was increasing rather than decreasing in amount. To remedy the situation "nothing can suffice save a real policy soon put into effect." But such a policy required an inventory. "The first thing is to take stock of the resources—to make an inventory." This, he recommended should be a "soil-survey plus an economic survey which shall consider and appraise the properties in their true value" (13). The second paper was a resolution addressed to the Public Domain Commission recommending that "an inventory be made of the land resources of Michigan by counties. This inventory should constitute a series of county reports, accompanied by maps, along the following lines:

(a) nature of physical conditions,

(b) present economic conditions, together with the record of past and present experiences in the use of the area,

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(12) For an interesting and complete review of the development of the public domain in Michigan see: Titus, Harold; The Land Nobody Wanted, Spec. Bull. No. 322 (1945) Agr. Expt. Station, Mich. State Univ. in cooperation with Mich. Dept. of Conservation, Lansing. Harold Titus of Traverse City was a writer and journalist; for many years he was a member and chairman of the Conservation Commission.

(13) Lovejoy, Parish S., "The Need for a Policy for the Cut-over Lands of Michigan," Twenty-Second Annual Report of the Michigan Academy of Science (1921), pp. 5-7, Lansing.

Lovejoy was a great and now almost a legendary figure in Michigan land and conservation affairs. He was an early forestry student at The University of Michigan; later a supervisor in the U.S. Forest Service; member of the faculty at The University of Michigan; and staff writer for Curtis Publishing Company. He helped organize the Michigan Land Economic Survey in 1922; later he held several posts with the Conservation Department and was its advisor on land policy and programs. A touching obituary by Aldo Leopold appeared in The Journal of Wildlife Management 7: 1(1943). A glacial boulder bearing a bronze tablet stands as a memorial to him near the headquarters of the Pigeon River Forest.

(c) a classification of the land according to its highest indicated use" (14).

This resolution could not have been made at a more opportune time. In 1921 the Public Domain Commission was abolished and the Department of Conservation was formed from its parts together with a number of other state agencies (15). When the new department, now at last with a concentrated jurisdiction over public land affairs, looked at the "wide array of state projects based on wild land use (that) had grown up in a more or less Topsyish manner, without much plan and with little understanding as to how they might cooperate or overlap in functioning" (16) the recommendation of the Academy made much sense. An old statute authorizing a "Soil and Economic Survey" was conveniently found to exist; cooperation with The University of Michigan, Michigan State University, and the State Department of Agriculture was worked out, and funds were made available for an experimental field season in Charlevoix County during the summer of 1922. The results of this trial showed both the practicability of the general plan and the urgent need of the information it produced. The Land Economic Survey was established and added to the other divisions of the Conservation Department.

The purpose of the Land Economic Survey was to produce a detailed inventory of the northern lands together with reports on economic conditions within them. Although classification was necessary to establish meaningful categories for mapping there was not, as mentioned previously, any attempt to make a classification of the land in "its highest indicated use" as recommended by the Academy resolution (17). Because the inventory was intended not only as a basis for policy formation but also for land management purposes it was necessarily to be done in great detail. There was no precedent or experience in making such an integrated survey; soil and cover mapping techniques were available, but the economic survey had to be developed almost wholly from necessity.

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(14) It is interesting to note in passing that no such "classification" was made by State officials or agencies. Lovejoy pointed out that, although it might be done in theory, it would be highly subjective and temporary because of the "variables which affect or determine the precise time and manner in which given lands should or will be developed." He also noted that the bulk of the surveyed lands was still in private ownership and "the equities in real estate are sensitive." Lovejoy, P. S., "Theory and Practice in Land Classification." <u>Journal of Land and Public Utility Economics</u> 1:2(1925), pp. 160-175.

(15) Reorganized into the Department of Natural Resources under the 1963 revision of the State constitution.

(16) Titus, <u>op</u>. <u>cit</u>., p. 15.

(17) Perhaps this points out the shadowy boundary between the subject of geography, concerned with "what is where," and land planning dealing with the remedial measures necessary to bring about "things as they ought to be."

The permanent staff of the Survey consisted of a Director, Horace Andrews, who was also a forester; a Soil Surveyor, Lee Roy A. Schoenmann (18); a Land Economist, Wade DeVries, and two general aides who were draftsmen during the winter. In summer the staff was supplemented by a Hydrological Engineer, a Soils Inspector, J. O. Veatch (19); two additional assistants; nine linesman surveyors, principally students from the universities; four soil surveyors contributed by the Bureau of Soils at Michigan State University; and one or more cooks and assistants. The total yearly cost, in 1924 was approximately $29,000 (20). Additional specialists were available from the faculties of the University; Frank Leverett was a frequent consultant. The novelty of this integrated survey attracted much attention and many visitors from governmental agencies.

Field operations in the first year were experimental and many changes were later made. A conversation with one of the first-year surveyors (21) tells a little of the operations. Field crews consisted of a cover and base mapper together with a soil and slope mapper. Most of the field time was taken up with boundary delineation and the determination of soil types. One section per day was considered a good field accomplishment. The instruments were a compass together with a soil auger; the only basic maps were the General Land Office plats, more than a half-century old, showing the section corners of which little evidence remained, and drainage features where these crossed section lines. Leverett's map was available but used only for general purposes. The original field scale was eight inches to the mile, subsequently changed to four inches.

After the experimental first field season and some changes in the following few years, the Survey "shook down" to a set of standard procedures. The following material on techniques and results came in the main from Barnes' account written in 1928 (22).

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(18) Schoenmann was the original soil mapper of the Survey and principal instructor to its field workers. Later he became the Director and after the dissolution of the Survey was a member of the faculty of Michigan State University.

(19) Jethro O. Veatch, a pioneer soil scientist and student of land, is principally responsible for developing the soil knowledge of northern Michigan as well as for many concepts and contributions to land study to be mentioned later in this report. He was a principal figure in the Michigan Land Survey and for many years a member of the faculty at Michigan State University from which he has retired but in which he still works.

(20) From Proceedings of the Department of Conservation, 1923-24, "Budget for the Land Economic Survey, 1924," p. 728.

(21) O. H. Clark who for many years was in charge of lake and stream improvement for the Conservation Department and later was a Lecturer in Geography at The University of Michigan.

(22) Barnes, Carlton P., "Land Resource Inventory in Michigan," Economic Geography, 4 (1929) 22-35. Carlton Barnes was a Forest Mapper of the Survey.

The operational personnel were divided into three classes: specialists, soil and cover mappers, and land economists. The specialists were, in part at least, consultants and part-time persons who made studies and appraisals of mineral resources, water resources, and wildlife and recreational possibilities. One specialist party made chain and instrument traverses to locate unidentifiable section corners and road positions. The soil and cover mapping crews consisted of two men who were given assignments of one-quarter township (nine square miles.) The soil man mapped soils and slope. He took auger borings at regular intervals, measured the slope in degrees, and noted such features as wet spots, escarpments, and sand and gravel deposits. The cover mapper recorded natural vegetation, agricultural land use, and in general such cultural features as houses, roads, railroads and railroad grades. The field scale used by both mappers was four inches to the mile; a forester's compass on a jacob staff and a soil auger were the only tools; the method was pace mapping. The mappers followed the section and quarter section lines so that each section was traversed at least twice and each part was seen from no greater distance than one-quarter mile. Offsets and triangulations were made wherever necessary. The mapping was done on prepared sheets marked off in ten chain (one-eighth mile) lines.

Soils were mapped as types following U.S. Bureau of Soils techniques. Most of the soils of northern Michigan had not been described or named and Veatch was constantly busy with descriptions and correlations. On the published soil maps most of the soils are identified by local names, such as "Grayling Sand," indicating that they were original with theSurvey. The finished map was published in color at 1:63,360o scale and was in great detail (Fig. 3). On the reverse side of the map was the "Soil and Agricultural Report" containing several features. The soil types were described and illustrated by profile drawings and their value to agriculture discussed (23). A short history of settlement and development of the county was given together with tables of agricultural land use and a dot map showing the distribution of hibitations and towns. Of particular interest to this study was a map of "Natural Divisions" (Fig. 11) which were combinations of the glacial landforms and soils (24). There was tabular information concerning the use of these divisions for agriculture.

The cover mapper was responsible for indicating the nature of the forest growth, other natural vegetation such as sedge marsh, upland grass, fern and bracken cover, as well as agricultural land, used or abandoned. A standard set of thirty or more symbols was used in various combinations to indicate the character, size, and density of forest cover. As an example:

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(23) Obviously not a recommendation of "highest indicated use" but a statement of encouragement or warning upon which individual judgment could be based.

(24) The earliest maps labeled these "Physiographic Divisions" and did not show their soil correlations. Later maps called them "Natural Divisions" or "Land Types."

''
P M
0-3

indicated a mixed stand of small hardwood in which poplar was dominant and maple (together with some or all of beech, yellow birch, hemlock, basswood, elm, and white ash) was subdominant. The size of the trees (0-3 inches) indicated a young growth and the double mark ('') showed medium stocking. Agricultural land was recorded as cropped land, farmed stump land, pastures, stump pastures, orchards, and idle agricultural land. The reverse of the published map gave a "Farm-Forest Report" repeating some of the same materials as shown on the reverse of the soil map but containing in addition summary tables on the distribution and extent of agriculture in the county. There was also a map of "Economic Divisions" based on land use; as might be expected, this showed considerable correlation with the Natural Divisions.

The economic inventory consisted of an inventory of the economic conditions made by the Land Economist and his assistants from data gathered in the local courthouse together with information derived from interviews with local officials and land owners. These were plotted to produce three principal maps: Land Ownership, Intent in Ownership, and Assessed Valuation; together they expressed the local opinion of the value of land in the county. They were correlated by the Land Economist with the field maps to produce the reports mentioned above (Figs. 9 and 10).

The correlation of these maps led to the first recognition of "Natural Districts." As stated by Wade DeVries, (25) "the field compilation of these three types of maps is made independently by different investigators who attempt no intercorrelation of the data during the course of their field work. However, even in the very first county inventoried by the Land Economic Survey, a very marked degree of correlation between these three types of maps was apparent..." DeVries' idea was to express the economic materials which had been collected in an areal frame that would show their relationships to the physical elements. "In order to make this correlation clearer the detailed farm-forest maps were combined into a more simple map of the natural districts which represent definite associations in nature of soil, drainage, topography, and natural forest cover. The boundaries between such districts are not general boundaries, but rather the detailed lines established in the field as marking the separation of different soil-forest type associations. The natural conditions within each district are thereby placed in marked contrast to the natural conditions within every other district" (Fig. 11).

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(25) DeVries, Wade, "Correlation of Physical and Economic Factors as Shown by Michigan Land Economic Survey Data," _J. Land and Pub. Utility Economics_, 4:(1928) 295-300.

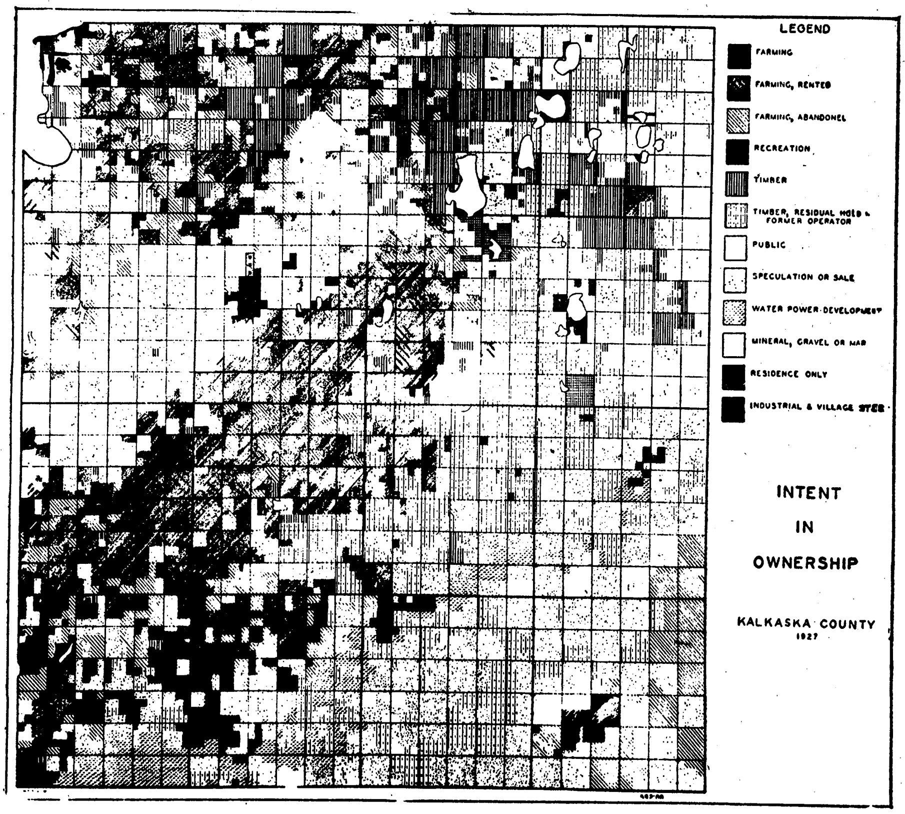

Fig. 9. Intent in ownership, Kalkaska County.

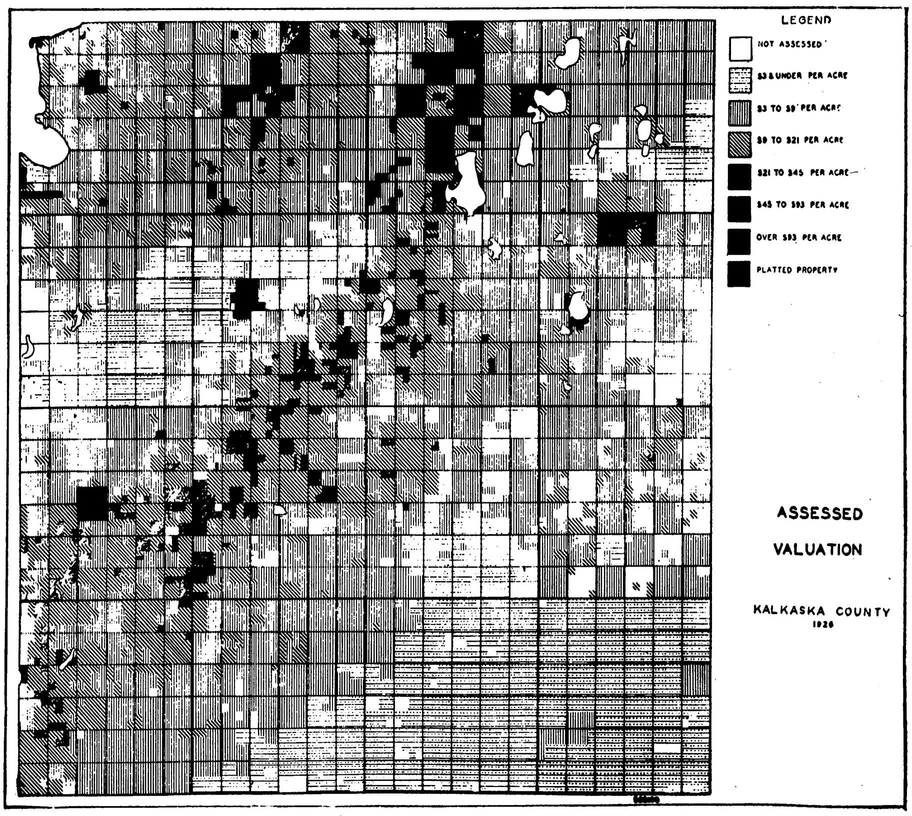

Fig. 10. Economic inventory in Kalkaska County. From Barnes, "Land Resource Inventory in Michigan" (after DeVries).

It seems clear from the preceding material that the concept of natural districts, later expressed by Veatch and others as "land types," arose from the need of a summary device for detailed mapping; for this necessity the very obvious natural combinations of surface-soil-vegetation-drainage in northern Michigan served as an answer. They were not used in the Survey for reconnaissance purposes and were not delineated in the field, but rather were recognized in the office comparison of the field maps.

DeVries' correlations between the natural land divisions and the economic factors were clear and impressive. He believed that after sixty years of farming and attempted farming on all of the natural divisions, local opinion of the productiveness of the divisions as expressed in assessments for tax purposes did represent both their present and presumed potential value for agriculture and that the percentages of each type in operating farms and abandoned farms as shown by the Survey maps represented proof of this local opinion. Using the three counties, Chippewa, Kalkaska, and Crawford, most recently surveyed, he ranked the natural land divisions of the three taken together into a table in which the first criterion was the percentage of land in farms. For this ranking he found very good correlation in the assessed valuation of both farm land and wild land and reversed correlation with the percentage of abandoned farm land (Fig. 12).

DeVries' paper reached publication five years after compilation of the results of the 1922 experimental field season and is the first definite statement of the natural division concept which this investigator can find in the scattered literature on the subject. It seems likely, however, that the concept was established before DeVries' publication because the Reports, mentioned earlier as parts of the printed county maps, contained maps of the natural divisions under various designations.

This paper in the Journal of Land and Public Utility Economics is cited above as the first statement of the character of the natural land division. It contained the philosophical background and methodological description of their origin. It is however possible that another paper by DeVries actually predated the one noted. In 1927 DeVries presented before the Michigan Academy an "Economic Survey of Chippewa County" (26) in which he stated that "In studying the natural environment of Chippewa County, Michigan, the various natural features such as soil, drainage, topography, location, and forest growth are considered in relation to one another as forming natural districts. Because of the interrelationships of these features, it follows that a certain soil is associated with a certain class of topography and a certain type of forest cover. Likewise, a certain forest type naturally associates itself with a certain soil type and a certain degree of drainage. In Chippewa County, the natural districts as defined on this basis are very definite and distinct units

(26) DeVries, Wade E., "An Economic Survey of Chippewa County, Michigan," Pap. Mich. Acad. Science, Arts, and Letters, 8:(1927) 255-268.

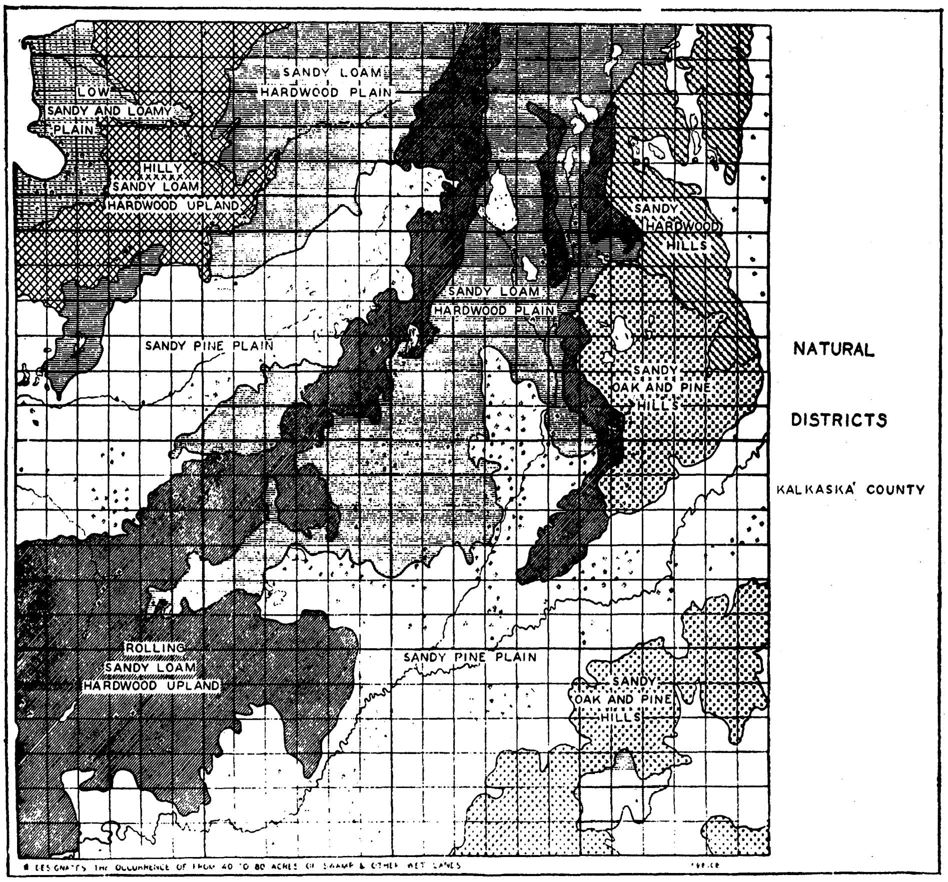

Fig. 11. Natural districts, Kalkaska County. From Barnes after DeVries.

CORRELATION OF PHYSICAL AND ECONOMIC FACTORS*

A	B	C	D	E	F	G	H	I	J	K
Natural District	County	Amount of Land in Farms		Amount of Farm Land Abandoned		Valuation per Acre in Farms		Valuation per Acre of Wild Land		Average Rank of Natural District
		Percentage	Rank	Percentage	Rank	Amount	Rank	Amount	Rank	
Clay	Chippewa	67	1	2	1	$26.50	1	$10.50	1	1
Shore Border	Chippewa	17	7	6	2	14.50	4	8.60	3	4
Rolling Sandy Loam Hardwood Upland	Kalkaska	54	2	19	5	13.90	5	6.35	7	4¾
Sandy Loam Hardwood Plain	Kalkaska	34	5	27	8	12.30	6	5.95	9	....
	Crawford	51	3	26	7	18.05	3	8.00	4	5⅝
Hilly Sandy Loam Hardwood Upland	Kalkaska	41	4	33	9	8.90	10	8.75	2	6¼
Low Sandy and Loamy Plain	Kalkaska	30	6	34	10	12.10	7	7.90	5	7
Sandy Hardwood Upland	Chippewa	13	8	14	4	8.50	11	6.70	6	7¼
Loamy Hardwood Tablelands with Sandy Valley Slopes	Crawford	8	10	55	14	18.60	2	6.05	8	8½
Mixed Sand Swamp Clay Transitional	Chippewa	3	13	11	3	10.10	8	5.50	10	8½
Loamy Sand Oak and Pine Upland	Crawford	6	11	41	11	9.60	9	4.35	13	11
Stony	Chippewa	11	9	23	6	3.40	16	3.20	18	12¼
Sandy Hardwood Hills	Kalkaska	4	12	....	......	5.80	14	4.75	12	12⅔
Sandy Pine Plain	Chippewa	....	......	....	......	....	......	3.30	17	....
	Kalkaska	8	10	48	13	5.60	15	3.85	14	13
	Crawford	3	13	44	12	8.40	12	4.90	11	....
Sandy Oak and Pine Hills	Kalkaska	1	14	89	16	2.85	17	3.80	15	....
	Crawford	1	14	57	15	6.90	13	3.35	16	18¾

* Location, such as nearness to large towns, has practically no influence on the valuation of the land in these counties. Some of the lowest assessed values in each county were found to be adjacent to the county seat.

Fig. 12. Correlations in Kalkaska, Crawford, and Chippewa Counties. From DeVries.

with easily apparent boundaries. Each district possesses a unity of character and contrasts strongly with every other district." The Papers of the Academy reach publication in the year following their presentation and it would seem that DeVries' two articles were published at about the same time.

It is worth a note to observe that the depression of the early thirties that gave life to several federally supported land projects killed the Michigan Land Economic Survey. It was a State project that became an early casualty of the lack of funds. Although one-half of the northern counties still remained to be inventoried, it had accomplished much of its mission. It had demonstrated that most of the northern land, at least from the economic point of view of the time, would not succeed in private ownership and that public ownership was a permanent and desirable condition. Enough inventory had been done in various parts to give a working basis for management of the public domain.

During the depression also, air photography made for agricultural adjustment purposes became generally available. When the State again had funds to complete a few remnants of inventory it was found that two men in an automobile equipped with a mapping odometer and relieved by the air photographs of much of the time-consuming task of boundary delineation could do the work in a fraction of the time required by foot methods (27). By air photo techniques "spot" jobs could be done quickly when required and there was no need to continue the administrative or field personnel of the Survey.

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(27) The first use of air photographs for inventory work in Michigan was in the Isle Royale Survey in 1928-29, directed by K. C. McMurry.

THE LAND TYPE IN MICHIGAN

I

The Survey had been using the natural land division, commonly refered to as the land type, as a summary device and a basis for its county Report statistics for several years before it was put to use for other purposes. Veatch seems to have been much interested in the land type both as a practical tool and as a philosophical concept. In 1937, some years after his other publications on the subject, he wrote: "The beginnings of any new idea, whether the idea be grand or humble, lie in the dim and distant past... At any rate during the past few years a bright idea has appeared to a few investigators engaged in land classification and land utilization studies. The idea is that a kind of natural division of the land surface can be differentiated which combines, or integrates, a number of separate features of topography and soil into units to which can be tied studies in human ecology, or economic studies pertaining to the use of land. If such a natural environment unit can be established, economic studies will have a more solid base and can be more easily compared, correlated, and evaluated. The idea is that use of land studies will have greater value and meaning if they are made in relation to natural divisions of the earth's surface, rather than in relation to political or economic divisions... The ideal natural geographic division would combine all of the natural groups which have human environmental significance... It is too big an order to fill for any individual, or group of individuals, to integrate all of the natural factors into a system from which taxonomic units of any size can be drawn. But perhaps a few of the natural factors can be combined and the imperfect natural divisions resulting can be useful nevertheless... The aim is to construct a natural division of land which will be more directly useful to the agriculturalist, the ecologic geographer, the economist, and the land planner than is the soil-type units of the Soil Survey or the separate climatologic, physiographic, and geologic divisions. Possibly such natural divisions as here conceived might be designated as pedonomorphic..." (28). The article was intended primarily for soil scientists and Veatch points out that soil types as mapped are rarely homogeneous but contain variations and other types to the extent that the types as published are actually land types rather than soil types. In this article he refers to the earlier work of R. M. Harper in Alabama and Florida, 1913 and 1914, recognizing the natural divisions of those states.

Several years before this summary article, Veatch published a short paper (29) that set forth his ideas of land division together with a land division

(28) Veatch, J. O., "The Idea of the Natural Land Type," Proc. Soil Science Society of America, 2(1937) 499-503.

(29) Veatch, J. O., "Natural Geographic Divisions of Land," Pap. Mich. Acad. Science, Arts, and Letters, 14(1930) 417-432.

chart and map for Michigan.

As an introduction it suggests divisions of the earth's surface, the "lithosphere," along three somewhat parallel lines: Landforms, Natural Land Divisions, and Use Divisions, the first and second of which come together at the land type level. Each of these divisions consists of a hierarchy of increasingly more specific categories (30). The Landform Division is based on physiography and physiographic processes; it descends from continents to topographic forms such as hills and valleys. The Natural Land Division which Veatch calls "geographic" is based on climate, soil, and vegetation. It descends through four divisions for which examples are given. These are:

First Division: Land Regions, such as Arctic, Temperate, and Tropic.

Second Division: Major divisions, such as Steppe Black Lands, Gray lands north forest, Brown Earth Lands, Deserts, etc.

Third Division: Land Types, based on topography, soil, and vegetation, such as Coastal Flatwoods, Grayling Pine Plains, or Chippewa Clay Plains. This is the level at which the Landform Division runs into the Natural Land Type Division and places the land type into the hierarchy according to Veatch's ideas.

Fourth Division: Consists of the most minor unit which is equivalent to a soil type.

This philosophical introduction is interesting but the major contribution of the article is found in a table and map dividing Michigan into "Land Divisions" based on topography, soil, and vegetation. Figure 13 is a page of the table which listed sixty-five divisions in the state. The map in the published article was on a very small scale, apparently reduced from a 1:750,000 base. The sources Veatch used for this compilation are not stated, but presumably they were the soil maps of the Bureau of Soils and the Land Economic Survey together with the map of surface formations, and his own wide knowledge of surface conditions in the state. Figure 14 is a reproduction of the Lower Peninsula part of the Natural Land Divisions map used as an overlay of the glacial landforms; the strong concordance of the natural divisions with the landforms, especially in the northern half of the peninsula is evident.

Three years after the paper reviewed above, Veatch published another which seems to have been derived in some part from the same ideas (31). Its message in a philosophic sense was that land is better classified on a "geographic"

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(30) Such a hierarchy is contained in or implicit in almost all systems of natural land units.

(31) Veatch, J. O., "Classification of Land on a Geographic Basis," Pap. Mich. Acad. Science, Arts, and Letters, 19:(1933) 359-365.

Name	No. on map	Soil	Topography	Vegetation
Missaukee clay plains........	16	Mainly sandy loams and dark-colored loams over impervious reddish clay; medium to high fertility	Flat or wet and swampy with low swells	Forest mixed hardwoods, maple, beech, elm, basswood, white pine, hemlock, fir, cedar and spruce
Grayling pine plains..........	17	Sands, dry, acid, low fertility and productiveness; large aggregate acreage of peat soil included	Level and pitted dry plains; smaller areas of sandy hill land; swamps and lakes included	Forest; Norway and jack pines; smaller growth blueberry, sweet fern, grasses, lichen; oaks and aspen second growth
Ogemaw pine hills............	18	Sands, dry, acid, low fertility; smaller aggregate of light sandy loams and sands underlain by sandy and impervious clays	High broadly rolling hills and plateau-like upland forming a drainage divide	Forest; Norway pine characteristic; in part white pine and mixed hardwoods, pine and hemlock
Gladwin clay upland.........	19	Sandy loams and light loams over red clay; medium fertility and productiveness	Moderately rolling and nearly level; small aggregate of wet land	Forest; mainly hardwoods, maple, beech, birch, basswood; local areas of mixed white pine; fir and spruce on wet land
Iosco sand plains.............	20	Mainly dry, acid sands of low fertility; small aggregate of wet infertile sands, and moderately productive sand over clay	Nearly level; low sand ridges on the lake shore	Forest; mainly Norway, jack and white pines
Montmorency hill land.......	21	Sandy loams underlain by sandy clay; moderate fertility; dry acid sands of low fertility included	Broadly rolling hills and both wet and dry sandy valleys and plains; high plateau-like upland	Forest; part pine and part hardwood hills, Norway, white and jack pines on the dry valleys and plains

Fig. 13. Table from "Natural Geographic Divisions of Land." From Veatch. This describes six of the sixty-five land types.

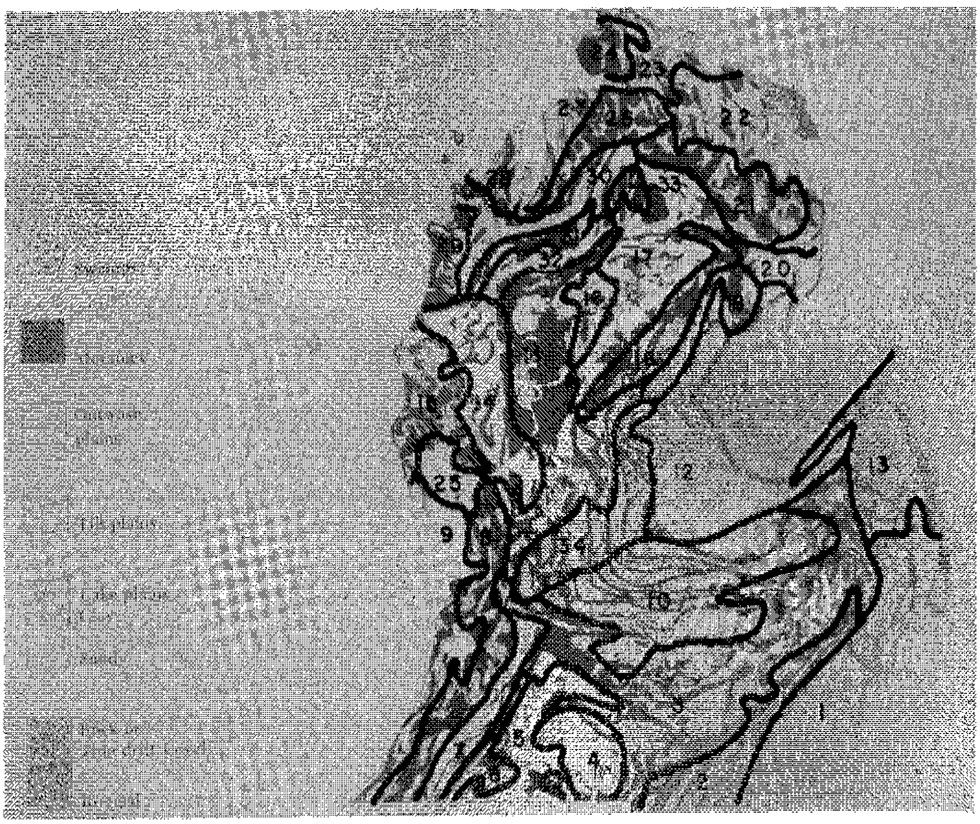

Fig. 14. The Southern Peninsula of Michigan showing the "Natural Land Divisions" after Veatch as an overlay on the surface formations. This shows strong correlation in the northern part of the peninsula.

basis, that is, by a combination or synthesis of its components such as surface, soil, vegetation, and drainage than on a single one of them. He writes, "physiographic divisions and topographic forms have served as a proper basis for the geographer's correlations... but two other factors enter which are not everywhere implied in the physiographic, or surface, divisions. These two factors are soil and vegetation... In effect what is here proposed is to add the factor of soil to the physiographic, or surface, divisions in mapping the land types..."

He proposes a land classification scheme consisting of a hierarchy of categories as follows: Zones, which are climatic; Divisions of these zones; Physiographic divisions; Units of separate relief features; Subdivisions of the relief features on the basis of soil. This final entity is presumably equivalent to a land type although this is not specifically stated, but in the table which follows entitled "Key to Land Types of Michigan" the units described seem to be land types and some of them bear names used earlier by Veatch for Michigan land types.

An important feature of the article and a principal reason why it is included in this report was a "Key" to the land types of Michigan that are separated into two "Divisions" (see above): the Podsol-forest land division and the Brown-forest soil division. As an example he adds a breakdown in greater detail of one of the major land types. The key which follows is reproduced from the pages of the original article.

After 1930 the land type concept graduated from the philosophic status and was put to use in practical land classification. The large amount of detailed inventory information resulting from the Land Economic Survey was not intended for a "highest use" classification, but in 1931 Schoenmann presented a paper before the Michigan Academy of Science wherein the natural district concept was used as a base for land planning (32). It is not necessary for this report to give the details of this long article, but, as might be expected, the environmental data were expressed in terms of the natural divisions that were used in the Alger County Report. Nine such districts had been found in the county "each possessing a marked unity and individuality of character throughout its entire extent, that places it in sharp contrast to each of the eight other natural districts." Schoenmann stated eight possible types of land utilization, and his problem was "to allocate these eight possible uses over the nine natural districts." He did not expect that "any one of these possible uses will survive... foreign competition, or even domestic competition by the other seven possible uses, except as it may find an unusually favorable setting and environment here."

This was an academic paper; it is not now known whether the local officials of Alger County profited from its findings. From the point of view of

(32) Schoenmann, Lee Roy A., "Land Inventory for Rural Planning in Alger County, Michigan," Pap. Mich. Acad. Science, Arts, and Letters, 16:(1931) 329-361.

Key to Land Types of Michigan

NORTH TEMPERATE LAND ZONE

Great Lakes Plains Region (physiographic-pedologic)

(Parent soil material unconsolidated glacial deposits)

I. Podsol-forest land divison (northern part of state)
  A. Dry, sandy-gravelly forested plains (major type)
    1. Pine plains type
      a) Norway pine — jack pine plains (Grayling subtype)
      b) White pine plains (more loamy and gravelly soil — Stambaugh subtype)
    2. Hardwood plains type
      a) Kalkaska subtype (more limy soils)
      b) Au Train subtype (less productive, acid hardpan soils)
  B. Diversified wet and dry, sandy, forested plains
    1. Sand and peat swamp type (mainly coniferous)
    2. Sand and peat swamp type (mixed hardwoods and conifers, more productive clay soils associated)
  C. Hilly sandy land (diversified topography, soils, and vegetation)
    1. Pine land, deep, dry sand (few lakes, streams, or swamps)
    2. Hardwood hills, deep sands, lakes, and swamps associated)
    3. Hardwood hills, heavier soils, and more stony land
  D. Sandy plateau upland and bench land
    1. Hardwood plateaus (intersected by deep valleys)
      a) Sandy table-land (steep escarpments and valley slopes)
      b) High stream-cut bench land (Munising subtype)
    2. Level and gently rolling sandy highland (lakes, swamps, shallow depressions)
  E. Lake bed clay plains (few or no lakes, generally not stony)
    1. Low-lying clay-swamp plains (Chippewa subtype)
    2. High, stream-cut clay plains (Ontonagon subtype)
  F. Rolling, stony, clay plains (lakes and swamps)
    1. Clay-ridge type (oval or parallel ridges, sandy and swampy valleys associated)
      a) Hardwood ridges (more limy soils)
      b) Hardwood and conifer ridges (high altitude, very stony, Iron County type)
    2. Rolling, clay plains (large proportion of wet land associated)
    3. Stony, clay land — swamp type
      a) Stony loam, hardwood–conifer land (rock outcrop, wet mineral soil and muskeg swamp associated — Gogebic subtype)
      b) Limy soils (Trenary-Onaway subtype)
  G. Stony, bedrock plains and plateaus
    1. Limestone bedrock type
    2. Sandstone bedrock type
    3. Crystalline bedrock type
  H. Superior highland, mountainous plateau and rock-knob land
    1. Huron Mountains type
    2. Copper Range rock-knob type
    3. Negaunee rock-knob type
  I. Swamp-plain type
    1. Spruce–cedar swamp, small bodies of wet and dry sands associated
    2. Swamp with islands of loam and clay soils associated
  J. Dune type
  K. Water (larger water-covered areas)

II. Brown forest-soil land division (southern part of state)
  A. Dry, sandy, gravelly plains (major type)
    1. Oak–hickory land (more clayey and more productive soils)
      a) Smooth plain subtype
      b) Deeply pitted, lake-swamp subtype
    2. Pine–oak land (deeper sands and less productive soils)
      a) Southern oak–hickory sandy land
      b) Northern pine–oak sandy land
      c) White pine–hardwood land (gravelly and more loamy soils)

3. Prairie land (only a few areas of sufficient size to constitute separate land types)

B. Diversified wet and dry sandy plains (few or no lakes and streams)
   1. Intermixed wet and dry sands (sandier and less fertile soils)
   2. Intermixed wet and dry sands (large proportion of clay and the more fertile wet sandy soils of the Wauseon-Gilford types)

C. Hilly sandy land (basins, knobs, lakes, swamps, few streams)
   1. Pine and mixed hardwood subtype (dominantly deeper sand)
   2. Oak–hickory and maple–beech subtype (higher proportion of sandy loam and loam soils)
   3. White pine–hardwood land (higher proportion of sandy loam)

D. Level lake-bed clay plains land (more fertile soils, hardwood forest)
   1. Darker wet clay land (muck land associated, no lakes, few streams, not stony)
   2. High clay land (partly stony, more deeply trenched by streams)

E. Rolling clay plains land
   1. More level land (few or no lakes and streams, swales and plats of dark-colored soil, small proportion of muck land)
   2. Rolling land (large proportion of muck and other swampy land in net form or in widely distributed shallow basins)
   3. More strongly sloping land (stream dissection, very small proportion of swamp)

F. Dune land

G. Muck swamp land (only a few areas of sufficient size to constitute a separate land type)

As an illustration of how the major land types of the state may be subdivided into a great number of smaller units, the dry, sandy, gravelly plains (II A) of the southern part of the state are selected:

DRY, SANDY, GRAVELLY PLAINS (MAJOR LAND TYPE)

Oak–hickory and other hardwood land (Fox type of soil comprises 50 per cent or more of the area)

I. Smooth highland (relatively few streams, lakes, and swamps)
   A. Heavier soils (maple, beech, oaks, walnut, elm, etc.)
   B. Sandy soils (oaks or oak–hickory)

II. Pitted and diversified plains (lakes and swamps numerous)
   A. Heavier soils (mainly loams)
      1. Cobbly and gravelly soils
      2. Soils free from stones
   B. Lighter soils (mainly sandy loams and sands)
      1. Level land
      2. Basin slopes
   C. Dark soils (maple, beech, elm, walnut, oaks, etc.)

III. Valley plains
   A. Chains of lakes and swamps
      1. Deep sand soils associated
   B. Terrace plains bordering rivers (few or no lakes)
      1. Loamy and darker soils
      2. Lighter and sandier soils

IV. Dissected terrace plains and escarpments (no lakes or swamps)
   A. Slopes with moist and dark soils at the base
   B. Slopes with dry sandy and gravelly wash at the base

Subdivision may be carried even farther than has been done here, although there may be no practicable need for such refinement. The particular unit selected for mapping will depend upon the scale of the base map used and the purpose in mind.

this report it was the first time the natural district concept had been put to use in land planning in Michigan.

The second published use of the land type as an application tool appeared in a bulletin by Veatch in 1933 (33). In his earlier (1930) writing he had divided the state into sixty-five natural land divisions. Each of these was a discrete geographical unit identified by a local name. The criteria he used to separate the divisions seem to have been mainly soils but, as has been pointed out, these had concordance with the natural districts used by the Survey. The 1933 bulletin was an attempt to express the agricultural value of the land of the state. The approach was through the delineation of "Major Land Types of the state (which) according to present studies can be embraced into 10 or 12 divisions." Actually he listed eleven of these major land types with twenty-one subtypes stated and others implied. There were:

Lake Bed Clay Plains Type	Sandy Plateau Type
Rolling Clay Plains Type	Rock Plains Type
Dry Sandy Plains Type	Rock Knob Type
Sandy Hill Land Type	Swamp Plains Type
Wet Sandy Plains Type	Dune Type

Each of these, he states, "is a natural division based upon the intrinsic nature of the soil; the nature of the soil association, a uniformity or complexity of distinct types; the topography; the natural drainage and the native vegetation. A map of natural land types would be subject to no greater change and would have no less permanent value than a soil or geological map. The economic significance of a land type, however, will vary in accordance with the changes in economic conditions and scientific discovery and advance in agriculture" (34). The types were described in considerable detail and seem to be, from these descriptions, similar to the natural districts used by the Survey and some of them identical with or similar to those delineated by Ross Pearson in Ogemaw County (35) in what appears to have been the last practical application of the land type concept in Michigan twenty years later.

Veatch then assigned an agricultural value to each of the land types. This value was not necessarily the same for the same land type wherever found in the state because of differences in climate and extent of agricultural use of the local area. He separated the land into first, second, or third class for agriculture. This classification also had local variations so that first

(33) Veatch, J. O., Agricultural Land Classification and Land Types of Michigan, Spec. Bull. No. 231, Agr. Expt. Station, Michigan State University, Section of Soils, Apr. 1933, East Lansing.

(34) No map of the distribution of these land types as such appeared with the article. Possibly Veatch used the map of the 1930 article as a basis.

(35) Pearson, Ross N., "Some Values from Recreational Land Use in Ogemaw County, Michigan," Pap. Mich. Acad. Science, Arts, and Letters, 40:(1955) 217-227.

class land in one area might have potentially but not actually the same value as first class land in another. A map composed of colored dots showed the state distribution of these three classes of agricultural value. This map was later revised to include a fourth category (36) and still later generalized for black and white publication that is reproduced in Fig. 15. On this the differences in classification is somewhat apparent in the pattern of the moraines (third class) which border the High Plains in contrast to the inner surface of sand plains (fourth class).

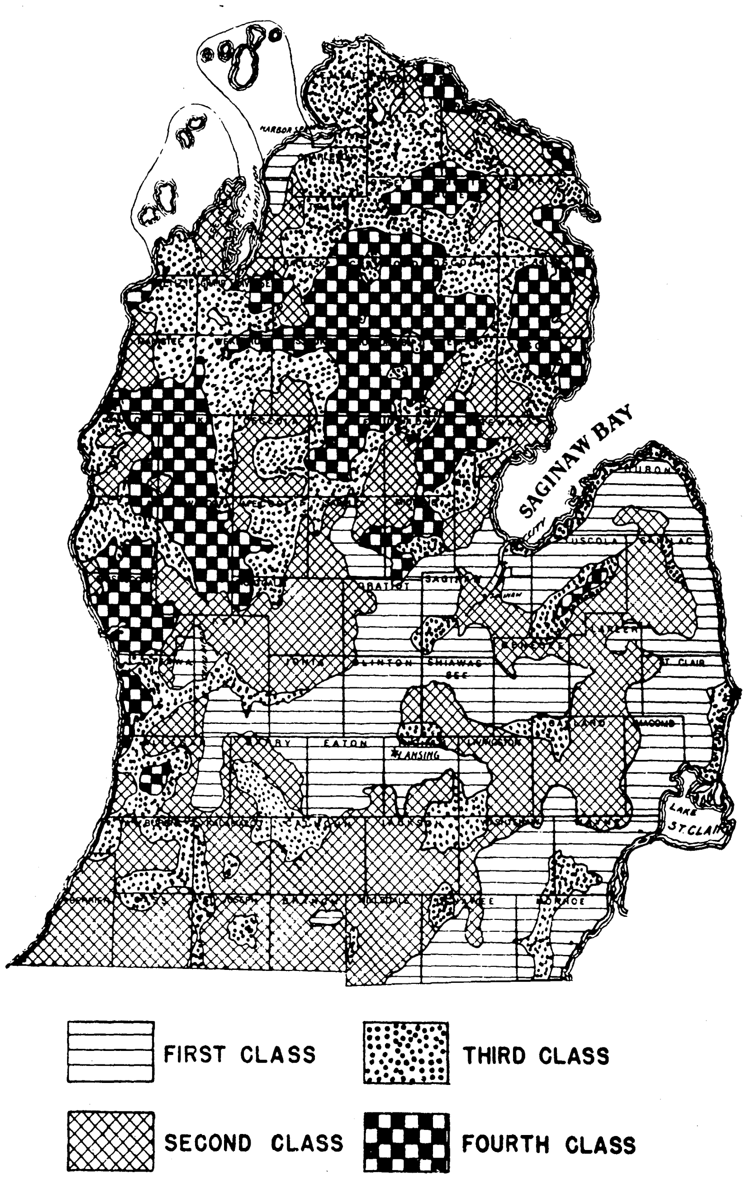

Fig. 15. The Lower Peninsula of Michigan from Veatch's map in the <u>Land Classification and Land Types of Michigan</u>.

(36) In Bulletin 290, Agr. Extension Service, Mich. State Univ.

Veatch's last paper in which he used the land type pattern as a framework for assembling land data appeared as a bulletin for the benefit of fruit growers in the southwestern part of the state (37). In this, the four major physiographic divisions of the county were divided into seventeen land types. Each of these was described in terms of its topographic components, soil components, native vegetation, hydrographic components, and related land types. Each was evaluated for orchard purposes in fairly specific recommendations and instructions for fruit growers. The map which accompanied the bulletin was on approximately 1:75,000 scale and showed the separate distributions of each land type, in places fifteen or more areas of a single land type, so that a grower could locate his land with accuracy down to ten acres or smaller. Unfortunately no descriptions of the field techniques are included; from the date it could be possible that the AAA air photography was available and this may have been the first land typing done with air photography.

By the mid-1930's the land type had been firmly established as a tool in land research in Michigan; elsewhere somewhat similar ideas were developing among soil scientists. Although the Land Economic Survey had been discontinued the materials it had collected were available for research purposes and its techniques were still models. During the depression and "New Deal" years federal projects, notably the Tennessee Valley Project, engaged the attention of land students; state agencies were busy on various enterprises under the Submarginal Land Program and similar governmental undertakings. In the second half of the decade, however, there was a general return to state supported research and to the use of the land type.

Of a number of papers prepared by the staff of the Agricultural Experimental Station at Michigan State University it is useful to mention two by Ivan Schneider that utilized the land type as a basic tool. The first of these (38) was an investigation of land ownership, especially public ownership, in relation to land quality. Dickinson County had not been covered by the Survey and Schneider made a land type survey as a basis for his operations. The paper does not give any details of this except to say that the land types were "consolidated into only four types" rated for agricultural purposes on the basis of their physical characteristics.

A second paper (39) made a survey of the number and condition of farm

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(37) Veatch, J. O., and Partridge, N. L., <u>Utilization of Land Types for Fruit Production,</u> Berrien County, Michigan, Spec. Bull. No. 257, Agr. Expt. Station, Michigan State University, East Lansing, Dec. 1934.

(38) Schneider, Ivan F., "Land Ownership in Relation to Land Types in Dickinson County, Michigan," <u>Pap. Mich. Acad. Science, Arts, and Letters</u>, 25: (1939) 437-442.

(39) Schneider, Ivan F., "Changes in the Distribution of Farm Buildings in Relation to Land Types in Charlevoix County, Michigan, <u>Pap. Mich. Acad. Science, Arts, and Letters</u>, 28:(1942) 455-463.

buildings in Charlevoix County and compared this with the data from the original Survey mapping of the same county twenty years previously. The natural divisions or land types established by the Survey were used as a measure of the land quality. The findings showed that agriculture had expanded and prospered to some degree on the land types best suited to farming and had dwindled on others.

II

The delineation and use of land types as composite units in Michigan, so recognized and mapped in the field as contrasted to their employment as summary devices, was initially done at the field camps conducted by the Department of Geography at Wilderness Park in Emmet County. These were under the direction of Professor Kenneth C. McMurry (40) and were engaged in training graduate students as well as used for headquarters for land research undertakings. Lovejoy, Veatch, and Schoenmann were frequent visitors at the camp and participated in the instruction. The curriculum was based on soil and cover mapping by foot methods and economic inventory from public records following the techniques and practices of the Land Economic Survey. In 1937, probably through Veatch's interest, "land typing" became a part of the instruction. It was done by groups in which some or all of the students had experience in basic soil and cover mapping from a previous camp season.

Leverett's map of surface formations furnished the basic pattern for differentiation. By reconnaissance land types were identified in terms of surface, soil, and cover. This followed Veatch's idea mentioned earlier in this section "to add the factor of soil to the physiographic, or surface division." The land type boundaries were established by road traverses in automobiles and run out by pace methods where necessary. As might have been expected there was always the temptation to estimate rather than to pace and also to generalize difficult soil complexes (41). Land typing was popular with students because land types were large and readily identified units and much of the work could be done from an automobile in contrast to foot mapping of soil and cover.

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(40) Kenneth C. McMurry was chairman of the Department of Geography at The University of Michigan for thirty-three years. He was a contemporary of Lovejoy, Veatch, and Schoenmann and participated with Sauer in the Academy deliberations that led to the formation of the Land Economic Survey. For many years he directed summer field camps in northern Michigan in which the curriculum was based on Land Economic Survey techniques. In these camps many geographers and geography students acquired their basic field training.

(41) The writer was Professor McMurry's assistant at the Wilderness Park camps in the summers of 1937 and 1938.

Fig. 16. J. O. Veatch at Wilderness Park, 1938.

Some of the land typing work done by camp students reached publication. A good example is furnished by a study by Mary Stirling (42) from which the following extracts and illustrations indicate methods and results. "After a reconnaissance of the county had been made, a tentative set of land types was established, representing constant combinations of soil, drainage, vegetation, and landforms. Thus considered without reference to land use or occupancy the land type is a synthesis of physical characteristics which generalizes relatively large units in the field. In this investigation boundaries were sketched from an automobile when possible and distances were checked by the speedometer or by a plane table in areas not accessible by road. Before field work was begun the base map was drawn up from the original land-office survey plat and the roads were added.

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(42) Stirling, Mary Caroline, "Land Types in Emmet County, Michigan," Pap. Mich. Acad. Science, Arts, and Letters, 24(1938) 55-59.

Mary Stirling, now Mrs. Richard Cross, was a graduate student in geography at The University of Michigan.

(The) county is divided into three kinds of surfaces: sandy lake plain, outwash plain, and moraine... The land type breaks these regions down into more specific groupings without achieving the detail of the standard soil or farm-forest map." The northern half of the county was surveyed and divided into ten land types on the pattern presented in Fig. 17.

The article also contained a map showing the correlation between the land type mapping and the detailed soil mapping done by other groups of students (Fig. 18). This shows good correlation between land type and soil boundaries in the western part but much poorer in the eastern. This the writer suggests, results from similarity between some of the eastern land types, generalization by the land typers, and also imperfect field work.

An illustration of interest in this article is a diagram (Fig. 19) which shows land types as composites of a generalized schematic drawing of the soils of the county. The drawing, the basis of the diagram, was sketched by Schoenmann during one of his visits to Wilderness Park and later made into a finished drawing by Richard Goldcamp; to this Mary Stirling added the land types. The soil drawing is, of course, diagrammatic rather than actual but does illustrate well the complexity of soil types on glacial landforms.

Three other papers resulting from the summer camp training of geography students can be found in the Michigan Papers. Dick and Ware (43) made a map and a correlation study of the land types of Livingston county; this was published individually but was actually preliminary to a larger general study of the county completed by Ware after Dick's death in an accident. Foster's article (44) deals with somewhat the same materials as those contained in Schneider's study of the following year (see footnote 39) and was also related to Mary Stirling's earlier land typing. Pearson (45) used the land type pattern of Ogemaw County in a manner somewhat resembling the economic Reports of the Land Economic Survey in his study of tax values and recreational land use. This article, published in 1955 is the last reference which this investigator can find of the use of the land type as a tool in Michigan. However, the references cited probably do not represent every instance in which the land type was used in land research; "title search" as noted in connection with Pearson's article is an imperfect check. There were also several other doctoral dissertations on northern Michigan topics in which the land type concept was used.

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(43) Dick, W. B., and Ware, S. J., "A Land Type Map of Livingston County, Michigan," Pap. Mich. Acad. Science, Arts, and Letters, 25:(1939) 373-383.

(44) Foster, Fred W., "Farmsteads and Land Types in Emmet County, Michigan," Ibid. 27:(1941) 351-367.

(45) Pearson, Ross N., "Some Values from Recreational Land Use in Ogemaw County, Michigan," Ibid. 40:(1955) 217-227. This paper, mentioned earlier and used later in this report, is an example of one that might be missed by "title search" alone as it uses land types as a framework for data assembling but does not contain the words "land type" in its title.

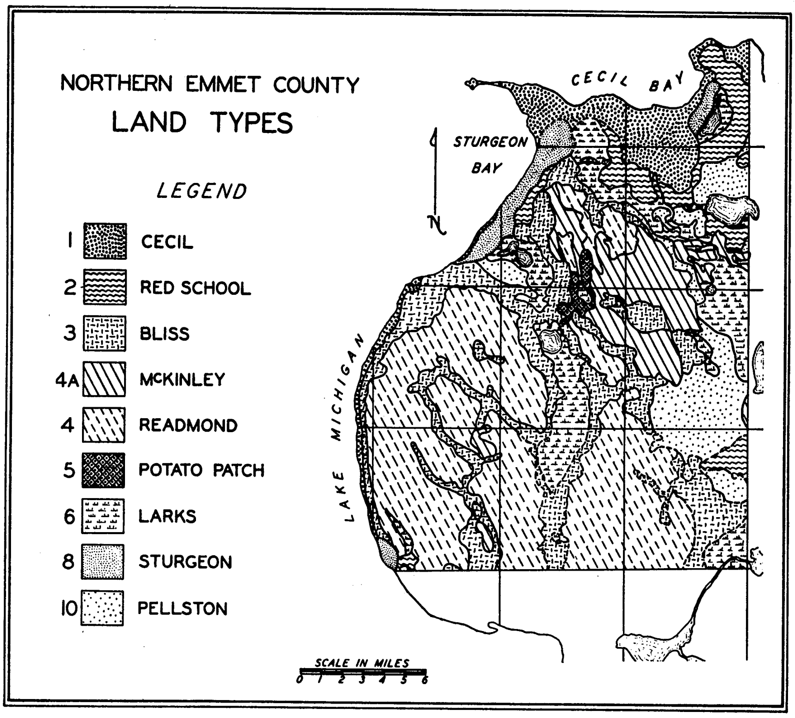


Fig. 17. Land types, Emmet County.

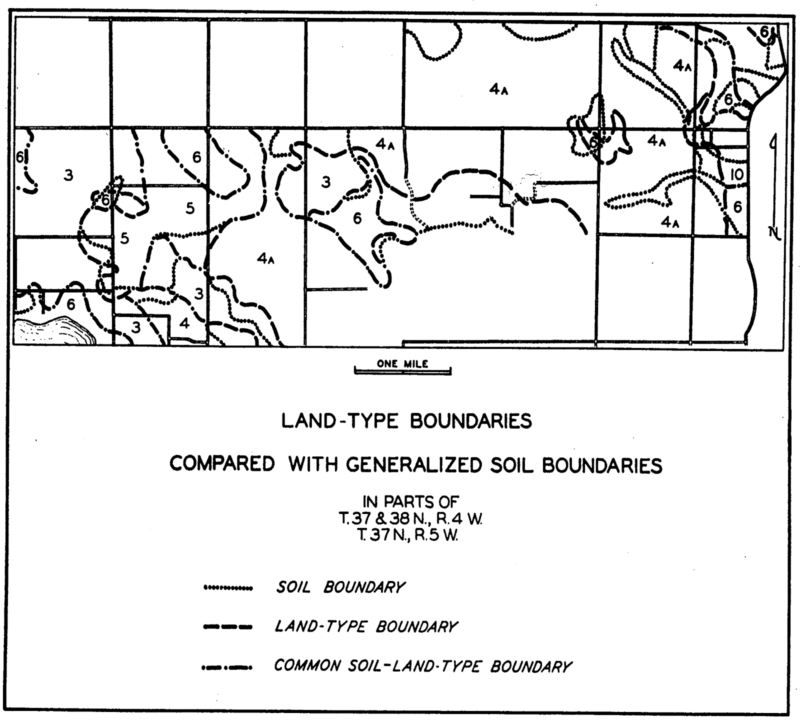
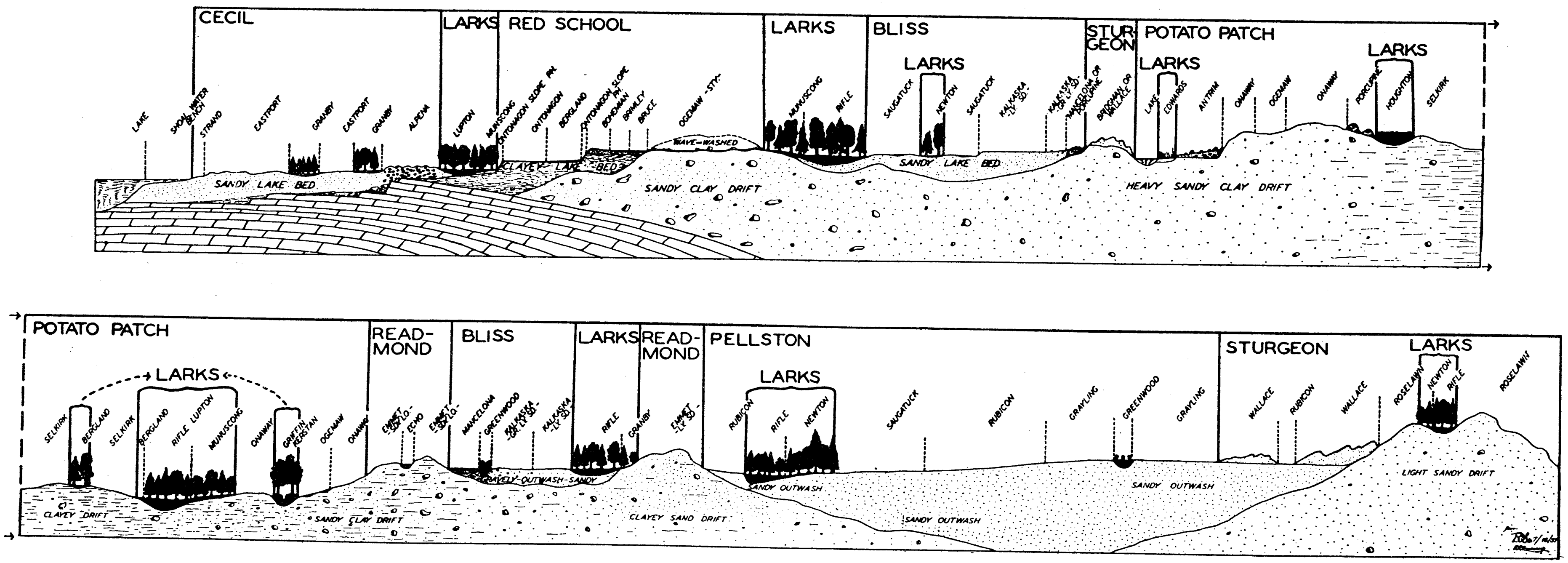


Fig. 18. Land types and soil boundaries, Emmet County. From Stirling, "Land Types of Emmet County."



PHYSIOGRAPHY AND SOIL DIAGRAM

FROM LEE ROY A. SCHOENMANN

Fig. 19. Soil types and land types in Emmet County, Michigan. Drawing also illustrates catenary relationships of soil types on glacial landforms. From Stirling, "Land Types of Emmet County."

III

It should be noted that the employment of the land type by The University of Michigan geographers at Wilderness Park was in a much different context than its earlier use by the Survey or by Veatch in his theoretical and philosophical writings on the subject. The Survey had "discovered" the land type, or the natural division as it was sometimes called, by boundary correlations of individually mapped single landscape factors and had used it only as a summary device. Many of Veatch's articles were theoretical in nature and the land types he delineated were synthesized from soil and surface maps of the state as a whole. The geographers at Wilderness Park, in contrast, recognized the land type as a composite unit in the field and mpaped it as such from direct observation. Although they probably did not know it, other mapping of composite units was being done elsewhere.

To what extent the thinking and writing of Veatch on the land type concept diffused out of Michigan cannot now be appraised. During the early 1930's there was much speculation and writing on composite landscape units and surface classification in various parts of the world. The Transactions of the Third International Congress of Soil Science in 1935 contains a number of papers on such subjects. As an example, one of these may be cited (46). It was an article written by Charles E. Kellog, then a member of the U.S. Department of Agriculture referring to a land classification system published the same year as a bulletin by Kellog and Ableiter, and setting forth a basic land classification method using composite units. Such a classification, he states, may be made by recognizing "natural land types" which are distinct combinations of climate, soil, relief, stoniness, and (natural) vegetation. This would seem to be identical with the ideas contained in Veatch's 1930 paper. The 1937 Soil Survey Manual indicated that the delineation of the "natural land types" was the first step in a soil mapping undertaking. Kellog continued in a theoretical way that these natural land types may be classified in terms of their use-groupings to form "social land units," a concept which comes close to the work of DeVries on correlation of economic factors as well as that of Ivan Schneider (47).

IV

The question might be asked, "what happened to the land type concept?" There is no single answer to this. After the depression times there were no

(46) Kellog, C. E., "A System of Land Classification," Trans. of the Third International Congress of Soil Science 1:(1935) 283-286.

(47) See footnote 38.

additional large scale land surveys in the lake states wherein the idea might have been useful. Although Veatch and The University of Michigan geographers continued to employ land types this was done principally in academic work. It would seem that the idea died because there was no more need for it.

The land type was a local concept. Much of the literature cited earlier appeared in the _Papers of the Michigan Academy of Science, Arts and Letters_ and apparently did not greatly influence land students elsewhere in the country or abroad. When the Northern Australia Land Survey was planned in 1947 the land type and Veatch's work were unknown (48). Rural land inventory and planning in the United States were important undertakings during the depression years when personnel and federal funds were available but became less significant after World War II when attention to land problems shifted to postwar reconstruction efforts on a world basis as exemplified by numerous United Nations undertakings. After the war also, geographic scholarship turned away from descriptive land studies in which the land type might have been a useful technique to other types of geographical research.

Finally, the land type concept was not a very profound one. In Michigan it arose _ad hoc_ from necessity. Somewhat similar ideas were developed in several parts of the world. Wherever land inventory and land classification needed to be done, some sort of natural units were found to suit the purposes. A few of these will be mentioned in following pages.

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(48) Stated in a letter from C. S. Christian, September 28, 1966.

REVIEWS OF SOME OTHER EXAMPLES OF COMPOSITE MAPPING

The work in Michigan on the land type and the natural land division was probably unique in the sense that it is not a direct antecedent to a number of other concepts dealing with composite landscape units which developed during the decade of the 1930's. These techniques for recognition and delineation of landscape units had one characteristic in common: they were all based on land surface differences for their major regionalization. This might be called "landforms" "geomorphology" or "topography." The principal reason for this commonality would seem to be that land surface was the element most readily seen and the boundaries of its composing units were observable in the field as well as on air photographs which came into increasing use during the decade. There had been considerable attention to land surface classification previous to 1920 and many land students, particularly soil scientists were trained in geology.

Another reason for interest in composite recognition came from the geographers who at that time put much stress on a "regional" approach to their subject. A region was thought of as an area which possessed for the purpose of study significant internal similarity and external differences (49). Major regions had been recognized for centuries but in the 1930's, attention to "microgeography" produced a profusion of regions, subregions, and smaller divisions in heirarchial systems both in research studies and in textbooks. Some of this writing was based on very vaguely defined criteria or on no criteria at all. Nevertheless there was a general concept that the earth's surface was made up of a mosaic of small regional units of homogeneous nature that could be put together in varying degrees of detail for different purposes.

THE MONTFORT STUDY AND THE TENNESSEE VALLEY MAPPING

One method which resulted in composite units, however unintentional, was developed by Vernor C. Finch and his students in the Montford area in southern Wisconsin (50). This was intended to map the landscape components as they occurred without specific attention to any composite boundaries. The mappers recorded the land conditions in three categories of environment: slope, soil, and drainage as the denominator of a fraction of which the land use in several categories was the numerator. Wherever any one of the conditions changed a

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(49) Treated at length by Whittlesey in American Geography, Inventory and Prospect, Syracuse University Press, 1954.

(50) Finch, Vernor C., "Geographic Surveying" and "Montfort." Bulletin of the Geographic Society of Chicago, 9:(1933) 3-44.

boundary was drawn. The mapping was in complete coverage, not by traverse or sampling. The result was an enormously detailed map of homogeneous units which required so much foot work that Finch doubted the utility of the technique (Fig. 20). However from the unit map could be derived thematic maps of the environmental elements and the specific land uses.

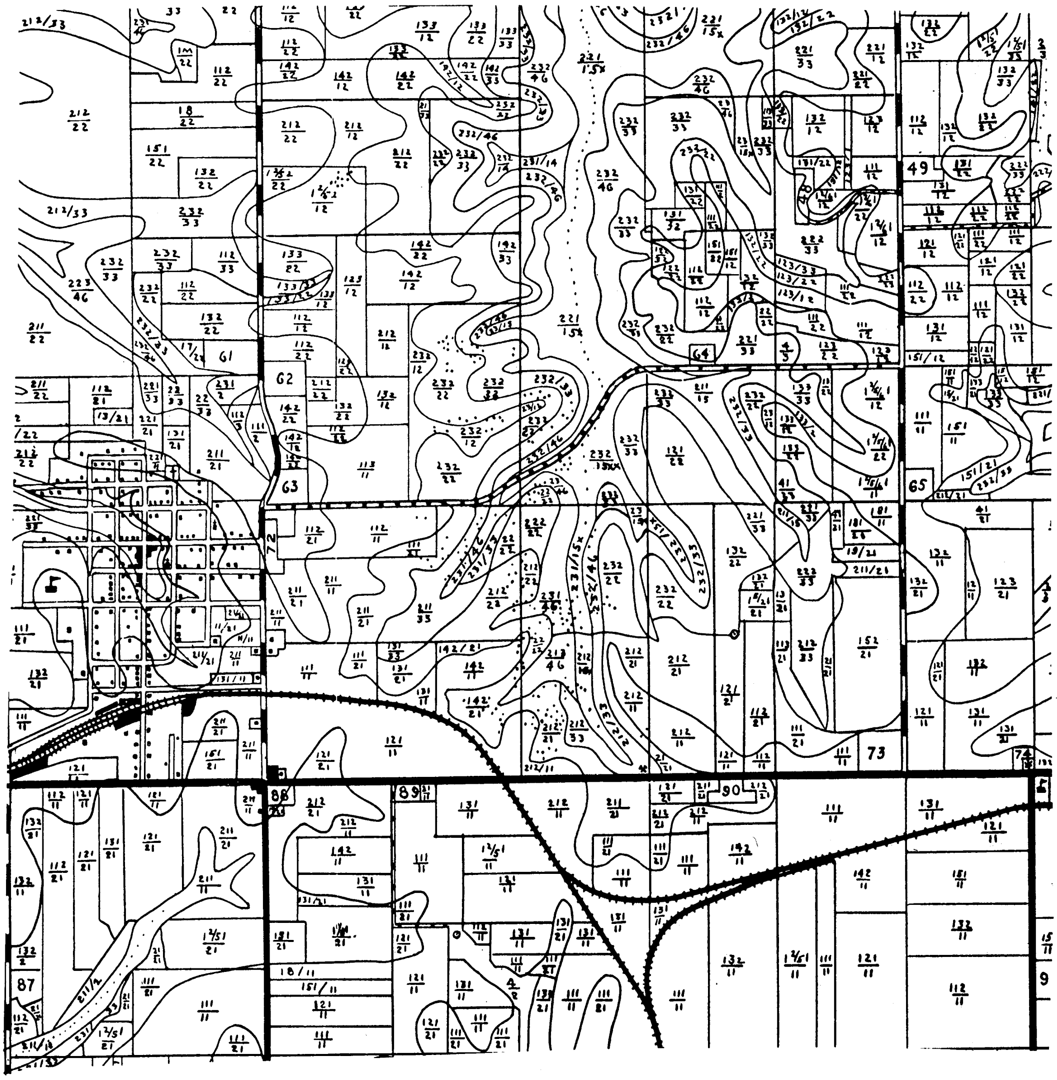

Fig. 20. Section of the Montford study mapping. Numerator of the fraction represents land use, denominator represents environmental components. Published scale approximately 1:15,000.

The Montfort method had some qualities related to the techniques developed by G. Donald Hudson and his associates for the "Survey of the Tennessee Valley" in 1934 and following years. In this large area mapping undertaking airphoto mosaics were available to reduce the amount of boundary identification and the mappers used automobiles for transportation. Each apparent unit area on the mosiac within a minimum size was investigated and its characteristics recorded in a fractional code considerably more complicated than that used in the Montfort study. The mapping was complete in coverage in the sense that each area was observed and recorded rather than based on some other similarly-appearing entity on the mosaic.

The Montfort study was an experimental trial of a method suggested by the "Spring Field Group" an informal field meeting of a number of prominent geographers (51). The Tennessee Valley method was developed for the problem in hand. So far as this writer knows, these were the first substantial mapping attempts in the United States that resulted in composite units.

Although the Montfort study and the Tennessee Valley mapping were similar in their recording codes, they were much different in their basic concepts. The Montfort work was actually a continuation of the Land Economic Survey methodology of simultaneous thematic mapping of several components. The resulting "composite" units were actually the small areas which happened to lie within the boundaries of the most restricted component. They were not recognized as composites in the field or mapped as such. Some of the boundary correlation is due to the nature of glacial terrain that has been discussed previously.

By contrast the Tennessee Valley mapping had qualities that pointed toward the composite mapping later carried out in the Australian surveys in the next decade. Each of the Tennessee Valley units were recognized as such from some key component on the air photographs and the characteristics seen in them were presumed to occur throughout the unit. Each unit was considered unique although there must have been many that were essentially alike. This point is probably of little significance because the mapping was to have been in complete coverage and was intended as an inventory of the valley area rather than a sampling.

BOURNE AND MILNE

At about the same time as these practical experiments in the United States, two British scientists were writing about composite units. Bourne, in his assessment of agricultural resources, set forth the concept that major regions are composed of "sites" which were homogeneous composites of climate, land surface, soil, and vegetation (52). The site would seem to be theoretically about the same thing as mapped in the Montford study without the land use factor and practically quite similar to Veatch's land type. Bourne's work was not widely noted in the years immediately following its publication but was almost identical with the conceptual approach of the Australian surveys (53) and is acknowledged by Webster as the philosophical basis for the land analysis system used by the MEXE-Oxford group, reviewed later in this report.

(51) The group varied from year to year: a photograph taken about 1934 shows K. C. McMurry, V. C. Finch, C. C. Colby, Derwent Whittlesey, and Wellington Jones. Whether or not this was most of the membership of that year is not known.

(52) Bourne, R., "Regional Survey and its Relation to Stocktaking of the Argicultural Resources of the British Empire," Oxford Forestry Memoirs 13: (1931).

(53) See Alan Stewart's comment in footnote 65.

A few years later Milne, working on soils in Africa, proposed the idea of the "catena." This was a recurring association of soils of widely differing morphologies which were found together in similar situations (54). As examples he cited different drainage conditions within the same geological formation and erosion of two kinds of geological structures, a bed rock and a cap rock. Such catenary relationships in soil distribution had been known but not as "catenas" to the Land Economic Survey mappers, especially Schoenmann (see Fig. 19), as common in the individual landforms of glacial deposition but probably were considered too obvious to mention. The detail required by the Michigan survey made catena mapping impractical even had it been known in the years before Milne gave it a name.

THE AUSTRALIAN SURVEYS AND THE LAND SYSTEM

Probably the most significant use of composite units in wide area mapping is to be found in the work of the Division of Land Research of the Commonwealth Scientific and Research Organization in Australia. This pioneering and very successful mapping system originated from circumstances that were in many ways similar to those which engendered the Land Economic Survey in Michigan.

The northern third of the Australian continent is an area of sparce natural resources other than mineral deposits. It has a tropical wet and dry climate that produces a savanna and savanna-woodland vegetation providing some, but not very extensive or rich pastureage in its natural condition. Much of the area is owned by the Australian government and some of it is used by graziers under Crown leases. Little of the area had been mapped and its agricultural and pastoral potential was known only in the most general terms. Following World War II, the C.S.I.R.O. organized the Northern Australia Regional Survey (55) in 1946 to "describe, classify and map, and assess the land use, developmental possibilities, and technical problems" of this area. The Survey was placed under the direction of Mr. C. S. Christian, now a member of the Executive of the C.S.I.R.O. and an internationally famous land specialist. Mr. Christian and his associate Mr. G. Alan Stewart, presently chief of the Division of Land Research, formulated the techniques for the survey based upon a concept that has become known as the Land System method.

> "The technique of the survey was a matter for considerable thought during the early part of the investigation... The survey was planned as a reconnaissance, therefore it could function and interpret

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(54) Milne, G., "Some Suggested Units of Classification and Mapping Particularly for East African Soils," Soil Research 4:3(1935) 183-198. Also, "Composite Units for Mapping Complex Soil Associations," Transactions, Third International Congress of Soil Science, 1:(1935) 283-286, London.

(55) The name was later changed to that stated in the first paragraph of this section.

only on a broad scale. The usual methods of detailed land classification could not be adopted. It was necessary to observe and define the major soil and vegetation units and to determine their relationships and distribution, but because of the limitations of time and the large area to be covered, it was not possible to map these units as such. A much broader mapping unit, a composite unit, had to be devised, one composed of a number of land type units" (56).

The composite unit which was devised was the "land system." According to Christian this "originated in Australia quite spontaneously" (57) from the necessity of the survey and was in fact his own concept. It is based upon the assumption that "each part of the land surface is the end product of an evolution governed by parent geological material, geomorphological process, past and present climates, and time" (58).

The Australian approach recognized the following heirarchy of composite units: the site, the land unit, and the land system. Of these only the land system was used as a mapping unit in the field. The site was recognized as being a homogeneous entity and a component of the land unit but much too detailed for the mapping scale of the surveys. In defining land units, Christian considered that "parts of the land surface having similar genesis can be described similarly in terms of major inherent features of consequence to land use; namely, topography, soils, vegetation and climate, and are regarded as being members of the same land unit" (59). The land unit, thus described is not necessarily a homogeneous unit such as the "site" as used by Bourne, but rather is identified by the similarity of such of its characteristics as are of "consequence to land use." An example cited by Christian is that of a land unit composed by a whole mountain structure with a variety of slopes, soils, and vegetation but which would have similar capacity in terms of land use.

If judged by the criteria of similar genesis and potential for land use, these land units are quite similar to the "natural divisions" used by the Michigan Land Economic Survey and by Veatch in his land type studies of the state. As a basic unit, although it was conceptional only and not used in the mapping process, the land unit has been criticized in Australia by ecologists because of its insistence on geomorphological-genetic unity. They hold that the basic unit should be one of similar instrinsic qualities and that genetic origin is subject to individual interpretation. In later soil studies a homogeneous basic unit was added by Gibbons and Downes (60).

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(56) Christian, C. S., and Stewart, G. A., Survey of the Katherine-Darwin Region, Land Research Series No. 1, C.S.I.R.O. (1952), pp. 20-21.

(57) From a letter from C. S. Christian, September 28, 1966.

(58) Christian, C. S., "The Concept of Land Units and Land Systems," Proc. of the Ninth Pacific Science Congress, 1952, Vol. 20, p. 75.

(59) Christian, ibid, p. 76.

Whatever was its validity as a basic concept, the land unit was also too detailed an entity for field mapping as necessitated by the scale and scope of the northern Australia survey. Some grouping of the units was required. For this purpose the land system was recognized and used. A land system is a grouping of land units which are "geographically and genetically related." As defined by Christian it is a "composite of related units as an area or a group of areas throughout which there is a recurring pattern of topography, soils, and vegetation. A change in the pattern determines the boundary" (61). The mappers recognized "simple" land systems which were associations of closely related land units; "complex" land systems which were actually associations of closely related simple land systems; and "compound: land systems, groupings of land systems, presumably complex themselves, associated for convenience in mapping. The boundaries of the land systems, identified in the field, could be traced on the air mosaics in the laboratory.

The methodology of the survey consisted of three major steps: The first of these was an examination of a rough mosaic together with such other information as was available to gain an understanding of the major lineaments of the area and to recognize on the air photographs recurring patterns of units. According to Christian, "the occurrence of a number of units in a recurring pattern on the ground gives rise to recurring patterns on the aerial photographs... The recognition of these air photo patterns and the determination in the field of the land characteristics associated with each component part of the pattern is the basis of the method used in the Australian Land Research surveys"(62). In this preliminary examination, supplemented by some field reconnaissance, geological structures, drainage systems, and general topography could be identified. The resolution of the photographs did not permit accurate identification of the vegetation but changes from one vegetation cover to another could be seen as tone changes.

The second step was the accomplishment of field traverses planned to sample the land as thoroughly as the requirements necessitated at specific points. The survey team consisted always of a geomorphologist, a soil scientist, and a plant ecologist; these were reinforced by such other scientists and specialists as the objectives required. The team traveled overland by jeep-type vehicles making such use as was possible of tracks but often through unbroken brush country, guided by a pathfinding group using compass and navigational procedures.

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(60) See footnote 63.

(61) Christian, op. cit., p. 76.

(62) Christian, C. S., and Stewart, G. A., Methodology of Integrated Surveys, UNESCO Conference on Principles and Methods of Integrated Areal Survey Studies of Natural Resources for Potential Development. Toulouse, Sept. 1964 (manuscript) p. 94. This most valuable document contains mention of most of the present land survey undertakings in the world and contains an extensive bibliography.

Detailed observations were made by the scientific team wherever necessary especially in the middle and at the borders of apparent land systems, approximately one observation to each five to ten miles of traverse. The speed at which an area could be covered depended upon the complexity of the surface as well as the ease of travel. In open Australian country as much as 175,000 square kilometers was done in a single field season; in the difficult terrain and cover of New Guinea, as little as 5,000 could be covered in a season.

The third step was the laboratory assemblage of the information and its extrapolation to the land system pattern on the air mosaic. From this a report and a map were published. The report contained sections on climate, geology, geomorphology, soils, and vegetation together with special sections on water resources, pasture resources, and present and past land use. Each of the land systems was described and illustrated (Fig. 21) and the map showed their distribution. A portion of a map is reporduced in Fig. 22.

There has been criticism of the survey in Australia: that it is too broad a network for effective land planning; that the extrapolation to considerable areas of a point sample produces too many individual errors in the map; and that the use of genetic units of geomorphology as the base for general land potential mapping is unsound. To an objective reviewer some of these seem to be negated by the announced objectives of the survey: it was to make a reconnaissance scale examination of large areas not a detailed examination of individual potentials; if geomorphological units recognizable on the mosaics were not suitable for the purpose, one might ask, "What else was available?" During the two decades since its inception the method has been used and also modified in several other parts of the world.

One of the intentions of the survey was that its findings could be used as base information in such areas as seemed to have agricultural or pastoral potential. One such extension of the system was made by Gibbons and Downes in southern Australia to map principally soils and vegetation (63). For this more detailed purpose it was necessary to increase the hierarchy of land units as proposed by the northern Australia survey by adding the "land component," a small and homogeneous soil-vegetation unit to analyze the land unit, recognized by but not mapped, in the northern survey. This seems to have in terms of vegetation and soil about the same relationship to the rest of the heirarchy as does Christian's "site." At the more generalized extreme, another unit, the "land zone," was recognized as an association of land systems with boundaries characterized by "significant differences in climate parent materials, or vegetation."

A comparison between the Michigan land type concept and the Australian

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(63) Gibbons, Frank R., and Downes, R. G., A Study of the Land in South-western Victoria, Soil Conservation Authority of Victoria, Melbourne (1964), 287 pp plus maps and diagrams.

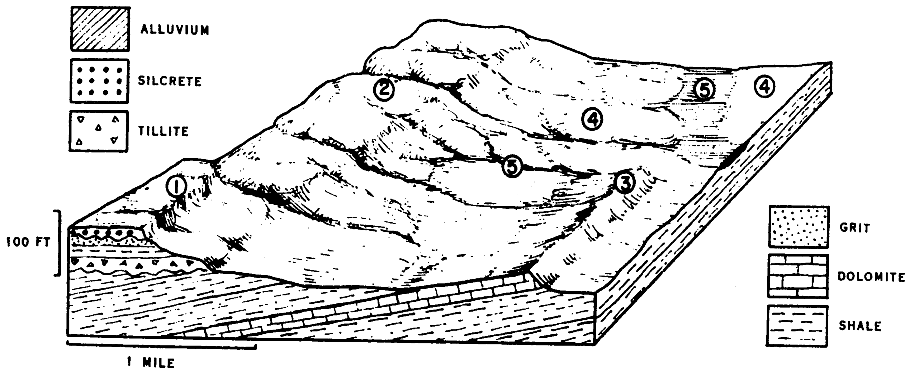
(17) Boondin Land System (300 sq. miles)

Broken uplands and stony plains with bluebush flats, in the east of the area.

Geology.—Weathered, flat-lying (?)Permian feldspathic grit and siltstone boulder tillite, with minor silcrete duricrust, overlying gently dipping Upper Proterozoic shale, dolomite, and mudstone (Nullagine "system").

Geomorphology.—Surfaces formed by dissection of the old plateau—duricrusted plateaux and benches: belts up to 5 miles wide, consisting of dissected uplands and spurs with summit remnants of silcrete duricrust; limestone foothills; lowlands with saline alluvial drainage floors; moderately dense pattern of incised branching tributary valleys; relief up to 100 ft.

Land Use.—Hill pastures with stunted mulga shrubland: ephemeral growth after rain should be heavily stocked; units 4 and 5 prone to degeneration and erosion; stock water little developed, probably adequate in units 5 and 6, although partly saline.



Unit	Approx. Area (sq. miles)	Land Form	Soil and Soil Association	Vegetation
1	10	**Summit remnants:** duricrusted, flat or gently sloping rocky summits up to ½ mile in extent, local slopes up to 5%; boulder mantle; marginal breakaways up to 30 ft high	Stony pavements of silcrete with little soil. Rock outcrop and 2	Moderately dense mulga and gidgee with a dense shrub layer, forbs, and short annual grasses: *Acacia aneura* (mulga) sub-alliance (30, 32, 33)
2	130	**Spurs, uplands, and hill slopes:** eroded below unit 1; flattish or slightly rounded stony crests, 50–100 ft high and up to ¾ mile in extent; main hill slopes are concave, attaining 50% in weathered rock below breakaways; spur margins are mainly convex, up to 15%		Moderately dense mulga, gidgee, and other *Acacia* spp., with a dense shrub layer, feathertop spinifex and other perennial grasses, sparse forbs, and short annual grasses: *A. aneura* sub-alliance (30)
3	<10	**Limestone foothills:** ridges about 50 ft high and ¼ mile long; benched, rocky slopes	Outcrop and very shallow, stony calcareous soils. Rock outcrop and 2	Sparse mulga and *Acacia* spp. with few edible shrubs, calciphilous forbs, and short annual grasses: *A. aneura–A. sclerosperma* sub-alliance (18)
4	100	**Lower slopes:** concave, up to 3 miles long and attaining 5%; dissected into interfluves up to 10 ft high and ½ mile wide, with concave marginal slopes, 0·5–1%	Stony soils, including shallow texture-contrast soils on hardpan. 6*a*	Open mulga with inedible shrubs, forbs, chenopods, and short annual grasses: *A. aneura* sub-alliance (29)
5	40	**Drainage floors:** up to ½ mile wide, gradients 1 in 100 to 1 in 250; central channelled tracts up to 200 yd wide; stony surfaces with scalds and clay pans	Presumably principally texture-contrast soils. Either 6*b* or 6*d*	Probably tall halophytic shrubland, with sparse trees, chenopods, herbage, and short annual grasses: *A. aneura–Kochia pyramidata* (bluebush) alliance (63)
6	20	**Channels:** up to 25 ft wide and 5 ft deep	Bed-loads of coarse sand	Fringing community, probably of *A. aneura–A. tetragonophylla* (curara) sub-alliance (10)

Fig. 21. Description and diagram of a land system. From "Lands of the Wiluna-Meekatharra Area," Western Australia, C.S.I.R.O. Land Research Series No. 7.

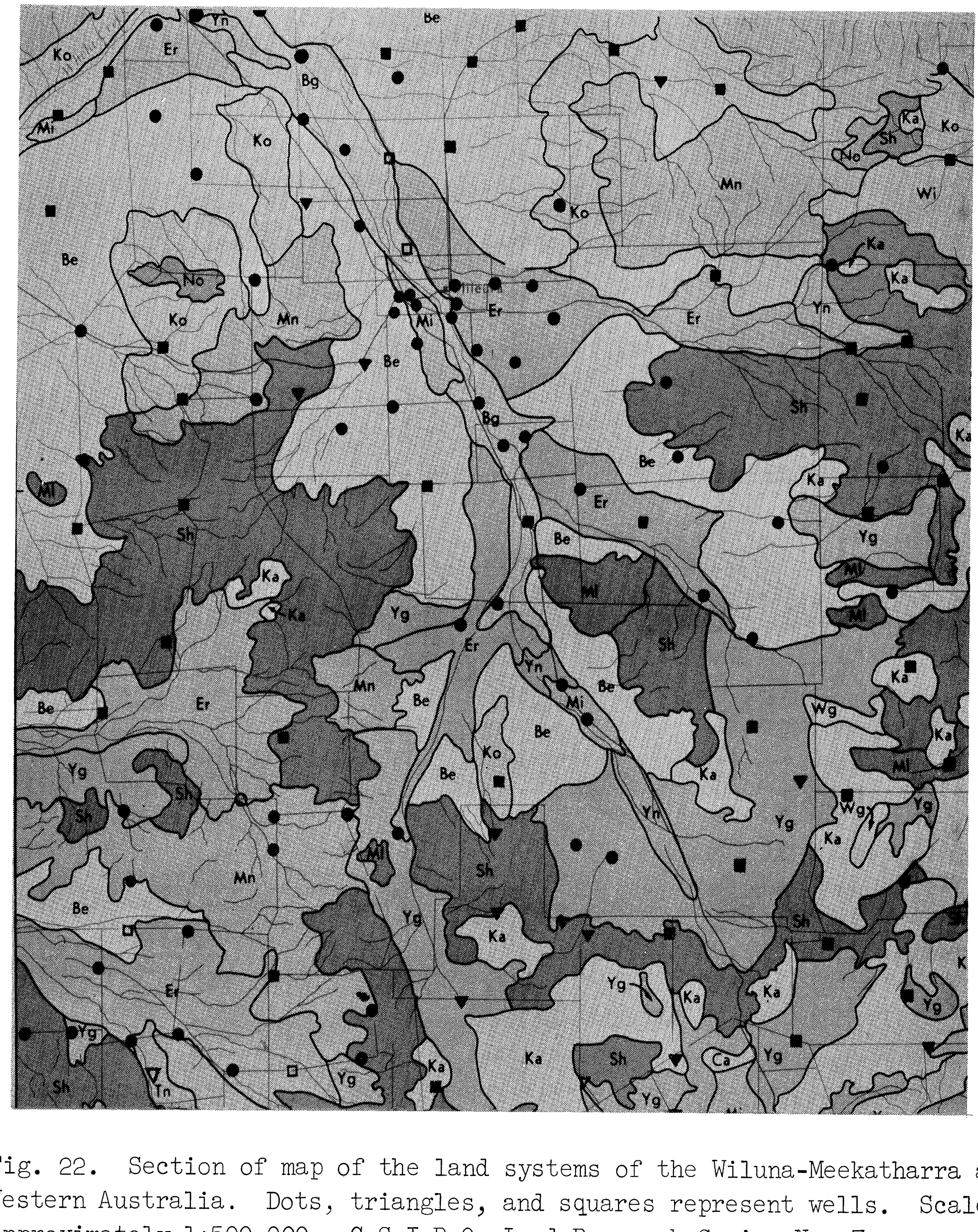


Fig. 22. Section of map of the land systems of the Wiluna-Meekatharra area, Western Australia. Dots, triangles, and squares represent wells. Scale approximately 1:500,000. C.S.I.R.O. Land Research Series No. 7.

land system shows both differences and likenesses. The Michigan land type was an "accidental" discovery from boundary correlation of detailed mapping. It was little, if at all, used as a reconnaissance method in any important survey undertaking although its utility for this purpose was demonstrated by the Michigan geographers as well as by Veatch. The Australian land system by contrast was developed as a concept for a specific purpose which it served, quite satisfacotrily it would seem, and has been widely copied. There are also similarities. If judged by the criteria of common genesis and land use potential one could equate individual glacial landforms in Michigan with Gibbons and Downes' land components; the "natural divisions" of the Land Economic Survey would qualify as land units; and the whole area of glacial deposition in the northern part of the Lower Peninsula would be a land system, perhaps if the lake plains were included, a compound land system. Although this analogy may be valid in a conceptional sense it certainly does not apply in an areal sense. The entire 25,000 square mile area in Michigan is a result of a single structural process, glacial deposition, in which the underlying geology is not important; a comparable area taken from the map of the land systems of the Wiluna-Meekatharra area (Fig. 22) contains forty-eight land systems.

In no sense is the Australian land system concept based upon the earlier work in Michigan; it was evolved for the purpose in hand. G. Alan Stewart writes "I was soil scientist with our first survey in 1946 and I was aware of the concepts of land type, soil association, and catena" (64) none of which seemed exactly suited to be the basic unit. He also notes that the work of Bourne (65) which was almost identical with the Australian approach had not then been followed up and was completely overlooked. To Veatch's commentary quoted earlier "Who knows where ideas come from?" this commentator must add a postscript: "Who knows where they go."

THE MEXE-OXFORD STUDIES

A type of land investigation involving composite units and quite different from the Australian survey is that presently being conducted by the Military Engineering Experimental Establishment (MEXE) in conjunction with Soil Science Laboratory of the University of Oxford in Great Britain. This is not a wide mapping program but rather is a series of experiments in terrain classification under the direction of Dr. P.H.T. Beckett and Mr. R. Webster. The objective is to develop a method by which terrain types can be recognized from air photographs, analyzed for their constituent elements, and the resulting data recorded on punched cards in such a way that it can be retrieved and understood by other persons than those who did the original analysis. This does not have any basic connection with the work of the Michigan Land Economic Survey but is here reviewed

(64) In a letter of November 21, 1966.

(65) See footnote 53.

briefly as a most promising example of the use of composite landscape units.

The present purpose of the work is to demonstrate the feasability of predicting terrain conditions of inaccessable areas from analyzed analogues in accessible areas for military engineering information. The investigators assume that the terrain conditions in any part of the world are results of erosion or deposition processes in geomorphological structures; that there is a limited number of geomorphological-climate combinations; and that in any one of such combinations the number of terrain types is small enough to be investigated and recorded.

The unit of recognition is the "repeated landscape patterns" later called a "land system." This is practically identical with the entity of the same name used by the Australian survey. The components of the land system are known as "facets" each of which is "a part of the landscape with distinct form, soil, rock, and water regime which is effectively uniform for the intensity of the land use envisaged. It may consist of one or several elements" (66). This concept of the composite unit is derived from the work of Bourne, the British scientist mentioned earlier who in 1931 set forth the idea that major regions are composed of "sites" which were homogeneous composites of climate, land surface, soil and vegetation (67). The term "facet" was also used by Wooldridge in 1932 to designate slopes or flats which he considered to be the basic units of surface relief (68). The facet is the fundamental unit that in combination with other facets make up the land system which is recognized by characteristic facet combination. A facet may occur in several systems of similar geomorphological nature. In field procedure facets are recognized by reconnaissance and the list revised if necessary during the detailed facet mapping. As an example the following list of facets is taken from a survey made near Oxford: spring lines, clay crest, clay slope, clay footslope, level bottom lands, very steep scarp of dissection slope, steep to moderate scarp of dissection slope, dip slopes above ground-water influence and lower dip slopes with high seasonal ground water (69). Land systems are recognizable on air mosaics as are also facets in some instances.

To be useful for the purposes intended these units of terrain analysis, land systems, and facets, must be stored in a retrievable system wherein a few

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(66) A Classification System for Terrain, MEXE Report No. 995, Christchurch, Dec. 1965.

(67) Bourne, R., "Regional Survey and its Relation to Stocktaking of the Agricultural Resources of the British Empire," Oxford Forestry Memoirs 13:(1931).

(68) Wooldridge, S. W., "The Cycle of Erosion and the Representation of Relief," Scottish Geogr. Magazine, 48:(1932) 30-36.

(69) From: Storage and Collation of Information on Terrain, MEXE Report No. 871, March, 1962.

known facets may be the clues to the nature of the larger land system. Some experimental work on such systems is now in progress. In these the land systems are presented on storage cards with their composing facets identified on drawings and air photographs; a file of systems and facets with characteristics and components will be prepared for punched card storage (Fig. 23).

Description of Land System as a whole. [CLIMATE (STATION and DATA); LITHOLOGY/STRATIGRAPHY; GENETIC LINKS AND GEOMORPHIC PATTERNS; SOIL; VEGETATION; PHYSIOGNOMY; ALTITUDE; RELIEF; LOCATION (1:1m MAP SHEET).]

Climate	:	1000 – 1300 mm. rainfall, bimodal; mild dry season.
Rock	:	Pre-Cambrian basement complex, mainly schists and gneisses mainly deeply weathered and lateritised.
Morphogenesis	:	Dissected old land surface in which massive laterite is preserved as level caps to major interfluves. Below these are long hill slopes leading to wide aggraded and frequently swampy valleys.
Soils	:	A variety of red loam lateritic (ferrallitic) type. (Buganda catena Kifu and Kaku series)
Vegetation	:	Forest/savanna mosaic with forest dominant along valleys.
Altitude	:	1300 m. approx.
Relief	:	120 – 150 m.

Diagram

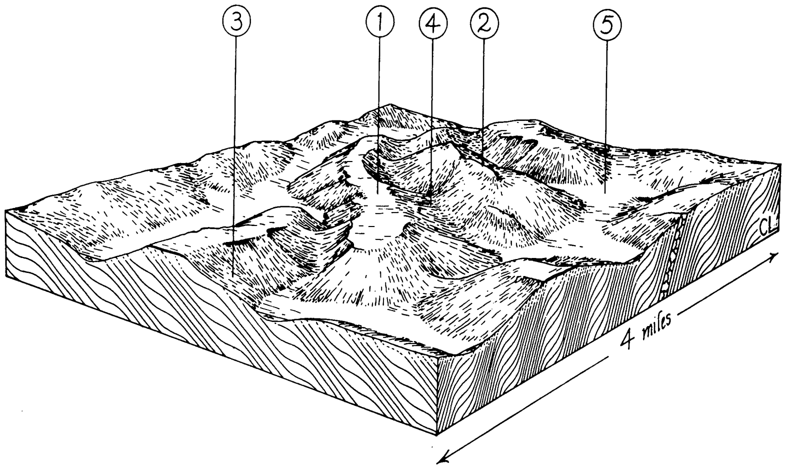


Fig. 23. A land system with its facets. From: "A Classification System for Terrain," MEXE Report No. 955.

The MEXE-Oxford work seems to have great promise for purposes other than those of military engineering. It is a possible basis for a world system of understanding landforms in their actual and detailed characteristics rather than by their lithologic and climatic genesis in somewhat the same manner as vegetation and soils are now understood from recent classification techniques. It seems to be adaptable to various parts of the world as shown by the recent report of a conference involving specialists from Great Britain, Australia, and South Africa (70). A workable storage system is now or shortly will be devised. With the expectation of satellite photography of fair resolution within a few years it is possible that the entire surface of the earth could

(70) Report of the Working Group on Land Classification and Data Storage, MEXE Report No. 940, Christchurch, 1966.

be known in detail and classified into the some 2000 to 4000 land systems of which its estimated to be composed.

AN ANALYSIS OF A LAND TYPE SURFACE

It has been stated in the preceding parts of this report that the composite units of landscape known as land types were recognized in Michigan primarily from the surface form of the glacial deposition with the added characteristic of soil. This part of the report is an attempt to analyze some aspects of a glacial surface which had been land typed in 1953 to ascertain which characteristics of the surface, either visible and observable or abstractions, appear in pattern to correlate with the land types.

For this purpose Ogemaw County in the southeastern part of the northern half of the Lower Peninsula was selected. This choice was made because the county has considerable differences in elevation; it had been covered by the Land Economic Survey; a map of its "wet areas" was available; and it had been land typed by a competent geographer.

The northwestern half of the county is covered by a belt of rugged moraines which form the margins of the High Plains and the extreme northwestern corner is composed of the high level outwash that constitutes the surface of the High Plains (Fig. 24). The southeastern section is covered by another moraine, much less rugged than the first and bearing a general rolling rather than hilly surface. Between these two surfaces is a lower trough which along the borders of the rugged moraine is occupied by some till plains of rolling surface. The bottom of the trough is filled with sandy outwash and glacial channel deposits, in places dry and in other waterlogged. This structure contains three general types of surface: plains, smooth to rolling surfaces, and rugged hills. These are distributed as shown in Fig. 24 which is taken from the Report on the Land Economic Survey map of Ogemaw County.

The division into land types was made by Ross N. Pearson in 1954 as a framework for data presentation in his study of recreational values in the county referred to previously. His map of the land types (Fig. 25) is used in the correlations between surface transformations and land types as digitalized in Fig. 40.

The only complete topographic map available for all of Michigan is the 1:250,000 series. Ogemaw county was assembled from the Traverse City and Tawas City sheets to form an approximate six-inch square (Fig. 26); from this elevations were read each one-tenth of an inch on both axes to form a matrix. The 3600 positions with elevations were entered on punch cards for analysis purposes.

Originally it was intended to use a map of soil types as one of the variables to be compared with the land types. Upon preliminary trial this proved to be impractical because of scale differences. The soil map, prepared by the Land Economic Survey and published at the scale of 1:63,360 shows soil types

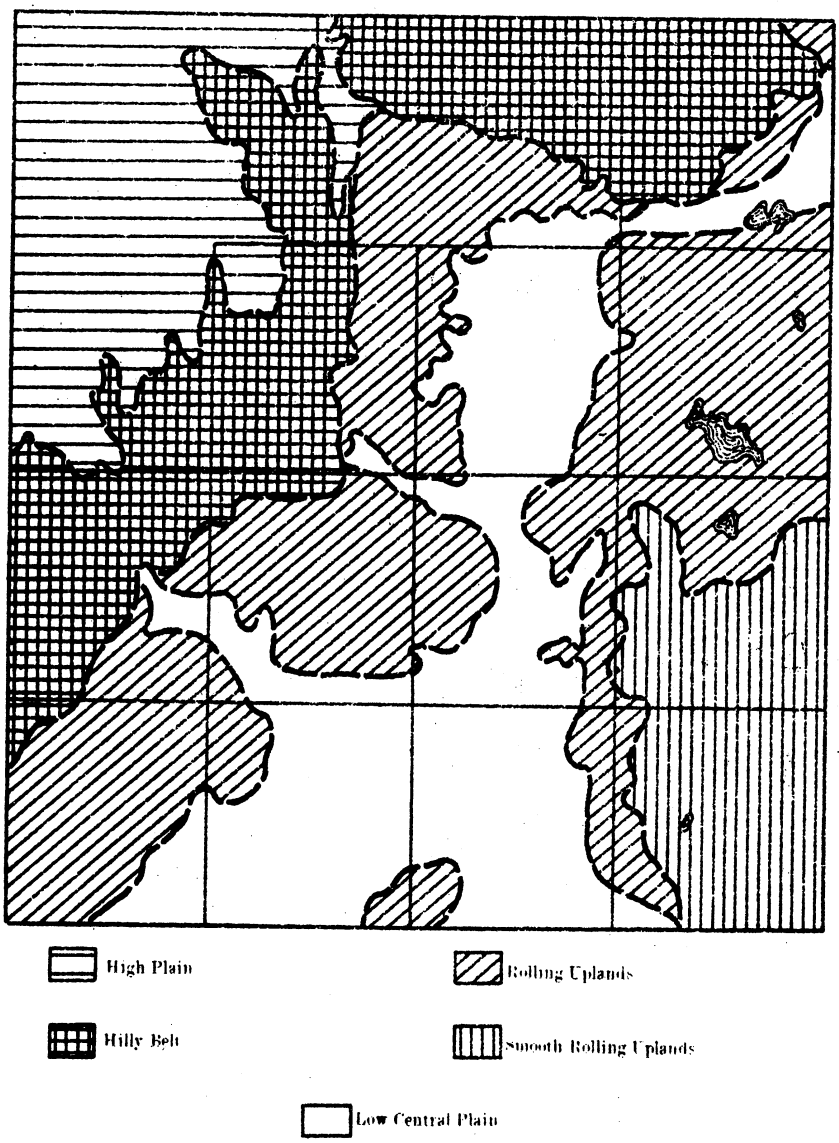


Fig. 24. Natural divisions of Ogemaw County. After Michigan Land Economic Survey report on soils.

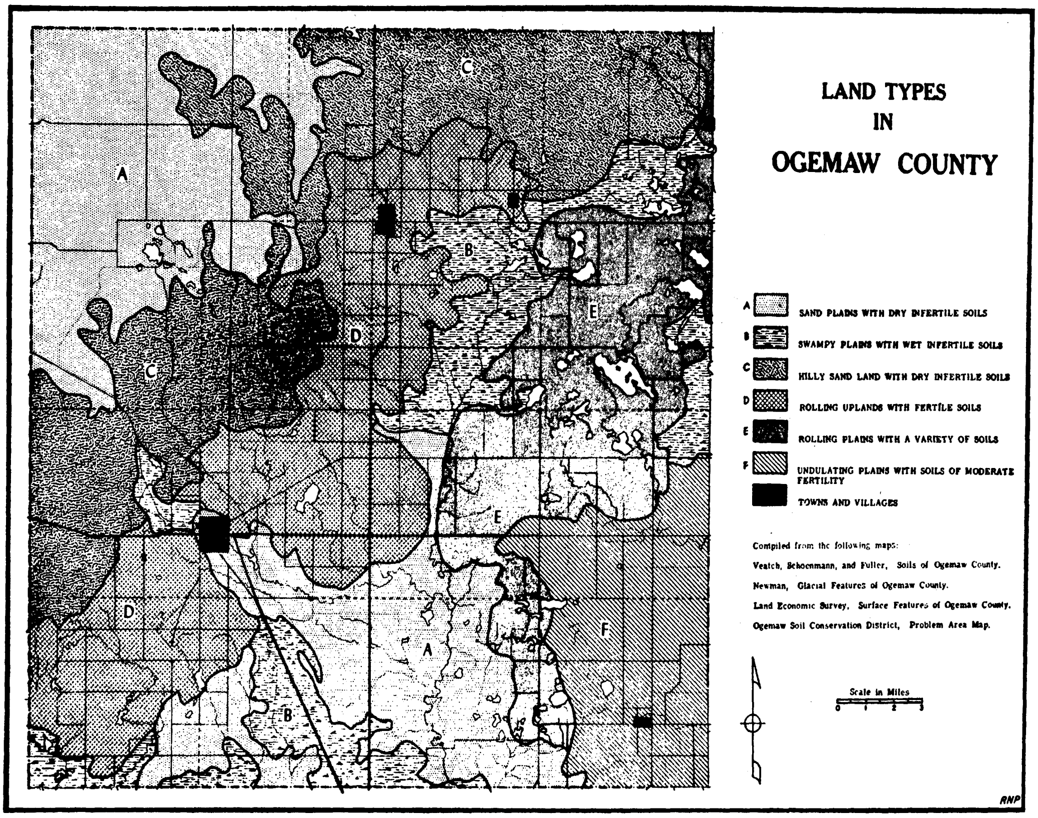
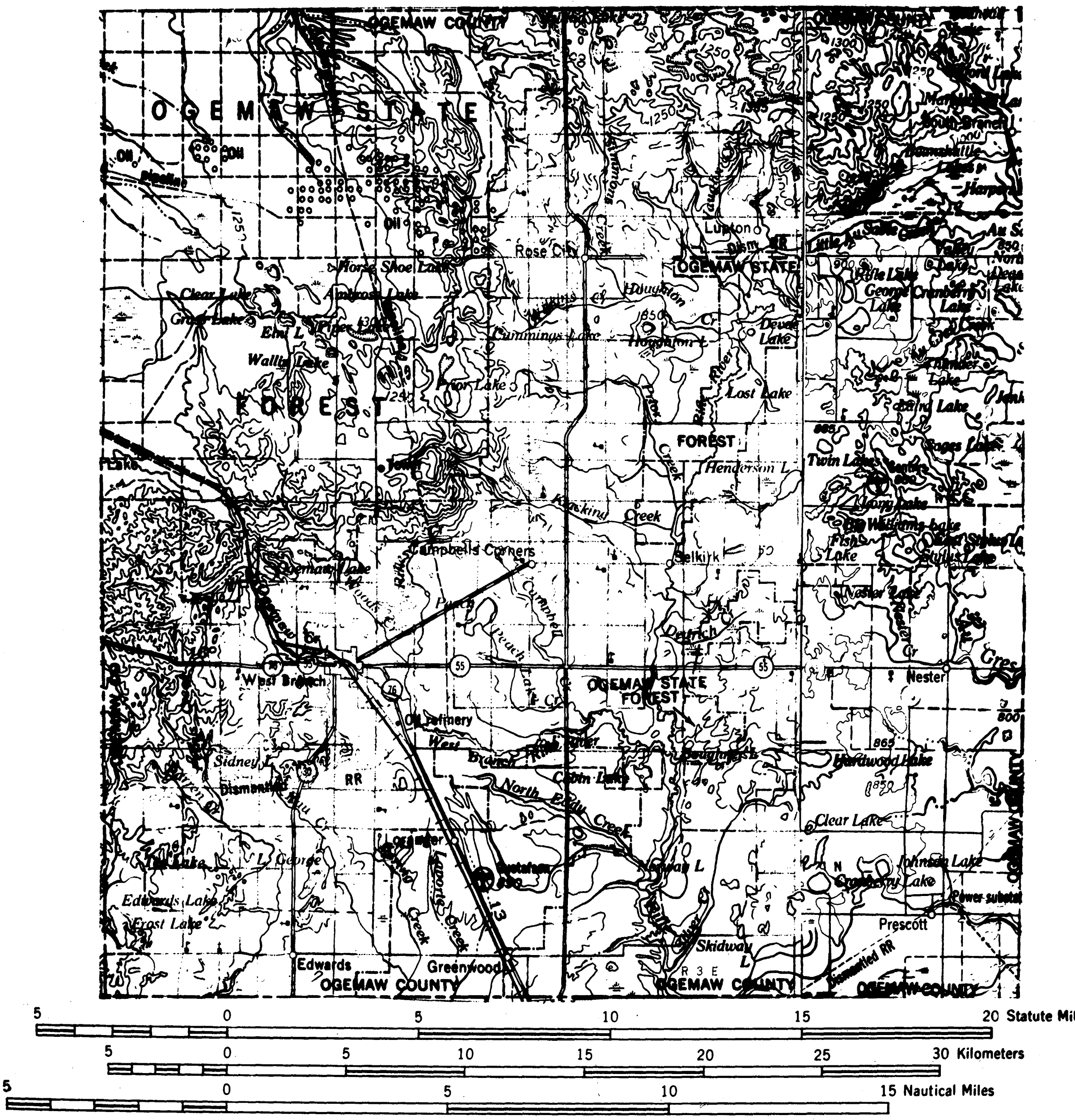


Fig. 25. Land types in Ogemaw County. After Ross N. Pearson.



CONTOUR INTERVAL 50 FEET

Fig. 26. Topographic map of Ogemaw County. From Traverse City and Tawas City sheets of the 1:250,000 series.

in distributions as small as ten acres (Fig. 3). Such detail could not be used on the 1:250,000 matrix. The more generalized soil maps such as that shown by Fig. 5 include a single type in more than one association. As a substitute, a map of wet areas (71) prepared by Veatch was enlarged from its original 1:1,250,000 scale and gridded to correspond with the elevations matrix (Fig. 45). A discussion of its correlative results appears later.

The digitalized surface with computer-plotter sections on both axes is shown in Fig. 27. The land types superimposed upon it have been generalized from Pearson's map by combining "Rolling Plains" with Undulating Plains" because no distinction could be found between these two classes in terms of topography: there was a soil distinction which could not be measured because of the difficulties stated earlier. The boundaries of the land types were also generalized by smoothing and adjusting to both the details and the computer-produced elevations of the block diagram.

Professor Waldo R. Tobler of the Department of Geography of The University of Michigan designed ten transformations of the topographic surface. These computed and plotted values derived from measurements of elevations, roughness, and slopes, were made to isolate certain characteristics of the surface of elevations. Each one shows as an artificial surface, differing from the original in terms of the transformation that has been done on it. Although some of these surfaces are later discussed as to their visual qualities their primary purpose was to produce numerical values which could be correlated with the land types to ascertain their prediction possibilities.

Professor Tobler's report follows.

AN ANALYSIS OF A DIGITALIZED SURFACE (Waldo R. Tobler)

The recent availability of topographical data in machine readable form permits increased flexibility of terrain analysis. The speculations which follow stem from my interest in picture processing, a field recently summarized by Rosenfeld. In particular, some topographic elevations recorded on punched cards have been treated as a digital picture. In the first instance only one set of information is manipulated; this is then combined with some additional data for a comparison with an existing classification scheme.

Given a set of topographic elevations there are a large number of secondary sets of data which can be derived from these given values. One obvious example is the mean elevation, another is the variance, and so on. If the geographical positions of the elevations are also available then other derivations

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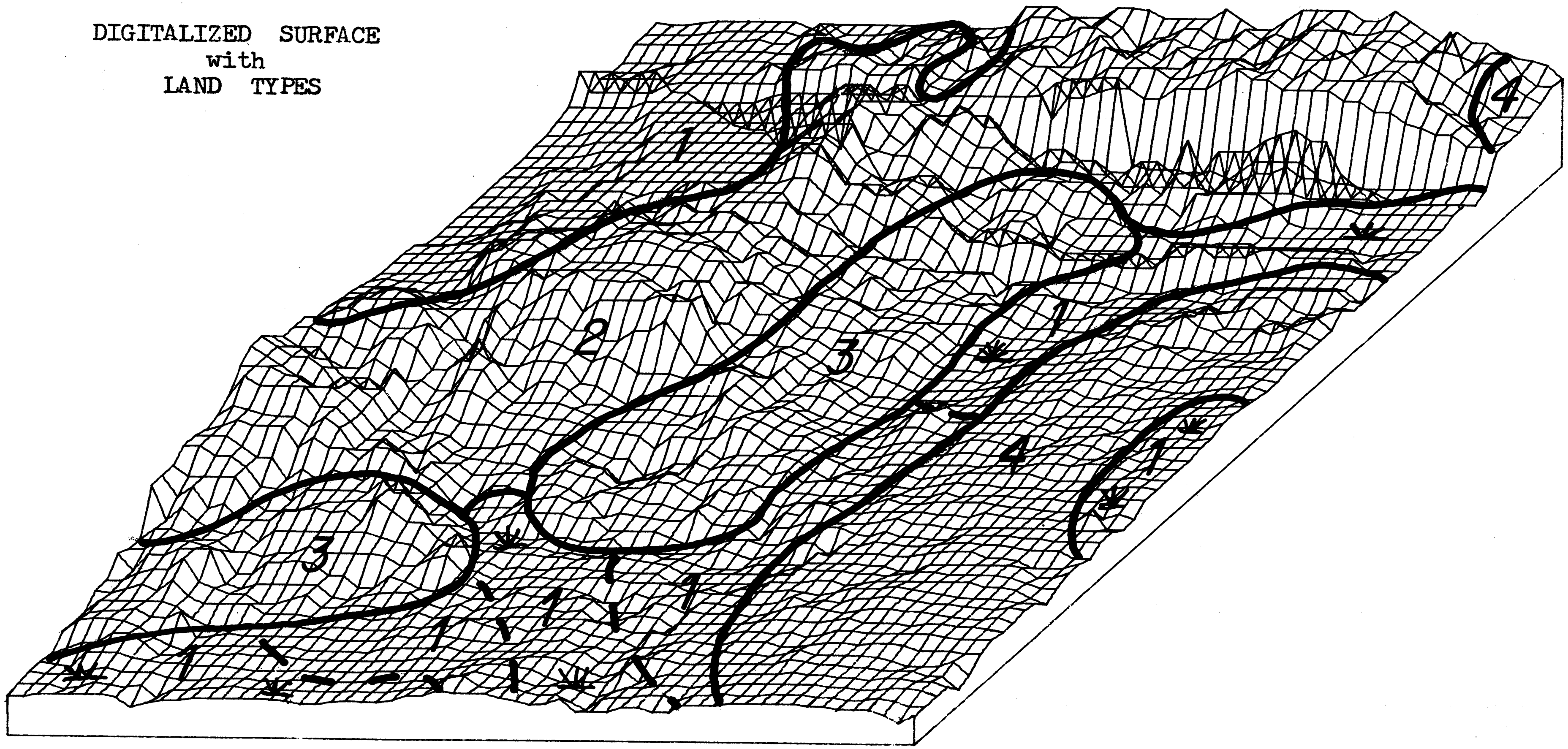
(71) Veatch, J. O., Patterns Based Upon the Distribution of Swamp Land in Selected Counties of Michigan, a map with commentary published as Journal Article No. 325, Agr. Exper. Station, Michigan State University (not dated).

DIGITALIZED SURFACE
with
LAND TYPES



1. PLAINS, Dry or Swampy
2. STEEP HILLS
3. ROLLING UPLANDS
4. ROLLING and UNDULATING PLAINS

Land types after Pearson; boundaries generalized and adjusted to computer topography and to computer-produced elevations.

Fig. 27. Digitalized surface and land types, Ogemaw County.

can be obtained; the slope is easily calculated for example. In the present instance topographical elevations are available as entries in a geographical matrix Z_{ij}, where the subscripts denote the spatial positions.

A convenient (and simple) point of view is to consider each derived data set as a transformation of the original data. Let there be N such transformations, symbolized by T_i, $i = 1,2,\ldots N$, where the magnitude of the number N is restricted only by one's imagination. It is now natural to make inquiries regarding the algebra of these transformations; in other words, how may they be combined? For example it is immediately clear that it may or may not be possible to form a logical product, that is, to perform the operations in sequence. To see this, consider the following two transformations:

$$T_1 = \text{Calculating the slope,}$$

$$T_2 = \text{Taking the average.}$$

It is valid to compute the slope as the first transformation, and then to compute the average of the slope. The result is a single number, the average slope. It is not meaningful to apply this sequence in the opposite order, since the slope of the average elevation (a single number) has no meaning.

Another simple property of transformations is that, in general, they do not commute. For example if

$$T_3 = \text{Local averaging}$$

and T_1 is, as before, calculating the slope, then

$$T_1(T_3(Z)) \neq T_3(T_1(Z)),$$

or, in words, taking the slope of the locally averaged elevations does not yield the same result as locally averaging the slopes. Other properties which might be investigated include the existence of inverses, and linearity. The relevant point, however, is that one might postulate that the process of terrain analysis consists of a (valid) sequence of such elementary transformations applied to the original elevations, that is

$$\text{Analysis} = T_k(T_j(T_m^2(T_p(Z)))).$$

In this symbolic example no particular interpretation is given the specific transformations (distinguished by subscripts). In general one would expect that different combinations would occur depending on the objectives of the specific analysis. Clearly the number of possibilities increases rapidly with modest increases in N. A large portion of the literature on terrain analysis, and on picture processing, is devoted to elaboration of specific transformations, including arithmetic operations (+,-,x,/), Boolean operations (And, Or, Nor), and specific "tricks" (thresholding, differentiation, Custering). This literature is readily accessible and requires no review here.

In block diagram form the foregoing sequence might appear somewhat as follows:

$$Z \rightarrow \boxed{T_p} \rightarrow \boxed{T_m} \rightarrow \boxed{T_m} \rightarrow \boxed{T_j} \rightarrow \boxed{T_k} \rightarrow \text{Analysis}$$

Clearly operations in "parallel" also seem required. An example in picture processing is given by Huang and Tretiak. Since research is in reality an iterative process, one would also expect feedback loops to occur.

As a specific example, ten matrices of data have been generated from topographic elevations in Ogemaw County (Michigan), using computer programs available in house prior to initiation of the current contract. These are illustrated in the accompanying figures, along with the original elevations, and two nominal data sets. A total of thirteen variables are consequently available for each of the 3600 matrix positions in Ogemaw County. Twelve of these variables are now used in an attempt to predict the thirteenth. Specific note is made of the fact that the geographic variable, location is <u>not</u> included in the analysis. All of the data sets, except numbers 8, 9, and 13, were obtained, as mentioned, by application of positionally invariant local operators (to use Rosenfeld's terminology) to the topographic elevations. The specific variables are:

No. 1. Local dodging (Fig. 29)

No. 2. First derivative averaged locally (Fig. 30)

No. 3. Second derivative averaged locally (Fig. 31)

No. 4. Local range (Fig. 32)

No. 5. Local variance (Fig. 33)

No. 6. Low low pass filter (Fig. 34)

No. 7. Low pas filter (Fig. 35)

No. 8. Topographic elevation (Fig. 36)

No. 9. Wetness (Fig. 45)

No. 10. High pass filter (Fig. 37)

No. 11. First derivative (Fig. 38)

No. 12. Second derivative (Fig. 39)

No. 13. Land type (Fig. 40)

A priori one would expect several of these items to be correlated, and this is indeed the case, as illustrated by the table. Variable 13 has now been used as a mask to obtain a 2% (180 observations) random sample on each of

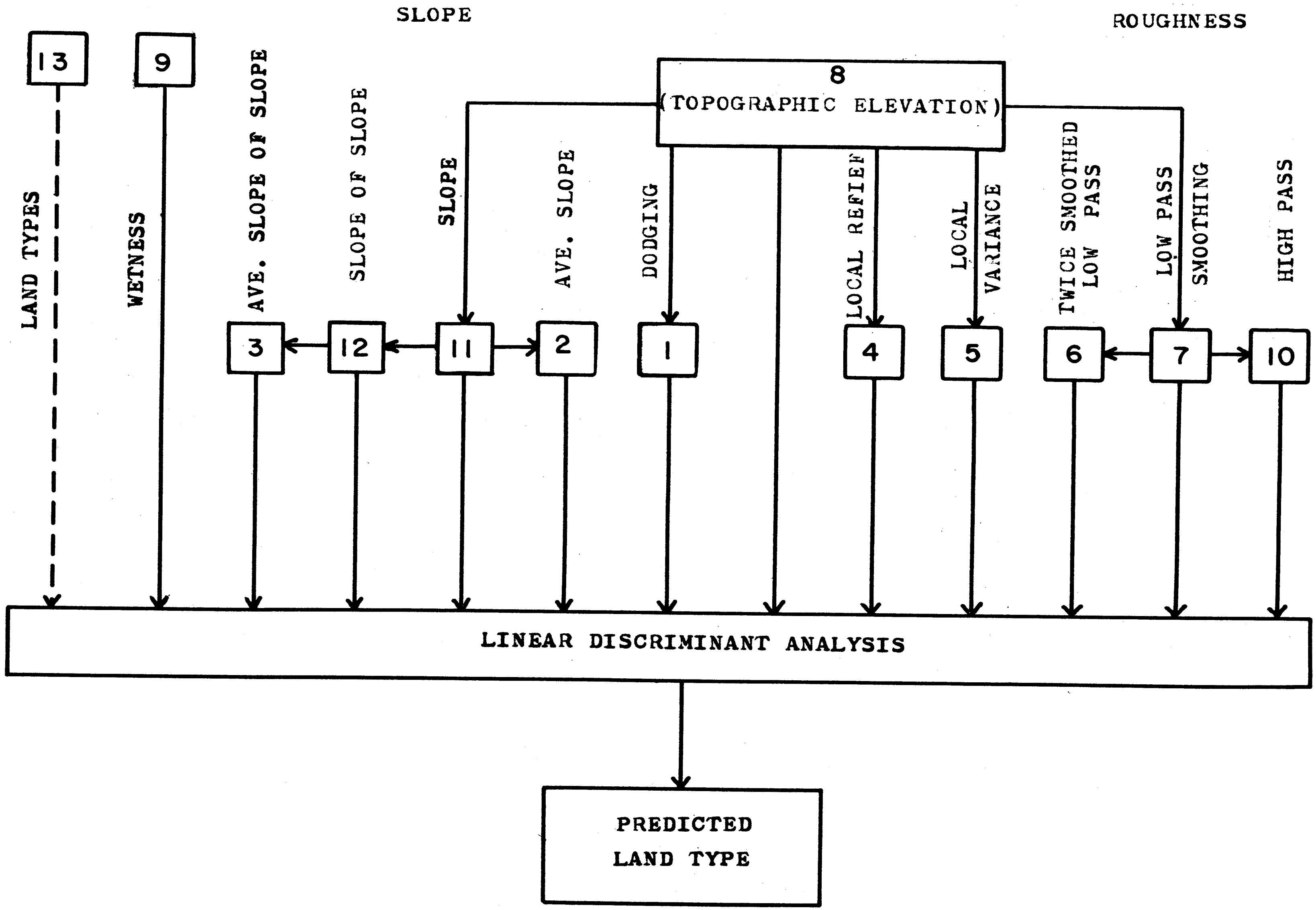


Fig. 28. Schematic representation of the variables and the analysis.

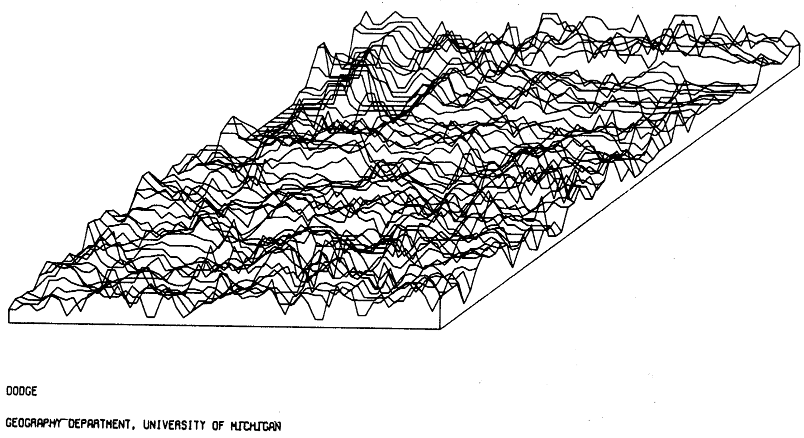


Fig. 29. Local dodging.

$$Z'_{ij} = Z_i + BZ_{ij} - BW_2,$$

where Z'_{ij} is the value in feet obtained for the ij^{th} location, Z_{ij} is the original elevation value at location i,j; Z_1 is the maximum elevation in the entire region (Ogemaw county), Z_2 is the minimum elevation in the entire area, and W_1 and W_2 are the comparable maximum and minimum values for the local neighborhood; $B = (Z_1 - Z_2)/(W_1 - W_2)$ unless $W_1 = W_2$ in which case B = 1. The neighborhood of i, j is chosen to be 3 cells on all sides of i,j (i.e., a total of 49 cells). The operator is a contrast enhancer, equivalent to gain amplification. Variable 1.

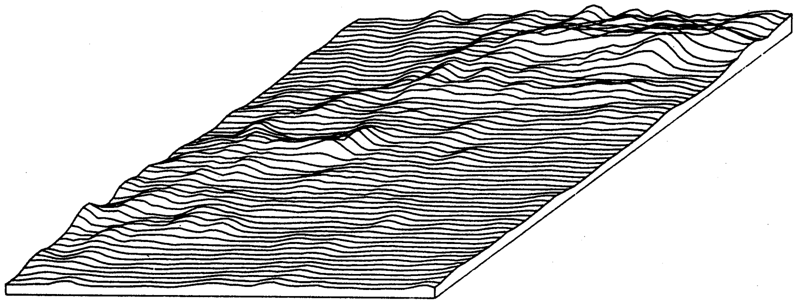


Fig. 30. First derivative averaged locally.

$$Z''_{ij} = \sum_{-p}^{+p} \sum_{-q}^{+q} W_{pq} Z'_{i+p,j+q},$$

where p = q = 1 defines the local neighborhood of 9 cells

$$Z' = \frac{1}{2d} ((Z_{i,j+1} - Z_{i,j-1})^2 + (Z_{i-1,j} - Z_{i+1,j})^2)^{1/2},$$

d is the distance between cells, Z_{ij} is the original elevation at location i, j, and

$$W_{pq} = \begin{matrix} 1/16 & 1/8 & 1/16 \\ 1/8 & 1/4 & 1/8 \\ 1/16 & 1/8 & 1/16 \end{matrix} .$$

Clearly the average slope is in units of feet miles^{-1}. Variable 2.

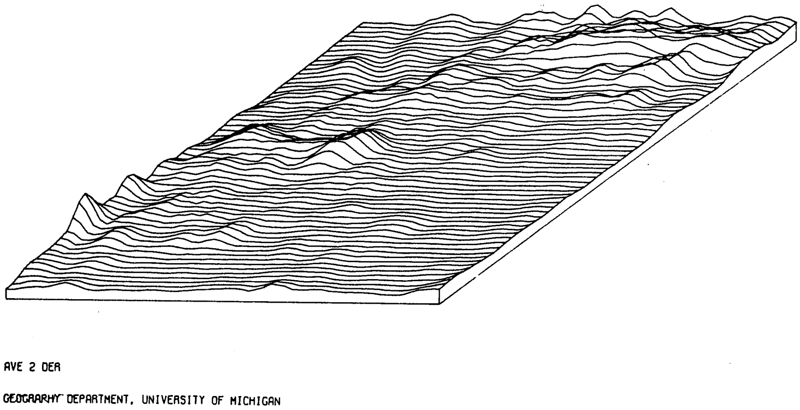


Fig. 31. Second derivative averaged locally.

$$Z''''_{ij} = \sum_p \sum_q W_{pq} Z''_{ij}.$$

Where the weights W_{pq} and the p,q neighborhood are the same as for variable 2, and Z''_{ij} is the slope of the slope, i.e., the rate of change of the slope computed by applying the operator from the previous variable twice, in feet miles^{-2}. Variable 3.

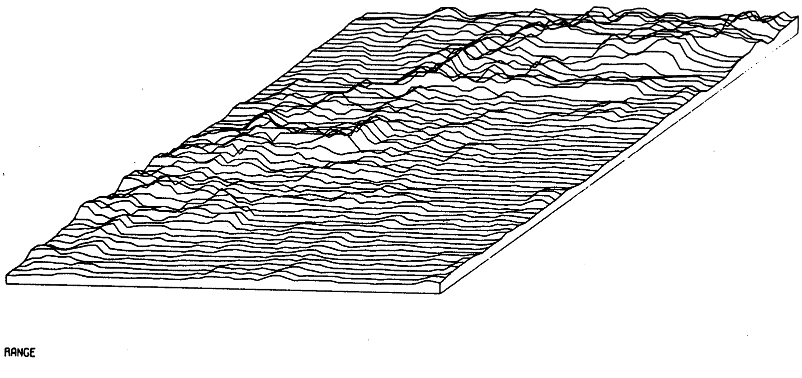


Fig. 32. Local range.

$$Z'_{ij} = Z^1_{pq} - Z^2_{pq}, \quad p = i+k, \quad q = j+k, \quad k = -1, \quad 0, \quad +1,$$

and Z^1_{pq} is the maximum elevation, and Z^2_{pq} is the minimum elevation occuring in the p,q neighborhood of j,i. This is sometimes known as the relative relief, measured in feet. Variable 4.

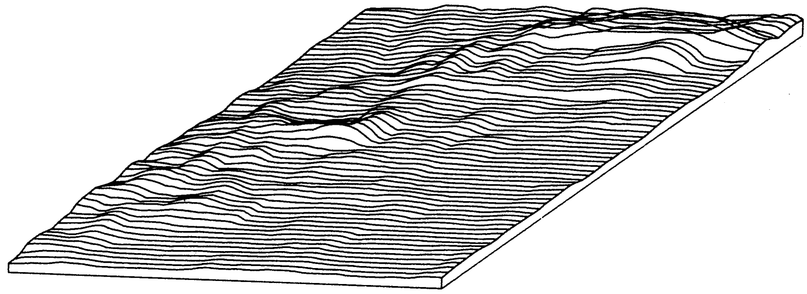


Fig. 33. Local variance.

$$Z'_{ij} = \frac{1}{N} \sum_p \sum_q (Z_{i+p,j+q} - \bar{Z}_{pq})^2; \quad p,q = -1, \quad 0, \quad +1,$$

where $\bar{Z}_{pq}$ is the average elevation in the p,q neighborhood, and N is the size of the neighborhood. This may be considered as a measure of roughness of the terrain, in feet^2. Variable 5.

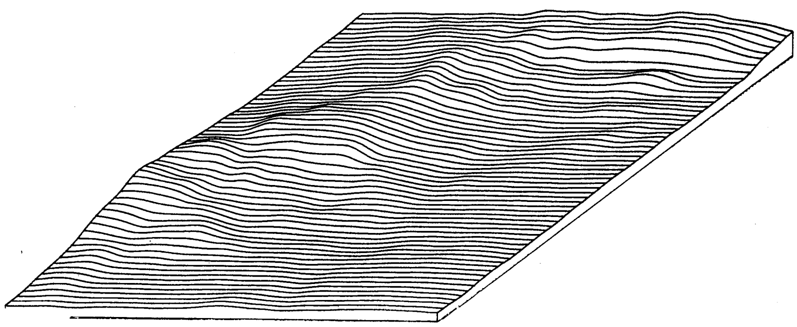


Fig. 34. Low low pass filter.

$$Z''_{ij} = \sum_p \sum_q W_{pq} Z'_{i+p,j+q}; \quad p,q = -1, \quad 0, \quad +1,$$

and the weights W_{pq} are as for variable 2. Z' is variable 7; that is, the binomially weighted moving average has been applied to the original elevations twice. Measured in feet. Variable 6.

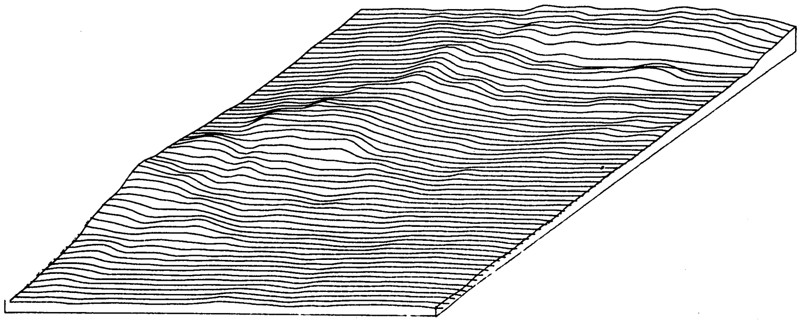


Fig. 35. Low pass filter.

$$Z'_{ij} = \sum_p \sum_q W_{pq} Z_{i+p,j+q}; \quad p,q = -1, \quad 0, \quad +1.$$

Z'_{ij} is the value in feet of the result of applying the two dimensional binomially weighted moving average to the elevations. The weights are detailed in the description of variable 2. Low pass filtering has the effect of smoothing the topography. This variable is so closely correlated with variable 6 that it was rejected by the discriminant analysis program. Variable 7.

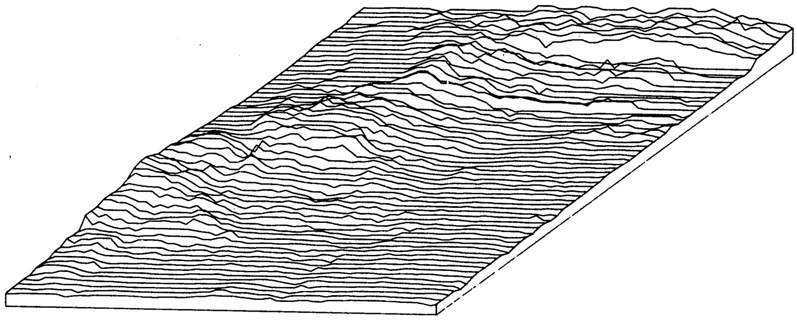


Fig. 36. Topographic elevation. Measure in feet above sea level as recorded on the 1/250,000 USGS topographic quadrangles Traverse City and Tawas City, with 50 ft contour intervals. Recorded on punched cards every 1/10th of an inch on the maps (2083 ft on the ground). Variable 8.

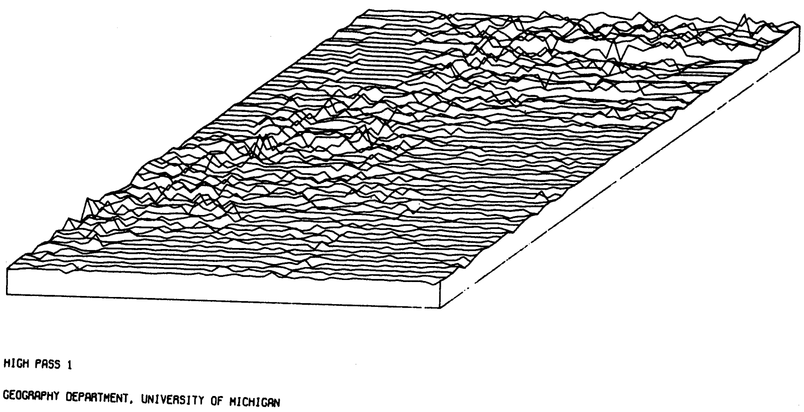


Fig. 37. High pass filter.

$$Z''_{ij} = Z_{ij} - Z'_{ij} + \bar{Z},$$

where Z_{ij} is the original elevation (variable 8), Z'_{ij} is the low pass filter (variable 7) and $\bar{Z}$ is the average elevation for the entire region (Ogemaw County). Variable 10.

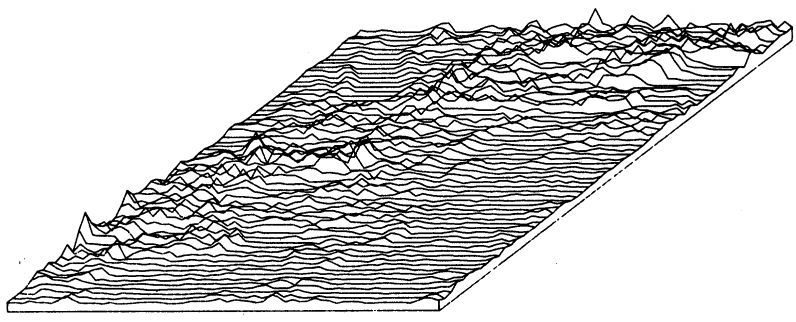


Fig. 38. First derivative. Measured in feet miles^{-1} this is the same as the Z' of variable 2, i.e., the slope, but not averaged over the local neighborhood, or, a finite difference approximation to the instantaneous slope. Variable 11.

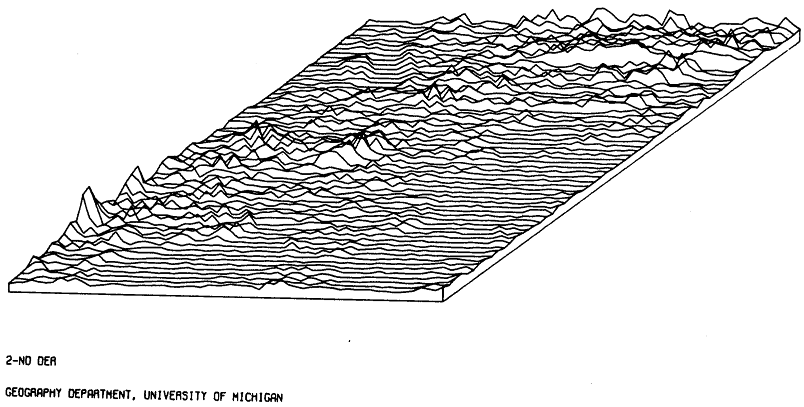


Fig. 39. Second derivative. Measured in feet miles^{-2} this is the same as the Z" of variable 3, i.e., the rate of change of slope, but not averaged over the local neighborhood. Variable 12.

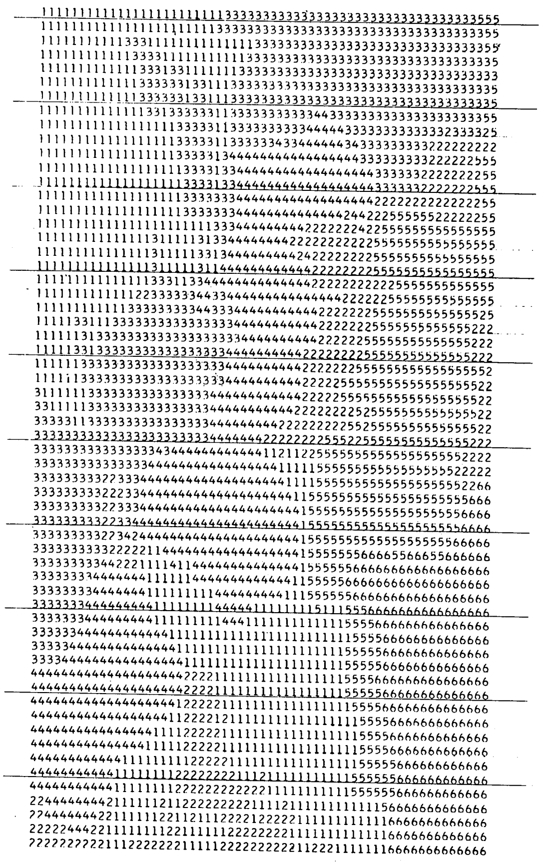


Fig. 40. Land type. Computer representation of the six classes of land type: 1 = sand plains with dry infertile soils; 2 = swampy plains with wet infertile soils; 3 = hilly land with dry infertile soils; 4 = rolling uplands with fertile soils; 5 = rolling uplands with a variety of soils; 6 = undulating plains with soils of moderate fertility. The land type is labeled variable 13.

	1	1.00											
V	2	-.07	1.00										
A	3	-.12	0.79	1.00									
R	4	-.06	0.89	0.67	1.00								
I	5	-.10	0.93	0.82	0.80	1.00							
A	6	-.02	-.16	-.01	-.12	-.08	1.00						
B	7	0.02	-.17	-.02	-.13	-.09	0.99	1.00					
L	8	0.10	-.17	-.03	-.12	-.08	0.98	0.99	1.00				
E	9	-.03	-.01	0.01	-.01	-.01	-.15	-.16	-1.6	1.00			
S	10	0.55	-.03	-.06	0.02	0.01	0.02	0.06	0.20	-.02	1.00		
	11	0.03	0.79	0.60	0.83	0.70	-.17	-.18	-.17	-.00	0.05	1.00	
	12	-.12	0.63	0.77	0.48	0.65	-.05	-.06	-.05	0.04	0.00	0.39	1.00

Fig. 41. Correlation matrix.

No. of Observations originally in group:

		1	2	3	4	5	6
And Assigned to Group:	1	21	0	2	2	1	0
	2	6	11	0	5	6	3
	3	2	0	35	2	0	0
	4	0	0	1	21	1	0
	5	5	5	0	4	9	2
	6	11	2	0	1	8	11
Percent Correctly Assigned: (Total=61%)		47%	61%	92%	60%	35%	69%

Fig. 42. Classification results using all 12 variables.

No. of Observations originally in Group:

And Assigned to Group:	1	2	3	4	5	6
1	21	0	2	2	0	0
2	7	12	0	6	5	1
3	2	0	35	2	0	0
4	1	1	1	21	0	0
5	3	3	0	2	17	3
6	11	2	0	2	3	12

Fig. 43. Classification results omitting wetness (variable 9).

No. of Observations originally in Group:

And Assigned to Group:	1	2	3	4	5	6
1	20	0	0	1	0	0
2	5	10	0	7	9	4
3	3	1	37	2	0	0
4	0	1	1	21	1	0
5	3	1	0	1	5	0
6	14	5	0	3	10	12

Fig. 44. Classification results using only variables 2, 5, 8, 9.

MEANS (THE LAST COLUMN CONTAINS THE GRAND MEANS OVER THE GROUPS USED IN THE ANALYSIS)

VARIABLE	GROUP 1 GRP	2 GRP	3 GRP	4 GRP	5 GRP	6 GRP	
1	1002.78911	963.42867	1153.99853	1036.40331	1075.88320	1173.80581	1063.67943
2	33.07040	49.43517	133.77774	84.90474	38.61776	22.66325	66.44789
3	50.93824	66.31489	163.62271	93.67300	49.30672	29.08337	82.93847
4	34.33333	57.22222	133.68421	98.85714	41.60000	22.50000	70.70621
5	18.42171	25.90889	67.16271	44.84220	18.47520	11.04556	34.21246
6	1053.73333	874.77778	1234.52632	959.91429	857.40000	841.18750	1008.85311
7	1052.51111	873.44444	1235.94737	957.97143	858.36000	841.68750	1008.50847
8	1050.11111	868.05556	1240.92105	956.57143	862.20000	842.50000	1008.75706
9	0.11111	0.61111	0.02632	0.22857	0.36000	0.25000	0.21469
10	1008.24444	1005.55556	1015.84211	1009.48571	1014.72000	1011.75000	1011.07910
11	27.33333	53.38889	140.65789	88.31429	35.00000	20.12500	66.80226
12	52.62222	56.83333	171.94737	97.71429	50.16000	22.62500	84.52542

STANDARD DEVIATIONS

VARIABLE	GROUP 1 GRP	2 GRP	3 GRP	4 GRP	5 GRP	6 GRP
1	191.56941	143.61794	195.84164	137.37324	162.35004	136.84272
2	23.68496	28.42318	68.34981	37.27970	20.56380	7.93659
3	30.19396	39.70489	91.05666	39.42615	24.66401	13.38890
4	26.21155	38.88982	75.16364	56.76429	26.64270	11.83216
5	11.43446	17.21465	37.46962	20.17022	9.83394	4.16295
6	207.20559	54.81257	110.63593	78.07137	13.79311	12.16672
7	207.13639	54.53463	115.39285	79.03740	16.06207	12.08149
8	207.20129	49.79779	123.60495	83.83958	22.82542	12.90994
9	0.31782	0.50163	0.16222	0.42604	0.48990	0.44721
10	9.66050	10.55642	33.62152	15.08090	8.88125	3.78594
11	28.18768	37.27346	100.77706	57.20437	32.44611	13.36600
12	48.85986	45.13542	119.08116	63.80972	47.59961	13.58860

SUMMARY TABLE

STEP NUMBER	VARIABLE ENTERED	VARIABLE REMOVED	F VALUE TO ENTER OR REMOVE	NUMBER OF VARIABLES INCLUDED	U-STATISTIC
1	6		45.3433	1	0.4300
2	2		30.4100	2	0.2270
3	1		5.7231	3	0.1941
4	9		2.9248	4	0.1786
5	4		1.8797	5	0.1690
6	5		1.4601	6	0.1619
7	8		0.8894	7	0.1577
8	3		0.7863	8	0.1540
9	10		0.6481	9	0.1510
10	11		0.4314	10	0.1490
11	12		0.3264	11	0.1475

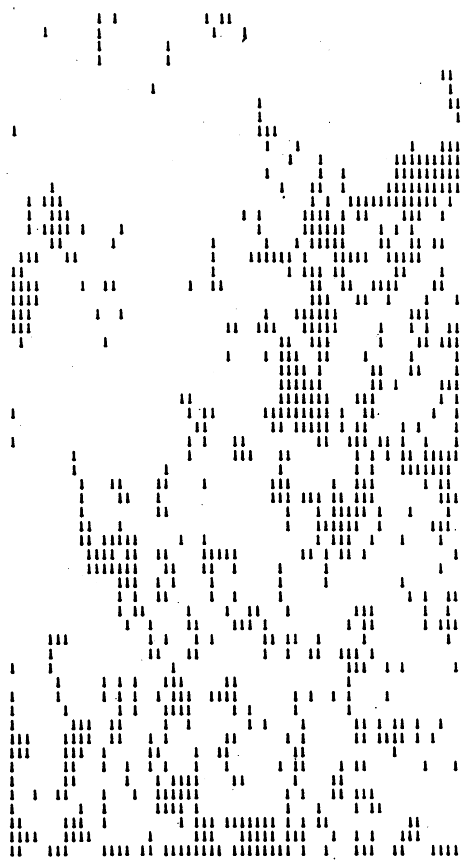


Fig. 45. Wetness. Computer representation of the binary variable wet or non-wet. 1 = wet, 0 = non-wet. Variable 9.

the twelve variables. This information was then processed using a stepwise linear discriminant analysis program (BMD07m) on The University of Michigan IBM 360/67. The precise form of the analysis and the interrelationships among the variables is shown schematically in Fig. 28. As can be seen, this resembles, but is not identical with the scheme outlined earlier. As can be seen from the tables, the accuracy of prediction of land type is approximately 60%, using a linear combination of the 12 variables. Somewhat contrary to expectation, variable nine, a nominal measure of wetness, not calculated from the elevations and not strongly correlated statistically with any of the other variables, did not contribute appreciably to land type classification. The use of a nominal variable in this manner is marginally legitimate, and the assumption of equal variances is clearly violated, but inspection of the table of means confirms that there is no clear joint association of land type with wetness. The double low pass filter (variable 6) and the locally averaged slope (variable 2), are clearly dominant in their ability to predict land type, given the variables used in the analysis. Now a prediction of 60% effectiveness may be considered to be satisfactory or unsatisfactory, depending on the risk associated with misclassification. The performance may of course be enhanced in several ways. One of these might be through nonlinear functions in the discriminant analysis. The addition of further information, in the form of more variables, or of a theory of land type formation specifying the interaction between variables, might improve the prediction.

SUMMARY

As Professor Tobler states in his report the number of transformations that can be made from a digitalized surface is limited only by one's imagination. These transformations produce "artificial" characteristics of the surface called variables; each is a quantified and geographically located value derived from a mathematical manipulation of the topographic elevations. It was not known in advance which or what kind of variables would predict the land types or if any of them would do so. It might have been expected, because land types themselves are generalizations in which surface conditions are the principal determinant, that variables which average or "smooth" the surface would show better predictability than those which enhance local irregularities. For this reason variables of both these characteristics were included. A program of ten transformations of the topographic surface together with the surface itself and the wetness factor gave twelve variables. It was hoped that some one or a few of these would be a proxy measure of the composite land type.

The 60% result, using all twelve variables was a disappointing although not unexpected finding (Fig. 42). The use of selected variables did not improve the predictability materially; dropping of the wetness factor (variable 9) or employment of only smoothed slope, roughness, topography, and wetness (variables 2, 5, 8, and 9) produced practically the same results as is shown in Figs. 43 and 44. Apparently none of the variables or combinations of them are good indicators of the land types.

The correlation matrix (Fig. 41) which shows the geographical correlation of the variables becomes more understandable when it is reorganized into categories of the conditions that are being measured. There are three of these: elevation measurements, slope measurements, and roughness measurements.

Elevation Measurements

Variable	8	7	6
8. Topographic Elevations	1.00		
7. Average Elevation	.99	1.00	
6. Average of Av. Elevations	.98	.99	1.00

This indicated the obvious facts that elevations, average elevations, and averages of the average occur in the same places.

Slope Measurements

Variable	11	2	3	12
11. Instantaneous Slope	1.00			
2. Average Slope	.79	1.00		
3. Rate of Slope Change	.60	.79	1.00	
12. Rate of Sl. Change by Neighborhoods	.39	.63	.77	1.00

In an area of glacial landforms the steepest slopes are found in the rough moraines and this is probably the characteristic that gives some symmetry to the table. That the geographical correlation is not better might be attributed to the fact that some of the landforms such as smooth moraines or rolling till plains have similar slope conditions but are distributed in various locations in the area. Because the land types are generally based on glacial landforms it might be expected that combined slope measurements and derivatives would be indifferent predictors of the land types.

Roughness Measurements

Variable	4	5
4. Local Relief	1.00	
5. Variance	.80	1.00

These two variables are about the same thing. Variable 4 is the difference between the high and low points in a neighborhood whereas variable 5 is the variance of the high and low elevations from the average elevation. It is to be expected that they would occur together whether on rough or smooth land types and would have low prediction significance.

Two of the variables, local dodging (variable 1) and high pass filter (variable 10), seem to have low geographical correlation with the other variables, except with each other. Local dodging has the effect of emphasizing the local roughness of a neighborhood of 49 squares while ignoring the general roughness. The surface produced (Fig. 29) shows high elevations on smooth land types; these come from amplification of minor surface irregularities. The high pass filter (variable 10) operates in somewhat the same manner but to a less extreme degree and shows local roughness after eliminating the regional (entire county) trends. Because these two are based on local conditions of difference they show little correlation with other variables.

The failure of variable 9, wetness, to show geographical correlation with the others was unsuspected but this lack of coordination is certainly an apparent fact from the correlation matrix. Figure 46 shows that the distribution of wetness is not a random one and that the association of wet areas with the Swampy Plains is obvious. However its ommission from Fig. 43 and its inclusion in Fig. 44, the classification tables, does not make any important difference. This leads to the assumption that wetness is not a result of the details of the surface configuration. The central trough which runs northeast-southwest through the county is composed partly of dry plains and partly of swampy plains. This might be a result of subsurface imperviousness of the drift but O. H. Clark offers a much better explanation: the wetness in the trough comes from an artesian system rather than surface irregularity. The adjoining high, sandy surfaces of the High Plains act as an absorptive catchment surface for rainfall and at saturation level the water flows out through the morainic belt as artesian springs.

Land types were recognized either by the correlation of thematic maps in the Land Economic Survey or by direct field observation by later students. The Survey had the additional data of soils and vegetation but did not have topographic maps. Its recordings of surface variations were made in terms or roughly measured and much generalized "classes of slope." The land typers at Wilderness Park whose techniques Pearson followed accepted surface variation classes as being characteristic of those of glacial landforms. This is to say that the surface of a "rough moraine" in many places might be more smooth than an undulating till plain and that of an outwash more rough than a till plain. This shows on some of the computer-drawn block diagrams as well as in some parts of the correlation table. The field observers, it would seem, generalized surface irregularities within the pattern of landform boundaries. Some inference might be drawn between this generalizing, perhaps unconscious generalizing, and the fact that Professor Tobler's report shows that variables 2 and 6 which are generalizations were the most accurate predictors of land types.

The factor of soil, of importance in land type determination, could not be included in the variables so an attempt was made to redefine the land types by surface classes alone. The six land types actually represent only three surface classifications:

Fig. 46. Wet areas and land types. Wet areas after Veatch; land types after Pearson. Cross hatched areas in solid boundaries represent land type designated "Swampy Plains."

Plains surfaces (types 1 and 2)
Hilly surfaces (type 3)
Rolling or undulating surfaces (types 4, 5, and 6)

If the Classification Table using all 12 variables (Fig. 42) is reorganized into these three groups of surface it would appear as follows:

And Assigned to Group	Number of Observations Originally in Group: 1 and 2	3	4,5 and 6
1 and 2	38	2	3
3	2	35	2
4,5 and 6	23	0	57
Percentage Correctly Assigned	60	90	75

This would seem to indicate that the flat surfaces have more anamolies from their defined flatness than does the hilly type from its defined hilliness.

Another observation might be that Pearson's land types which are used as a mask for the random sampling cannot be considered as absolute realities themselves, but rather are subjective entities derived from what may be thought of as generalizations of field observations. Although the human mind has some attributes of a computer it can "see" only certain and relatively simple abstractions or generalizations that might be derived from data manipulation by computer methods. For an example, the values shown by local dodging (variable 1) which emphasizes local differences as compared with the average of the local neighborhood almost certainly could not be comprehended by a field observer. In contrast the differences in elevation (variable 8) present a block diagram of the topography which would be both seen and comprehended. If one should look at a rugged morainic surface and observe that some parts were very rough whereas others were much less rough he might average his observations in his mind and classify the surface as merely "rough." This in effect would be similar to "smoothing" but it probably would be beyond direct observational comprehension to visualize the surface when twice smoothed, such as that shown by variable 6, which is one of the two that shows best predictability of the land types.

Examination of the three classification tables (Figs. 42-44) would seem to indicate the hilly land type, No. 3, to be the most readily classifiable by the data contained in this part of the study either by all or a few of the variables. The least predictable (35%) is land type No. 5, rolling plains with a variety of soils which by its definition perhaps is the least homogeneous.

The two variables which show statistically the best predictability for land types are the averaged slopes, variable 2, and the twice-smoothed relief, variable 6, which differed little from the once-smoothed relief, variable 7. These two variables create the surfaces shown by Figs. 47 and 48 on which the pattern of the generalized land types has been superimposed.

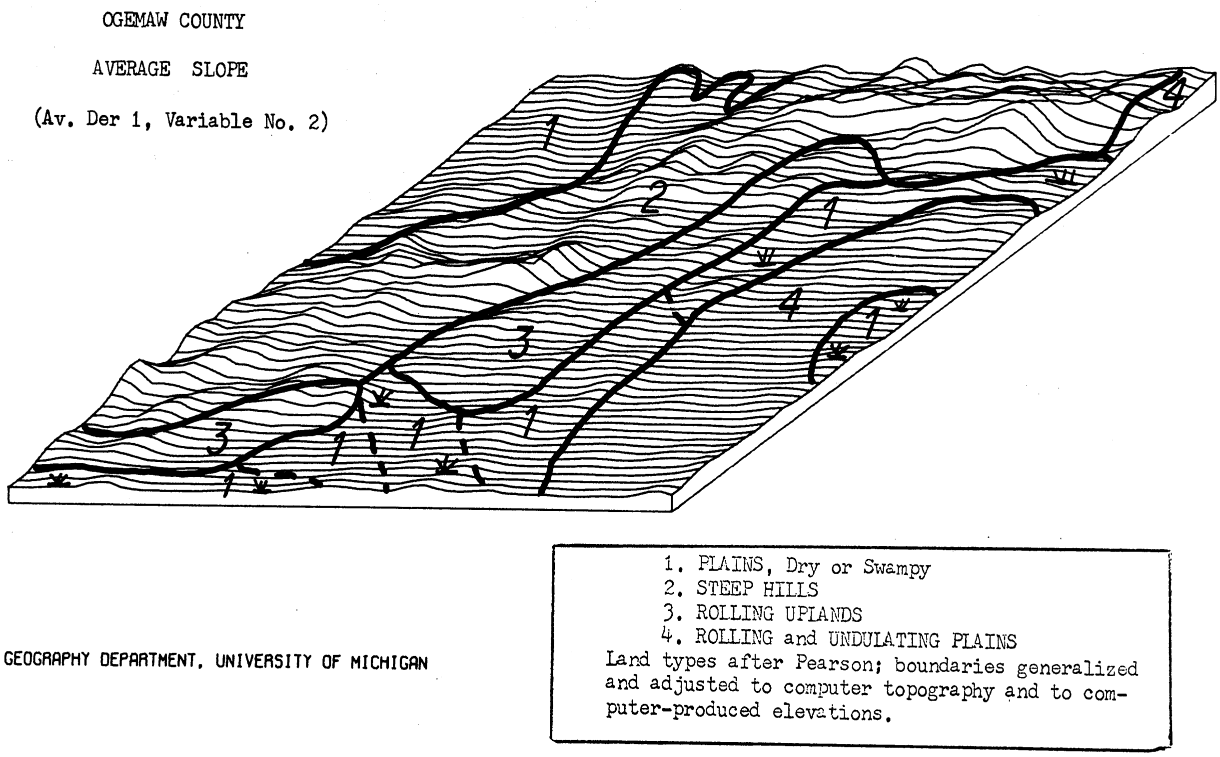


Fig. 47. Average slope and land types, Ogemaw County.

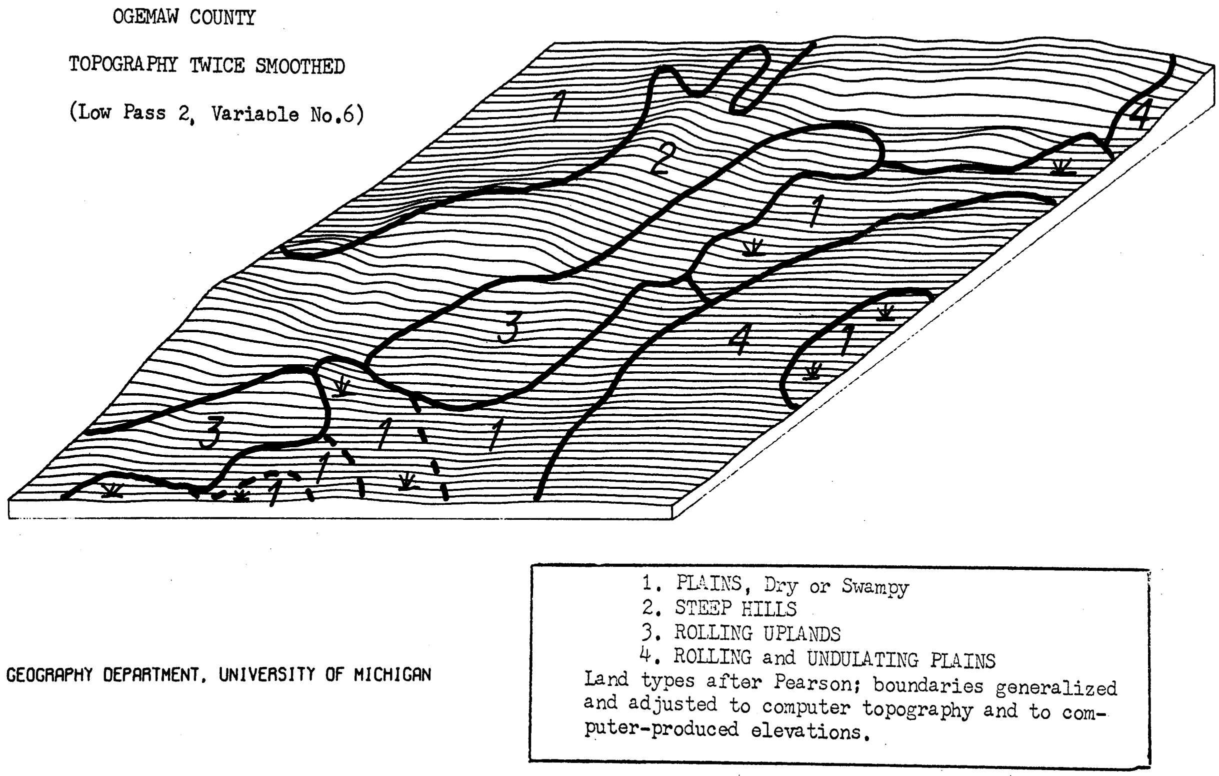


Fig. 48. Twice smoothed surface and land types, Ogemaw County.

These variables have the common attribute of generalizing or smoothing the details of the surface. Perhaps an explanation of their superior predictability may be found in the fact that the land types were derived principally from the glacial landforms and were identified in terms of their gross surface configuration with the added condition of soil. A "rough moraine," or an "undulating till plain" was itself a generalization of the details of its slopes and roughness.

The earlier parts of the study have stated that the land types as delineated in Michigan were specific composites of surface and soil with additional attributes of vegetation and drainage; perhaps it is futile to attempt to isolate them in terms of the details of only one of their characteristics.

CONCLUSION

In concluding this study the Principal Investigator offers some observations. These are on his own responsibility but he acknowledges that most of the ideas have originated from Professor Tobler.

For three centuries geographers and other scientists have been classifying the environment into "natural regions," convenient bundles into which the complex uniqueness of the earth's surface may be organized for understanding. Around each bundle a boundary may be drawn and the classification is complete; how useful it might be for many purposes may be questioned. The thematic maps of the Land Economic Survey showed enough boundary correlation that natural regions, land types, could be postulated. The mapped elements are themselves generalized and the resulting composite units even more so. For educational or reconnaissance purposes these "models" serve a valuable purpose and the exclusion of anomalous and "irrelevant" detail clarifies a general understanding; however such detail may be of importance to the problem in hand—a tank may bog down in an irrelevant swamp hole. One circumstance that has in the past led to delineation of composite regions by extrapolation of data from a relatively few investigated spots has been the difficulty—almost the impossibility—of obtaining quantified information, specifically located, over large areas. It is now becomming possible to do this and to handle and manipulate the mass of resulting information. Perhaps now the need for compositing is passing and that the units which exist, in part at least, "in the eye of the beholder" have served their historical purpose.

Quantified and located data need no longer be the fruit of foot-by-foot coverage of the ground. Topographic maps prepared by photogrammetry are examples of this; they are much better, faster prepared, and infinitely less expensive than they were half a century ago when made by other methods. The developing subject of remote sensing, now in its infancy, seems certain to develop techniques for ascertaining quantified data about the soil, vegetation, moisture content, lithology, land use characteristics, and other facts at any specific place on earth. Infrared, radar, and microwave photography from orbiting laboratories will produce information which could otherwise probably never have been gathered in view of time and cost limitations and some of which could actually not have been obtained by direct observation.

The tool for handling this mass of data is, of course, the modern computer. It has enormous capacity to store facts; to correlate, compare, and manipulate them; and to give them back in a great variety of associations and transformations. The time is approaching when we can know for any spot on the earth of what elements it is composed, in what amounts they exist at the place, and what combinations they form.

If regionalization is one of the basic techniques in geography, the computer can do it better. Modern statistical techniques such as analysis of variance, factor analysis, and clustering algorithms complement and extend the human ability to show composite likenesses and differences between one place and another. Boundaries are most valid when they are defined by specific criteria and the criteria change for each problem of substantive interest; if one puts the specific criteria into the computer, not only will the boundary be indicated but even will be drawn.

Except for educational purposes will we then need such composites as land types?

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13. ABSTRACT

An historical study of the land type, a composite land unit, as developed and used by the Michigan Land Economic Survey and other Michigan land students in the 1920's and 1930's. It's purpose is to bring together the history and scattered literature of this concept. Reviews are included of the "land system" as used by the Division of Land Research of the C.S.I.R.O. in Australia and of the work of the MEXE-Oxford group in England.

The last part of the report is a computer analysis of the digitalized land surface of one Michigan county. This employs ten transformations of the digitalized surface in an attempt to find one or a combination of transformations which will reasonably predict the land types that were made nearly twenty years ago.

14. KEY WORDS	LINK A		LINK B		LINK C	
	ROLE	WT	ROLE	WT	ROLE	WT