MICHIGAN ACADEMY OF SCIENCE, ARTS AND LETTERS

VOLUME XX

CONTAINING PAPERS SUBMITTED AT THE ANNUAL MEETING IN 1934

The annual volume of Papers of the Michigan Academy of Science, Arts and Letters is issued under the joint direction of the Council of the Academy and of the Executive Board of the Graduate School of the University of Michigan. The editor for the Academy is Alfred H. Stockard; for the University, Eugene S. McCartney.

Previous publications of The Michigan Academy of Science now known as The Michigan Academy of Science, Arts and Letters, were issued under the title, Annual Report of the Michigan Academy of Science. Twenty-two volumes were published, of which those numbered 1, 21 and 22 are out of print. Copies of the other volumes are still available for distribution and will be sent on exchange so long as the editions last. Applications for copies should be addressed to the Librarian of the University of Michigan.

The Annual Reports which are now being published contain the proceedings of the Academy. Applications for copies should be addressed to the Librarian of the University of Michigan.

The prices of previous volumes of the Papers and of other University of Michigan publications are listed at the end of this volume.

Volumes may be ordered by addressing the Librarian of the University of Michigan.

PAPERS OF THE MICHIGAN ACADEMY OF SCIENCE ARTS AND LETTERS

EDITORS

EUGENE S. MCCARTNEY
UNIVERSITY OF MICHIGAN

ALFRED H. STOCKARD
UNIVERSITY OF MICHIGAN

VOLUME XX

"Pusilla res mundus est nisi in illo
quod quaerat omnis mundus habeat."
—SENECA, *Naturales Quaestiones*

Ann Arbor

UNIVERSITY OF MICHIGAN PRESS
1935

Set up and printed,
April, 1935
Published, May, 1934

PRINTED IN THE UNITED STATES OF AMERICA
BY THE PLIMPTON PRESS · NORWOOD · MASS.

OFFICERS FOR 1934

President
HENRY A. SANDERS
University of Michigan

Vice-President
W. A. KELLY
Michigan State College

Section Chairmen

ANTHROPOLOGY, Wilbur L. Marshall, South Lake High School
BOTANY, Bessie B. Kanouse, University of Michigan
ECONOMICS AND SOCIOLOGY, Shorey Peterson, University of Michigan
FORESTRY, W. F. Ramsdell, University of Michigan
GEOGRAPHY, Edward C. Prophet, Michigan State College
GEOLOGY AND MINERALOGY, A. J. Eardley, University of Michigan
HISTORY AND POLITICAL SCIENCE, H. M. Dorr, University of Michigan
LANGUAGE AND LITERATURE, William A. McLaughlin, University of Michigan
MATHEMATICS, T. O. Walton, Kalamazoo College
PHILOSOPHY, DeWitt H. Parker, University of Michigan
PSYCHOLOGY, T. M. Carter, Western State Teachers College, Kalamazoo
SANITARY AND MEDICAL SCIENCE, Howard B. Lewis, University of Michigan
ZOÖLOGY, E. C. O'Roke, University of Michigan

Secretary
L. J. Young, University of Michigan

Treasurer
E. C. Prophet, Michigan State College

Editor
Alfred H. Stockard, University of Michigan

Librarian
W. W. Bishop, University of Michigan

CONTENTS

ILLUSTRATIONS

PLATES

FIGURES IN THE TEXT

MAPS

THE CENTRAL PYRENEAN PIEDMONT OF FRANCE

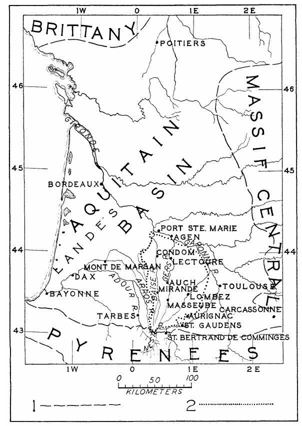
HENRY MADISON KENDALL

THOUGH the Aquitain Basin (Map 22)[1] of southern France is commonly regarded as one of the major geographic units of the European continent,[2] it can in no way be thought of as an undifferentiated lowland of uniform landscape. Morphologically, it is distinctly set apart by Brittany and the Massif Central on the north and east, by the Atlantic Ocean on the west, and by the high rampart of the Pyrenees on the south. One opening to the north, the Gate of Poitou (Poitiers), and one to the southeast, the Gate of Carcassonne, break through the otherwise well-defined rim of this saucer of land, half-covered by the Atlantic Ocean. In spite of these outlets, the land looks westward to the open ocean, whence come the rain-bearing winds which make it well watered. Some of its area is without a dense population and is admirably adapted to pastoral pursuits. Other portions with a greater density of population have characteristics eminently fitted to agriculture. It is not a land of industry, for it lacks the natural resources upon which modern industry is based. It is dominantly rural, though its major cities are born of the importance of commerce. From this point of view the Aquitain Basin is a clearly recognizable unit. When detail is examined, however, the variety of landscape expression becomes evident, and sectional differences assume paramount importance.

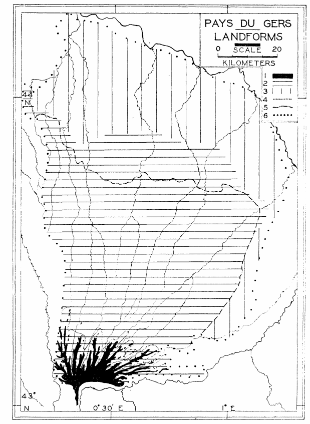
One of the group of tiles which, placed together, make up the mosaic of landscape of the whole Aquitain Basin is the Central Pyrenean Piedmont. It is known by a variety of *pays*[3] names, of which the collective *Pays du Gers* seems well suited, even though this is an extension of the usual sense in which that name is used. Pays du Gers and Central Pyrenean Piedmont of France may be used interchangeably.

THE SETTING

The Pays du Gers forms a distinct geographic region, though, because of its considerable area, which is about 8,500 square kilometers, it presents noticeable variety of detail throughout. It is set off clearly on three sides, but to the west it blends with other portions of the piedmont. To the south it is cut off by the Pyrenees and the valley of the Neste[4] while to the east and north it is delimited by the ribbon-like plain of the Garonne. To the northwest lies the expansive, low, sandy plateau of the Landes.[5] The limits have been recognized not on the basis of surface character alone, but from the aspect of the surrounding land as contrasted with that of the land inclosed within the bounds mentioned.



Map 22



Map 23

MAP 22. Southwestern France. Explanation of symbols: 1, limits of major physiographic regions; 2, limits of the Pays du Gers

MAP 23. Based in part on a map by L. A. Fabre, "Le Front nord des Pyrénées centrales et les hautes vallées gasconnes," on a scale of 1 : 200,000, in *La Géographie*, 11 (1905), Plate 3. Explanation of symbols: 1, undissected surface of the plateau of Lannemezan; 2, zone of asymmetrical valleys; 3, zone of mature interfluves and mature valleys; 4, northern and eastern limit of youthful valleys; 5, northern and eastern limit of youthful interfluves; 6, limits of the Pays du Gers

Surface configuration and hydrography

There is a continuous gradation of surface and drainage forms from the Pyrenean front to the Garonne Valley. Three zones of combined forms may be recognized. They are: first, the nearly level plateau surface with incipient drainage; second, the section of asymmetrical valleys[6] with asymmetrically placed major streams and youthful interfluves grading northward into mature ones; and, third, the zone of late mature valleys with widely meandering streams separated from one another by belts of maturely, dissected interstream spaces.

A broad expanse of nearly level land stretches northward from the front of the Central French Pyrenees (Map 23; Pl. LXXXI, Fig. 1). This is the plateau of Lannemezan, all that remains of a formerly more extensive mass of fluvio-glacial detritus.[7] The apex of this deposit is on the slope of the mountain which forms the left bank of the upper Neste Valley. From that point the land descends gradually and spreads out like a fan northward. Numerous streams, all contributing to the volume of the Garonne except a few which bathe the western edge of the mass, have cut their way headward into the fan, so that the present northern edge of the plateau is a succession of narrow, flat-topped, finger-like ridges separated from one another by steep-sided, V-shaped valleys (Pl. LXXXI, Fig. 2).

These finger-like remnants extend as much as thirty kilometers from the apex of the fan (Map 23). With increasing distance from the mountains they become narrower, and the valleys between them become wider and less notched. They are asymmetrical in cross-section with, usually, steep eastern walls and gentle western ones. Their floors are filled with alluvium, both ancient and recent. They are definitely aggraded.

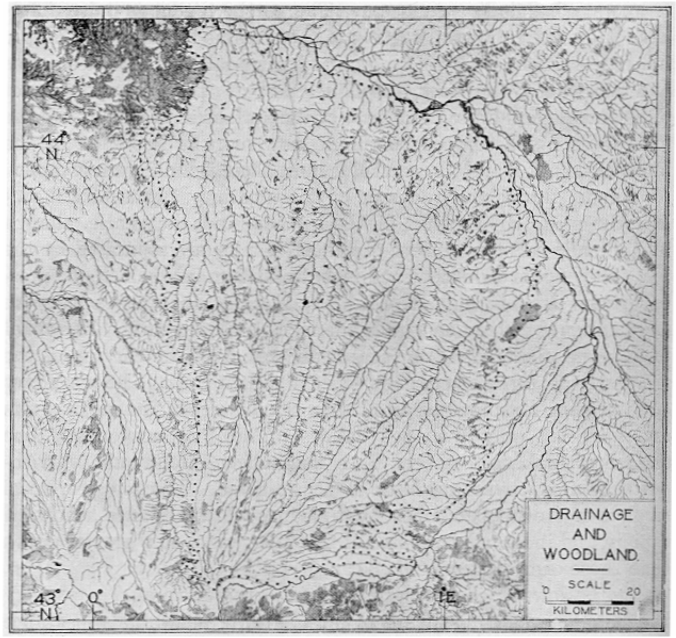
Beyond the latitude of Auch there are few youthful remnants of the upland surface. Northward the country appears to be made up of several lines of well-rounded hills. The valleys which separate them present the characteristics of late maturity or old age. They remain asymmetrical somewhat farther to the north, however.

As the Garonne River is approached, the valleys become narrower and the interfluves are more prominent. They break away sharply to the Garonne lowland over two levels of terraces,[8] which are well defined except where the river is sapping its southern valley side. All the affluents of the Garonne on its left bank cut trenchlike valleys through these terraces. Though these valleys are not wide or deep, they produce a surface which is dissimilar to that in the hilly land to the south. This surface marks a distinctive change of landscape between the Pays du Gers and the plain of the Garonne.

Only along its northern edge is surface water to be seen on the plateau of Lannemezan. The main body of the upland is not fretted with valleys, nor are there any lakes or marshes on it. In some places the water table approaches the surface, and, here and there, temporary bogginess may occur. The northern edge is quite different. Here the headward cutting of the streams forms a very deeply indented surface, both vertically and horizontally. It is the streams and their valleys that limit the plateau proper. The upper portions of the streams form an integral part of the surface in that they are the vital force which controls this limit, now more or less fixed by the intervention of man.[9] Beyond this limit there is a different complex.

Almost throughout the zone of outstandingly asymmetrical valleys the steep right banks of the streams and the gentle, though latitudinally serrated surface of the left banks, are separated by the flat valley floors of ancient and recent alluvium into which the present rivers are cutting (Pl. LXXXI, Fig. 3). In a few places the left bank is the steep one while the right bank is gentle. The relief of any one of the three surfaces is the result of the carving of the tributaries, except the channels of the main streams. The secondary streams have not progressed to the erosional stage of the major rivers and have cut only V-shaped valleys. They produce on any one surface a washboard effect. This roughening is found almost without exception on the surfaces of gentle slope. The few torrential rivulets of the steeper slopes[10] cut ravines which advance headward rapidly and indent the sky line of the valley sides to a greater depth than those of the opposite banks.

In the lowest, or northernmost, zone there is found a country which, if one looks eastward or westward, presents the appearance of an ocean breaking against a shore. Northward or southward the likeness is not lost; it merely appears, from the valleys, as though one were in a trough between two waves, or, from the interfluves, as though one were on the crest of a wave. Water has worked upon the land to reduce it until a veritable labyrinth of rivers, brooks, and rills separates isolated, gently rounded hills (Pl. LXXXII, Fig. 1).



MAP 24. The Pays du Gers and surrounding area. Based on Carte de France à 1 : 200,000 — 1927 édition

The stream pattern corresponds to the zonal arrangement of surface forms (Map 24). The rivers flow in a radial pattern from the plateau of Lannemezan in a general northward direction to their confluences with the Garonne. Near their headwaters they follow rectilinear courses and have few tributaries. Farther northward the number of tributaries, particularly on the left banks of the main streams,[11] is increased and the pattern is comblike. In the northernmost zone the number of small tributaries is decreased while that of large tributaries is increased. There the pattern is dendritic in detail. Throughout their whole length the radial arrangement of the streams from the plateau is fundamental. Other detailed patterns which are encountered are amplifications of this or are combinations of it with others.

The reaction of the streams to the climatic régime can be noted clearly. The period of highest water is usually during April and May, and it is followed by a period of extreme dryness. In July and August there is very little water in the major streams, and many of the smaller ones are completely dry (Pl. LXXXI, Fig. 3). From September onward there is a gradual increase in flow until a maximum, which is only slightly lower than that of early summer or late spring, is reached in December. After this there is a slight decrease until the end of January, when increased flow is again noticeable.

More startling than the seasonal changes are the changes induced by short periods of heavy rainfall. The effectiveness of storms is due, in part at least, to the impermeability of the soil near the headwaters of the streams and on the steeper slopes.[12] The reaction of the streams to sudden storms has long been noted.[13] A heavy rain of a few hours' duration produces a flooding of the flat valley floors of any of the major valleys. Evidences of human attempts at protection from these sudden floods, such as the retaining walls which line the Baïse at Condom, bear witness to the rapidity with which the streams answer to the changes in weather (Pl. LXXXII, Fig. 2).

Since the construction of the canal along the edge of the plateau of Lannemezan there have been fewer disastrous floods at the high-water periods, and the severity of the droughts has been considerably lessened,[14] but the regimen of the rivers has been very little affected. Their flow bears little relationship to the snow accumulations of the Pyrenees and can be more completely related to the rainfall regime of the Aquitain Basin as a whole.[15] There is variability throughout the basin, and the amounts of water in the various rivers decrease relatively as one proceeds eastward. The regimen does not vary, however.

Climate

The climate of the Pays du Gers is that which is found typically a short distance inland from the west coasts of continents in the middle latitudes. Though it shows a transitional character between marine, continental, and mountain climates,[16] there is a normal marine modification of maxima and minima of temperature and rainfall. There are no periods of extremes of heat or cold, and exceptional wetness or drought is not general. The position of the Pays du Gers, open as it is to the Atlantic and the Mediterranean winds, but shut in to the south by the Pyrenees, is the dominant feature of the local climatic control.

The climatic statistics for Auch[17] may be taken as typical of the whole region. The temperature is given in degrees Centigrade and the rainfall in millimeters. They are as follows:

	J.	F.	M.	A.	M.	J.	J.	A.	S.	O.	N.	D.	Year
Temperature....	4.0	6.3	8.2	10.4	14.7	17.2	19.4	19.9	17.1	13.0	8.0	6.0	12.0
Precipitation....	53	42	52	73	77	75	50	47	58	58	54	50	689.0

Soil

The soil, as recognized in its climatic soil group by Agafonoff,[18] is of the Brown Forest type.[19] Well-developed profiles are to be found in only a few places. In general, the soils of the steep eastern valley sides are being constantly removed by sapping and gullying as well as by soil creep. Consequently, whatever profile might have been developed is not now visible in its entirety. On the gentle western valley sides the covering of alluvium masks whatever development there has been. Under the mask it is possible to make out poorly developed profiles. On the valley floors recent alluvium, which is being added to constantly, prevents the formation of distinct horizons. Only in the undissected remnants of the plateau of Lannemezan have the soil-forming processes gone on undisturbed for a time sufficiently long to permit the formation of horizons which correspond to those by which the Brown Forest soil may be recognized. Even here the influence of parent material appears to remain.

Vegetation

The region lies within the belt of mixed hardwood forest, though very near its equatorward margin.[20] The beech family, represented dominantly by numerous oaks, constitutes the remnants of woodland left at present (Map 24). In view of the position of the area as regards climate and soil, it may be said that this family of trees was the most common in the past. Where the original cover has been removed and the land is not under cultivation, the forest returns slowly. Partly as a result of this, the valley bottoms are now dominantly grass-covered, with fringes of trees along the water courses (Pl. LXXXII, Fig. 3). The surface of the plateau of Lannemezan is now moorland (Pl. LXXXI, Fig. 1), though its original cover was probably similar to the present woodland elsewhere throughout the region.

In respect to the trees present the area is transitional between the Mediterranean and the oceanic categories of Gaussen.[21] Three types of deciduous oaks (*Quercus pedunculate* Ehrh., *Q. Robur* Willd., and *Q. pubescens* Willd.)[22] are dominant, though ironwood (*Carpinus Betulus* Tourn.), chestnut (*Castanea vulgaris* Link), maple (*Acer campestre* L.), sycamore maple (*Acer pseudoplatanus* L.), black locust (*Robinia pseudo-acacia* L.), hazel (*Corylus Avellana* L.), and hawthorn (*Crataegus oxyacantha* L.) are also common trees throughout. The evergreen oak (*Q. Ilex* L.), the cork oak (*Q. Suber* L.), and the olive (*Olea europaea* L.), suggesting westward extension of the Mediterranean type, are not numerous, but all of them exist even beyond the western boundary of the Pays du Gers. The Scotch pine (*Pinus sylvestris* L.) occurs quite frequently in areas of sandy soil. Fir (*Abies pectinata* DC.), spruce (*Picea excelsa* Link), larch (*Larix europaea* DC.), and beech (*Fagus sylvatica* L.) add a more northerly character to the woods in the few localities in which they occur.

Along the stream courses willow (*Salix alba* L., *S. amygdalina* L, and *S. viminalis* L.), alder (*Alnus glutinosa* Willd.), and several varieties of poplar (*Populus nigra* L., *P. tremula* L., and *P. alba* L.) form regular dense fringes. Other than in these fringes trees occur only in hedgerows on the valley floors. Prairies and meadows, interrupted by a few cultivated fields, make up the remainder of the covering. As one proceeds southward toward the plateau of Lannemezan, the grasslands of the valleys are less extensive (Pl. LXXXIII, Fig. 1). They finally give way to brush or deciduous oak cover.

The plateau and its finger-like extensions are fringed with this oak woods, which ceases abruptly near the 600-meter contour. On the plateau the vegetation is moor, except for a few scattered areas of oak woods (Pl. LXXXIII, Fig. 2). Furze (*Ulex nanus* Sm. to the west and *U. europaeus* L. to the east) and heather (*Calluna* *vulgaris* Salisb.) are dominant on this moorland, though two of the heaths (*Erica tetralix* L. and *E. vagans* L.) are found in the association. Their existence in place of a forest cover is a cultural matter. The continued pasturage of sheep on the plateau has done much to make natural reforestation ineffective.[23]

Originally the Pays du Gers was nearly completely forested, with occasional grassy patches along the streams.[24] The exceptions to the forest cover were edaphic and not climatic. The present state of the forest covering is an expression of the use which man has made of the area and not of the inherent fundament characteristics.

The base of human occupance

The complex of these features of the fundament make up the base for man's activity in the area. The Pays du Gers is definitely set off from surrounding regions and in this respect is typical of the whole northern piedmont of the Pyrenees. It is the largest of the many fans which spread out from the mouths of the Pyrenean valleys into the central declivity of the Aquitain Basin. For this reason its parts are more clearly defined than similar features of the other fans. It occupies a central position with reference to the Pyrenean front, and appears, therefore, to be the culmination of all the sedimentary deposits of the basin. It is a very prominent part of the Aquitain region.

The land surface is fundamental. The original feature of a cone of detrital material piled up at the base of a mountain range is essentially unchanged. From a valley worn deep by glacial action it extends, gradually decreasing in elevation, to the median line of the basin where flows the Garonne River. Back from this broad stream tributaries have eaten radially disposed valleys into the sides of the cone. They have all but removed the original surface, leaving, to the north, wide valleys with hilly interfluves, and, farther south, narrowing asymmetrical valleys with flat-topped interfluves, until finally the V-shaped valleys which scallop the edge of the plateau of Lannemezan are reached, and the remnant of the old surface, little disturbed, is attained. This is the base into which the ultimate roots of human life in the region are grown, and from which have sprung the fruits of that occupance.

POPULATION

Human beings have lived in the Pays du Gers for a very long period of time. The earliest occupance of the area about which anything is known was during the Paleolithic period. Aurignac, the type station of the Aurignacian subdivision of the Paleolithic,[25] lies near the southeastern edge of the region. Neolithic remains, both at Aurignac and at other points throughout the area, can lead only to the conclusion that human occupance has been continuous since early Paleolithic times.[26] The evidences of early occupance are not areally important in the present landscape, however.

Occupance in historic times has continued to mold the landscape into its present form. It is known that the Phoenicians had reached the Aquitainian coast in the fifteenth century B.C.,[27] and that they had trade relations with the people of the interior as well as with those along the coast. The land was well known to the Greeks and is briefly mentioned by Strabo.[28] It came under the influence of Rome and existed as a separate province.

Many of the towns are at least of pre-Roman date of establishment, and they indicate the almost static position of life within the area since that time. It was well known then as an agricultural area and it still remains so in essence. It has been many times contested for by Greeks, Romans, Goths, Moors, Spanish, and English, and only in relatively recent times has it come under French domination. The continual influx of cultural elements has not caused any sudden and emphatic change in the character of the occupance. Rather various items of all the cultures have been fused into one mass which makes up the present cultural phase of the landscape. The effect of these culture infusions may be measured in terms of the nature of the population and its distribution, the pattern of circulation forms, and the use of the land, but to estimate the part which belongs to each of the long series of cultures would be impossible, for they have been completely blended.

The nature of the population

The population of this part of France is very uniform in type. The inhabitants during the pre-Christian era were of the Iberian group of peoples,[29] and, despite the fact that invasions of other peoples have been recurrent, this fundamental stock has been little changed.

Successive waves of people, constantly overriding western Europe, plundered the land, but, with the exception of the Vascon influx from Spain, the invaders did not settle in considerable numbers. The Vascons were Iberian peoples, and consequently the character of the inhabitants of the region was not greatly altered when they came. For all others the Pays du Gers proved simply an obstacle to be overcome during the invasions rather than a coveted prize, though no satisfactory explanation has been made why this land should have been passed over by the invaders. Even after it had become part of France in 1453[30] the people remained isolated as a nearly foreign group.

During the last few centuries there have been minor infiltrations of people of other nationalities. Spanish[31] and Italians[32] are the most numerous, though there has been, in recent years, an influx of Swiss to the western part of the Pays du Gers.[33] Only very slowly have these people been absorbed. The inhabitants have remained nearly as free from admixtures as the Basques.

The present population is distinctly a rural one. The French census lists classes of population on the basis of the size of agglomeration in which the people live. Agglomerations of over 2,500 people are considered urban, whereas those of smaller size down to the individual house are considered rural. In the 1926 census,[34] the population of the whole of France is given as 40,743,854, of which 19,984,720 are listed as urban dwellers. The Department of Gers, which may be taken as representative of the Pays du Gers for statistical purposes, is listed as having a total population of 196,419, of which only 26,250 are urban dwellers. For the whole of France the population is 49 per cent urban whereas, in the Department of Gers, it is only 13 per cent urban. The rural character is further emphasized by the consideration of the proportion of persons engaged in agriculture. In France as a whole, in 1921, 23 per cent of the people were engaged in agriculture, whereas in the Department of Gers 48 per cent were so engaged.

The one basically geographic cause of depopulation[35] in the Department of Gers since 1846 (see Table I) has been industrialization and urbanization in other parts of France. To these other centers many of the younger people of Gers have gone, and few of them have ever returned. The character of Gers does not permit within its confines the growth of large cities which might combat this trend. Gers is a rural portion of France and by its own equipment it is forced to remain so. There has been a growing dislike for rural life during the last two generations, combined with the rise of the feeling that agriculture is not a desirable pursuit. The area can provide food, clothing, and shelter, but moneyed wealth is not to be found. The large city calls up illusions of great wealth and easier life than the farm. As a result, the youth of the country are strongly tempted to leave and do so. Thus the Pays du Gers loses population to other sections of France where rural life is not predominant.

TABLE I[36]

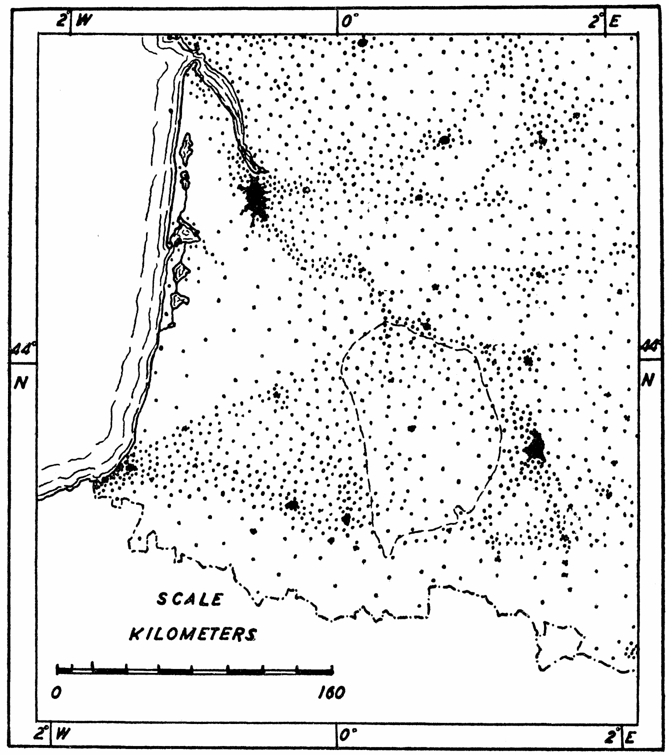
POPULATION OF THE DEPARTMENT OF GERS

1790	268,800	1846	314,885	1886	274,391
An VIII[37]	270,609	1851	307,479	1891	261,084
1806	295,021	1856	304,497	1896	250,472
1821	301,336	1861	298,931	1901	238,443
1826	307,601	1866	295,692	1906	231,088
1831	312,160	1872	284,717	1911	221,994
1836	312,882	1876	283,546	1921	194,406
1841	311,147	1881	281,532	1926	196,419

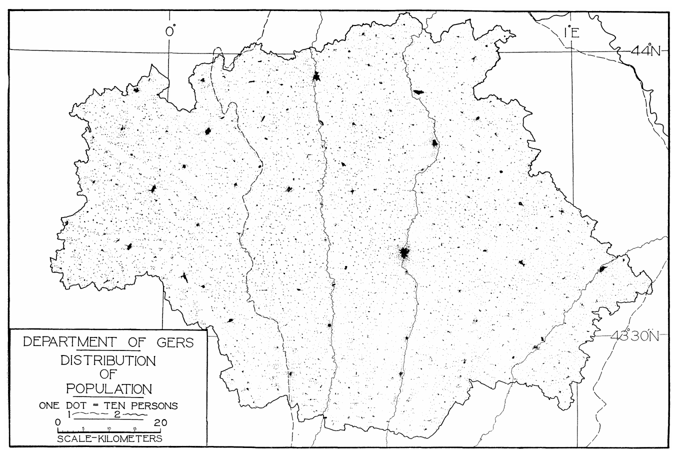
For 1926:	Agglomerated	72,134
	Scattered	121,132
	Others, including troops, etc.	3,153
	French	184,335
	Others	12,084
	Houses	57,315
	Households	54,807

The distribution of population

In contrast to that of surrounding regions, the population of the Pays du Gers is quite sparse (Map 25). The Garonne lowland forms a winding band of nearly evenly distributed population from the large seaport agglomeration of Bordeaux to the inland center of Toulouse. Even beyond this latter place the band continues until the immediate pre-Pyrenean valley is reached. To the west a triangular area of dense population exists between Bayonne, Tarbes, and Mont-de-Marsan. Of all the surrounding regions only in the Landes is a sparser population and a more scattered one to be found.



MAP 25. Population of southwestern France according to the census of 1926. One dot equals 2,000 persons. Dashed line indicates the limits of the Pays du Gers



MAP 26. Explanation of symbols: 1, limits of the Pays du Gers; 2, limits of the Department of Gers. Statistics from *Annuaire administrative statisique, historique, et commercial du Gers pour 1930* and from *Résultats statistiques du recensement général de la population effectué le 7 mars 1926*. Position of dots controlled by position of houses shown on the Carte de France à 1 : 50,000—1926 edition

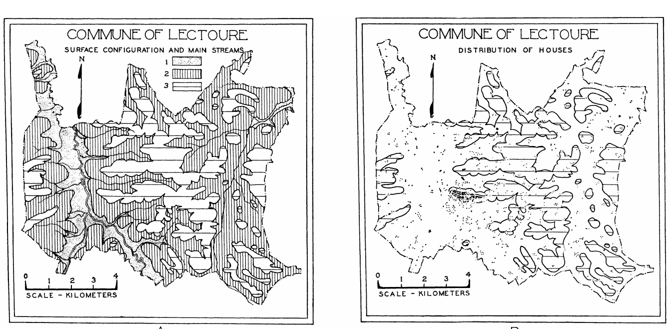
In detail, the population of the Central Pyrenean Piedmont is distinctly disseminated[38] (Map 26). A rather even spread with many scattered nuclei is to be noted. The largest of the nuclei is the city of Auch, with 12,500 inhabitants. This is the only urban agglomeration within the area. To the north of the city the dissemination is quite even, as is also the spotting of nuclei throughout it. To the south of the city the spread is more uneven, and the groupings are fewer and smaller. A closer examination of the patterns of two small sections will serve to show the essential differences between north and south.

The first of these small sections is the commune of Lectoure, which is in the north-central part of the Pays du Gers. The surface as a whole is in the mature stage of erosion (Map 27 A). The Gers River flows northward over a flood plain which has an average width of one kilometer. Rising in varying slopes, the valley walls stretch back to mature ridge tops. The eastern valley side is steeper than the western one. Tributaries to the main stream have eaten back into the original interfluves and have carved out steep-sided masses which project finger-like toward the main valley.

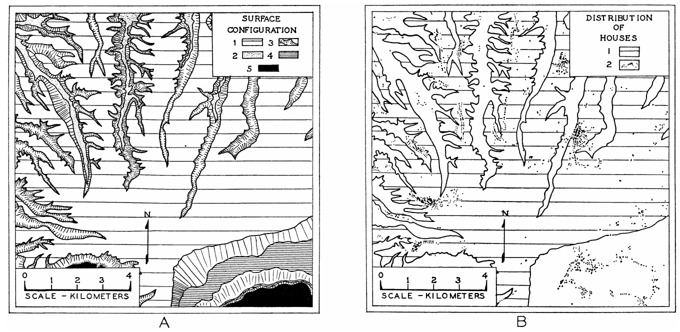
On the remnant of the upland surface which extends farthest toward the Gers River there is a large agglomeration, which is the town of Lectoure (Map 27 B; Pl. LXXXIII, Fig. 3). It comprises 58 per cent of the total population of the commune. The remainder is scattered over the whole area, with a notable tendency toward arrangement of houses in closely knit groups. All types of surface are used, but fewer houses are on the flood plains than on either the ridge tops or the slopes. The pattern of house distribution indicates decreasing density of population with increasing distance from Lectoure, regardless of surface types.

The plateau of Lannemezan stands in considerable contrast to the area of the commune of Lectoure. The gently inclined surface of the plateau slopes steeply down to the southeast and the southwest to valleys of Pyrenean streams (Map 28 A). To the north finger-like extensions project between youthful valleys of the rivers which have their sources upon the surface of the plateau. It is typically an area of narrow, steep-sided valleys and narrow, flat-topped interfluves.

The population is concentrated where the youthful valleys most closely approach one another on the outer fringe of the plateau (Map 28 B). The dissemination of houses is less than in the commune of Lectoure, and the population is almost exclusively confined to the ridge tops. Each interfluve bears a loosely arranged agglomeration which, in some instances, stretches along the ridge for a distance of two kilometers or more (Pl. LXXXV, Fig. 2). There are relatively few isolated dwellings.



MAP 27. Position of houses, from Carte de France à 1 : 50,000 — 1926 édition. Explanation of symbols: 1, flat valley floor; 2, valley sides; 3, ridge tops



MAP 28. The Plateau of Lannemesan

A. Explanation of symbols: 1, undissected plateau surface; 2, flat valley floors; 3, valley sides; 4, terrace of the Neste River; 5, Pyrenean slopes
B. Explanation of symbols: 1, undissected plateau surface; 2, houses

Population agglomerations

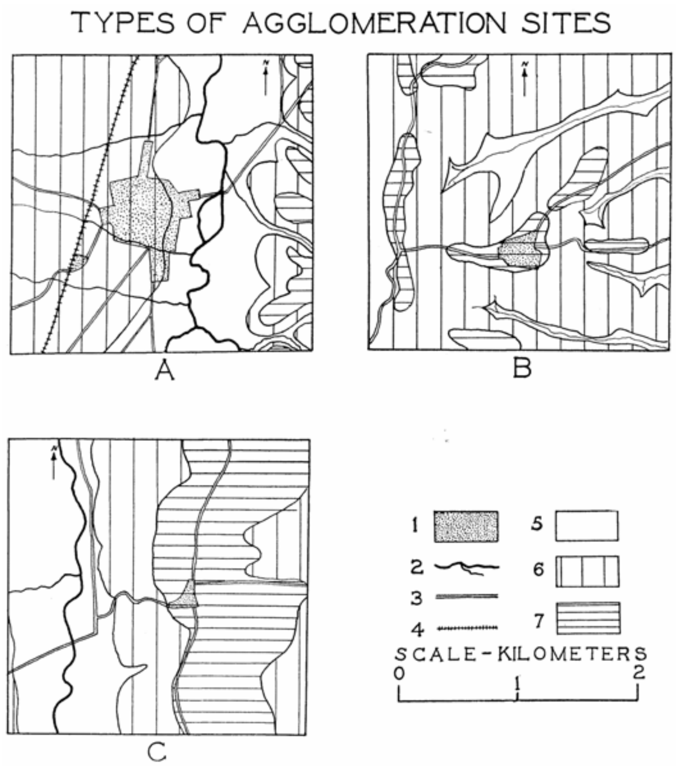
The presence of many agglomerations is the most conspicuous feature of the population distribution. Regardless of size, the groups of buildings convey the impression of fitting the setting almost as though they were part of it. They are dominantly of limestone in the west and of sun-dried brick in the east. In many instances a layer of stucco, made from local clays, covers these materials. The color is invariably the yellow-brown of weathered ferrous rock. Roofs of reddish tile throughout, except in the southwest, where Pyrenean slate is available near by, are also discolored by weathering. A massing of such buildings, whether large or small, results in the same kind of expression on the surface of the land. The conspicuousness is, however, more a function of site than of form of these agglomerations.

There are three characteristic sites on which these population groupings occur. One type of site is the gently sloping side of a main valley at the edge of the present flood plain (Map 29 A). The second type is the hilltop (Map 29 B). The third type is the crest of the steep valley side, where the interfluve is youthful in character (Map 29 C).

The valley sites are occupied in the area of mature valleys and more particularly where the interfluves are mature as well. The towns on these sites center on the intersection of two highways; one extends along the valley and the other crosses the valley and the interstream spaces on either side. This type of site is not occupied in the southern zone of youthfully dissected surface or for some distance northward into the central zone of mature valleys and youthful interfluves.

The hilltop site is most commonly occupied in the northern and eastern maturely dissected portion of the Pays du Gers (Pl. LXXXIV, Fig. 2). There the agglomeration usually centers about either an old church or a château, and consists mainly of closely packed houses, some of which are contiguous to the church or the château itself. The aspect of a walled town is created.

The site on the crest of the steep valley side in the areas where the interfluves still retain some of their youthful character is utilized in the southern and central surface zones (Pl. LXXXIV, Fig. 3). Near the northern extremity of the zone of mature valleys and youthful interfluves, where the interfluve edges become more fretted by the erosive action of an increased number of tributary streams, agglomerations are at the ends of the projections of these interfluves toward the main valleys. In the south some agglomerations occupy the whole width of the narrow interstream spaces.



MAP 29. Explanation of symbols: 1, area covered by agglomerations; 2, streams; 3, roads; 4, railroad; 5, flat valley floor; 6, valley sides; 7, ridge tops

In the choice of the last two types of site protection seems to have been the guiding principle.[39] All the older towns and villages have sites of one or the other of these two types. With the advent of comparative stability of government and freedom from invasion,[40] valley sites came to be occupied. The increase in completeness of articulation with the rest of France made positions along the main routes more desirable.

With increased population in the valley towns many of them have spread out over the present flood plains of the rivers, but in all such instances artificial control of river waters is practiced either by the construction of diversion channels upstream from the town or by building deeper, walled channels along the stream courses within the agglomerations (Pl. LXXXII, Fig. 2). Many of the groupings on the hilltops or on the crest of the valley sides, where these towns are situated near the major streams, have, with the increased importance of road and rail connections, spread from their original sites down the valley sides (Pl. LXXXV, Fig. 1). They have even grown across the flood plain in their attempts to overcome the handicaps of the positions imposed upon them by the necessities of another age.

The remainder of the population is distributed about the towns and villages in a manner dependent upon the pattern of circulation forms. These, in turn, reflect closely the surface configuration. Consequently the spread of population is quite evenly radial about the towns and villages in the zone of maturely dissected surface. Where youthful surface forms alone are present, the population spread has been confined to the ridge tops. The central zone is transitional in terms of population distribution, as it is in terms of surface configuration. However, there is no sharp break between the patterns in the various parts of the whole area.

CIRCULATION

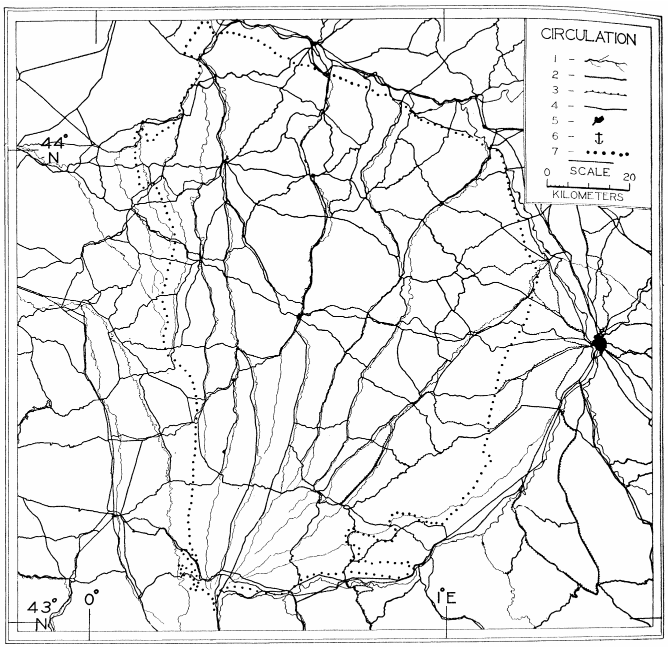
In the arrangement of all the forms of circulation the relationship to surface configuration is recognizable, though it is more clearly demonstrated in some parts of the region than in others. In the south limitations are imposed by the boldness of the relief. In the north relief is less hampering to free development, though the limitations are not sufficiently relaxed to allow the divorcement of the pattern of circulation forms from that of surface configuration.

Roads

Two classes of roads may be recognized on the basis of conspicuousness in the landscape. The hard-surfaced roads, whether they are "Routes Nationales" or "Routes Départementales," are most frequently traveled. They are characteristically about five meters in width. Along both sides and set back about two meters from the edges there are usually lines of trees (Pl. LXXXIV, Fig. 1). These draw attention to the roads perhaps even more than do the streams of traffic which flow along them. Such highways are the main or the major routes of communication. In contrast to them are the minor roads which are unsurfaced. Great variety in width and upkeep make them undesirable except as tributaries to the main highways. They vary from mere cart tracks or sinuous thin bands of unsodded surface to expanses of sand, clay, or gravel five or six meters wide. Usually they are not observable from any considerable distance and, though they may alter the landscape pattern in detail, their function in this respect is completely overshadowed by that of the major roads.

In general, the highways diverge radially from a focus on the plateau of Lannemezan (Map 30). One road crosses the plateau from the premontane valley of the Neste on the east to that of the Arros on the west. At right angles to it two highways stretch northward in a subparallel plan along the finger-like plateau extensions. About fifteen kilometers from the plateau they descend the left valley sides to the level of the present flood plains. One follows the valley of the Petite Baïse River to its junction with the Grande Baïse, along which the road continues its northward course. The other follows the Gers River. They extend along diverging courses in the same position relative to the valley floors as far as the latitude of Auch. North of this there are frequent shifts from one valley side to the other, depending upon the position of the streams in their flood plains. One road joins the Bordeaux-Toulouse highway in the Garonne Valley at Agen; the other, at Porte Ste. Marie.

Until the latitude of Auch is reached main east-west roads are infrequent but, in addition to the two mentioned above, many roads diverge northward. They follow ridge tops (Pl. LXXXVI, Fig. 1) or the edges of the valley floors. Frequently roads from tributaries unite with those in the main valleys. This upsets the regularity of the radial pattern.



MAP 30. The pays du Gers and surrounding area. Based on Carte de France à 1 : 200,000 — 1927 édition. Explanation of symbols: 1, main rivers; 2, standard-gauge railroads; 3, narrow-gauge railroads; 4, main roads; 5, towns with more than 2,000 inhabitants; 6, head of navigation on the Baïse River; 7, limit of the Pays du Gers

North of Auch, where the relief is less marked and the slopes are less abrupt, each large agglomeration of population is the center of a secondary radial pattern which masks the basic one. Ridges are more frequently chosen for roads in this section than are the valleys, though all types of surfaces are utilized with considerable ease (Pl. LXXXII, Fig. 1).

The base from which the present pattern developed is found in a pre-Roman route which connected Aquitain with Aragon across the central Pyrenees.[41] This route left the Pyrenees near the apex of the fan, crossed the plateau of Lannemezan, and followed northward along the water parting of the Adour and the Garonne drainage basins. Such a route avoided the bridging of streams and the surmounting of steep slopes. A portion of it is followed by the present road just to the northwest of the Pays du Gers.

More significant in the present pattern are the Roman roads. Only four of these have been definitely traced. One of them connected Agen on the north with St. Bertrand de Comminges on the south.[42] This is essentially the route followed by the present road in the valley of the Gers from Agen to Masseube. To the south of that place it found its way in zigzag fashion across the intervening valleys to its destination. Another highway connected Toulouse and Agen by way of Lectoure.[43] The third connected Toulouse and Dax.[44] The present road from Toulouse to Auch and on to the northwest follows nearly exactly the trace of this old Roman thoroughfare. The fourth was of a later date than the others. It connected St. Bertrand de Comminges and Dax, crossing the plateau of Lannemezan near the northern limit of its undissected surface.[45]

The choice of the particular trajectory which the present road follows across the plateau of Lannemezan is primarily the function of the road which preceded it and of the position of agglomerations of population on the portion of the plateau surface that extends northward. It is not a function of surface differences. So it is likewise with the course of the road from the south across the plateau. Minor roads are all straight, except those that bend slightly to the south to avoid the headwater ravines of the streams which have their origin on the upland surface.

In the zone of asymmetrical valleys and flat-topped interfluves the main roads, with one exception, extend along the grain of the country. The one exception is the road which forms a semicircle from Tarbes on the west of the region to St. Gaudens on the east. Between this road and the plateau the two routes previously mentioned as the skeleton of the whole pattern are the only main-traveled thoroughfares. To the north of it nearly every valley and a few of the interfluves are served by well-traveled highways. They extend as far northward as the next main east-west road, which is the one that winds its sinuous course from Toulouse through Auch. In this zone the ruggedness of the land surface is not great enough to prevent the construction of roads in almost any direction, but ease of communication on a north-south line has emphasized the importance of routes so oriented. The minor roads are for the greater part connecting links between the north-south highways, though occasionally they parallel the major ones.

To the north of Auch the undulating character of the surface is shown by the fact that the roads are no longer confined to the valleys or to the ridge tops. Nearly direct routes between the larger population agglomerations are followed. The roads are not laid out along straight lines, with no conformity to surface. At the same time they are much less closely controlled by it than they are to the south of Auch. In many instances the hamlets and villages are not located on the main highways, but are connected to them by short spurs. In a few places this indicates a local difficulty of surface, but more frequently it is a reflection of the character of the agglomeration itself. Many of them are older than the road system and consequently are too compact to allow the unimpeded movement of the traffic that passes over the main highways. The minor roads form a very complete connecting network between the main roads. They extend over all types of surface and link the whole population to the larger centers.

Auch, which is located on the border between the zone of roads closely controlled by surface features and the zone in which there is little control by surface, forms the center of an octopus-like pattern of main highways (Map 30). At Auch the north-south and the east-west Roman roads crossed, and, though the town does not owe its origin to that fact,[46] the road intersection has undoubtedly been an important factor in the development of that town as a center toward which the whole region is focused. Three main highways have been added to the original ones from Auch. One of these branches from the highway leading westward crosses the upland to the northwest and descends a tributary valley to the Baïse, where it joins a main north-south highway. The second of these additional roads branches to the southwest, follows up a tributary valley for about five kilometers, and makes its rather tortuous way across five interfluves to the plain of the Adour. The third supplementary road extends directly southeast from the city across valley and interfluve alike to Lombez in the valley of the Save . All these additions are relatively recent in construction and are dominantly political in importance. Auch is the *préfecture* of the Department of Gers. Condom, Mirande, and Lombez are *sous-préfectures*. The three roads link these latter towns with Auch and make it a focus for the whole region.

The basic pattern of highways is radial from the plateau of Lannemezan and, in its southerly portion, is limited in its digression from that form by the surface configuration. To the north the superimposition of other radial patterns, the most important of which is that about Auch, indicates a very weak control by surface. Purely cultural forces have subtracted from the effective natural focus position of the plateau of Lannemezan and have substituted the town of Auch in its place. Thus there is close integration within the region as well as direct articulation with the road systems of all surrounding regions, with the exception of the Landes.

Railroads

The railroad pattern is far less complex than that of the roads, though the rôle which the railroads play in emphasizing the focal position of Auch is great. Not only is this function well performed, but the railroads link Auch and, through it, the whole region to the densely peopled urban centers of France.

Main railroad lines extend in four directions from Auch as a center (Map 30). At the present time[47] a fifth main line is being constructed southward from Auch along the valley of the Gers. It has been under construction for a long time, and the original intention was to continue it across the plateau of Lannemezan to the valley of the upper Neste. A southward extension was to follow along the old trans-Pyrenean route. In event of the completion of this project it is suggested that the focus would shift and that the plateau, as represented by the town of Lannemezan, from which a spur line extends southward a short distance at present, would become the nucleus of the occupance of the region,[48] as it is of the setting.

Narrow-gauge railroads extend toward the center of the Pays du Gers from the north, east, and west. They serve the sections which are most remote from the main lines that cross the country, but they are not integrated with the essential pattern of railroads within the Pays du Gers.

Waterways

There is one other connecting link with the outside world, though it is of little importance as a bond within the area. The Baïse has been canalized as far as Condom (Pl. LXXXII, Fig. 2), which is a center of the armagnac[49] trade. Small barges ply between Condom and Bordeau along the Baïse River, the Canal lateral de la Garonne, and the Gironde estuary. This route is an outlet for a special commodity and is rarely used for any other purpose than the shipping of that commodity.

THE USE OF THE LAND

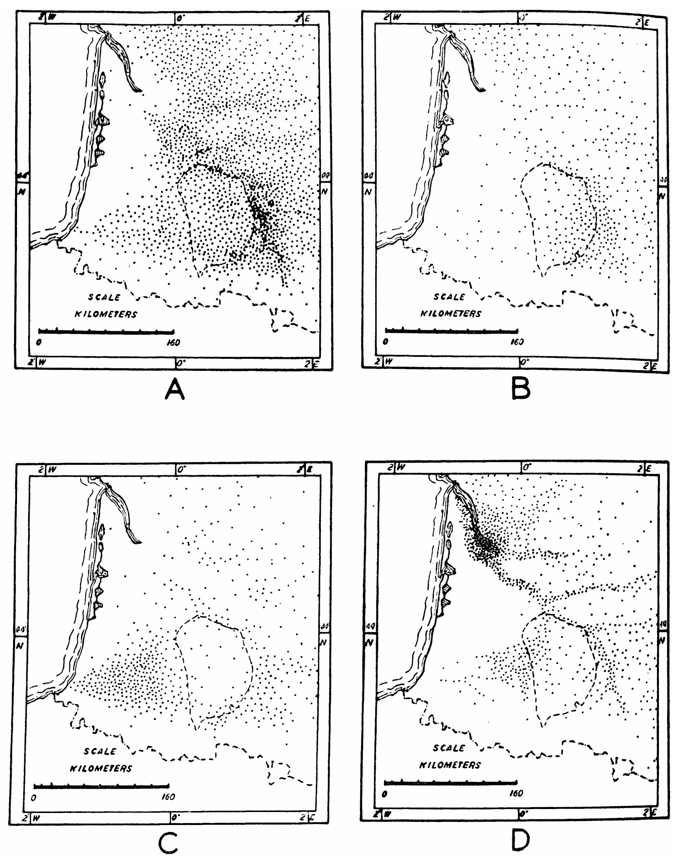
Close integration with the setting is shown in the forms of circulation throughout the Pays du Gers. The pattern of circulation forms is the framework upon which the population is distributed. These relationships suggest a regional unity. The nature of the population furthers the idea of unity within the region as well as of contrast with surrounding portions of the Aquitain Basin. It is the use of the land, however, which binds the elements of the setting, of population, and of circulation into a whole which is the landscape of the Central Pyrenean Piedmont of France.

The agriculture of the Pays du Gers

Within the Pays du Gers there is variation of detail, yet the basic combination of rural forms is the same throughout. Most of the land is cleared or has always existed without forest cover, and a large share of this is in crops. The portion which is not so used is taken up for the greater part as pasture land. Very little may be truly classed as waste. Sixty-two per cent[50] of the land is arable; eleven per cent is natural grassland; eight per cent is heath, moor, or brush land; seven per cent is wood-covered; and six per cent is in pasture or meadow. The remaining six per cent of the area is occupied by buildings, roads, and waste land.

Somewhat more than half the arable land is cropped. The dominant crop is wheat, and it is found more or less evenly distributed throughout. It occupies about twenty-seven per cent of the arable land. Its closest competitor, areally, is the vine, which extends over thirteen per cent of the arable area. Two other grain crops are important, oats on seven per cent of the land and maize on four per cent. The remainder is used for such items as garden crops, fruit, and, occasionally, rye. Each year a considerable amount of land is allowed to lie fallow or is used as rotation pasture.

In the animal industries cattle production for beef is distinctly the most important and is approached only by hog and poultry raising. In the amount of land used the animal industries as a whole are important throughout, for it is only in terms of an integrated system of crop raising and animal production that the rural occupance of the area is expressed.



MAP 31. Distribution of crops in southwestern France: A, wheat; B, oats; C, maize; D, vine. One dot equals 250 hectares. Dashed line indicates limit of the Pays-du-Gers.

Though wheat is the major crop almost throughout, the secondary crops vary in importance in the different parts of the Pays du Gers (Map 31, A-D). The vine is distinctly more important along the northern fringe and in the Bai'se lowland than elsewhere. Maize is of greater importance in the southwestern part and along the Garonne Valley fringes than it is throughout most of the rest of the region. This does not hold true locally, however. Oats are clearly the dominant secondary crop in the eastern half of the region. The particular use of the land in any one year may show an increase in any one of the secondary crops at the expense of the others in any portion of the Pays du Gers, but the average of conditions is that stated above.

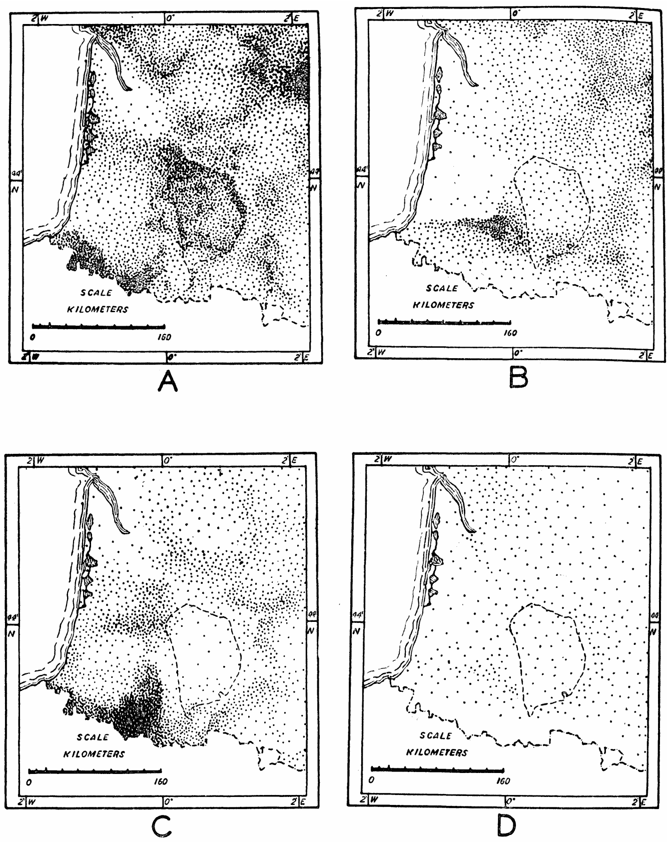
The same kind of variation is to be noted in the distribution of the animals (Map 32, A-D). Cattle are plentiful over all the land, but there are fewer as the plateau of Lannemezan is approached. On the other hand, the numbers of sheep and hogs increase in that direction. Sheep are not very numerous except in that portion nearest the Landes and on the plateau of Lannemezan, whereas hogs are present in the greatest numbers in the southern one third of the region.

The variations of the crop and animal combinations in quantity, though not in quality of types represented, reflect the characters of the surrounding regions. The Pays du Gers is an area of blending of the specialized forms of agricultural and pastoral pursuits found throughout the whole of the Aquitain Basin.

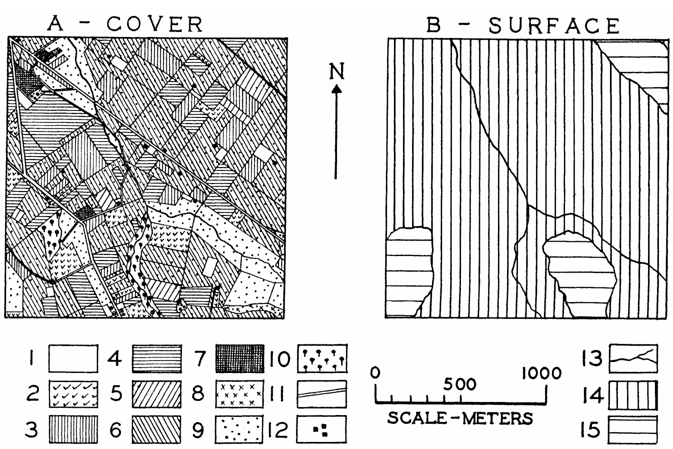
Land-use patterns

The patterns of land use fuse the differences within the Pays du Gers into a whole which emphasizes the setting and the distribution of people through it. To the north the waves of hilly land present the aspect of a huge park stretching as far as can be seen (Pl. LXXXII, Fig. 1). The surface is dotted with villages and hamlets and gives the appearance of being much more wooded than is actually the fact. Intermingled with the trees and clustered about the dwellings and along the roads the fields form a checkerboard with varying color indicating the crop, pasture, and woodland mosaic (Map 33, A-B). The fields are rectangular, and many are outlined by hedgerows from which the poplars stand up as thin spires. The major streams are definitely traced by the lines of willows, alders, and poplars along their banks. The roads, too, stand out because of the trees which mark their courses. Most notable over this whole scene is the concentration of pasture (Pl. LXXXVI, Fig. 2) and hay land in the valley bottoms (Pl. LXXXIII, Fig. 3) and the occurrence of cropped land on the hillsides. Though the checkerboard arrangement persists over valley and hill alike, there is little regularity in orientation. In some places the fields bear a close relationship to the population agglomerations. In others they are oriented with respect to the roads. Yet, over all, the exact demarcation of field lines is the dominant impression.

Greater conformity to the pattern of surface features is to be noted farther to the south (Map 34, A-B). With increasing asymmetry of the valleys in that direction there is an increased amount of land unsuited for crops or even for pasture. For this reason more of the land is wooded or covered with brush (Pl. LXXXVI, Fig. 3). The valley bottoms retain their function as pasture land or meadow, but the crop land is very definitely arranged in conformity with the surfaces of gentle slope. The western valley sides and the flat-topped interfluve remnants are the sites of most of the cultivated land. There results a striplike pattern oriented in a roughly north-south direction in which cultivated land is nearly paralleled by pasture and meadow, and that in turn by woodland and brush land.

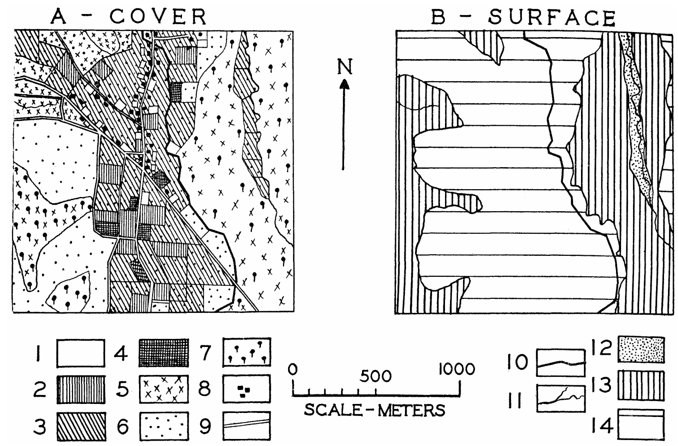


MAP 32. Distribution of animals in southwestern France: A, cattle; B, hogs; C, sheep; D, horses. One dot equals 250 head. Dashed line indicates limit of the Pays du Gers



MAP 33. A small area near the northeastern limit of the Pays du Gers. Explanation of symbols: 1, garden; 2, vineyard; 3, maize; 4, wheat; 5, oats; 6, land from which hay is cut; 7, clover; 8, brush; 9, pasture; 10, woods; 11, roads; 12, houses and barns; 13, streams; 14, valley sides; 15, ridge tops

Beyond the zone in which the valleys are flat-floored the same type of arrangement is found, except that less of the valley bottom is used for pasture and none of the valley sides are used for cropping other than of the garden type. A few fields nestle in the tree-covered valleys, but these are either pasture or hay lot (Pl. LXXXIII, Fig. 1). Crop cultivation is limited to the finger-like projections of the dissected edge of the plateau of Lannemezan.



MAP 34. A small area on one of the northward projections of the dissected edge of the plateau of Lannemezan. Explanation of symbols: 1, garden; 2, maize; 3, land from which hay is cut; 4, potatoes; 5, brush; 6, pasture; 7, woods; 8, houses and barns; 9, roads; 10, canal; 11, streams; 12, flat valley floors; 13, valley sides; 14, ridge top

The surface of the plateau is cultivated only along its northern edge or around the few population agglomerations which exist upon it. The surface is not divided into fields, and little breaks the monotony of the continuous stretch of scrubby vegetation except here and there some small forest remnant (Pl. LXXXIII, Fig. 2). Sheep grazing is unrestricted in its extent upon this land, but no fenced pasture exists.

The general pattern of land use in the Pays du Gers reflects very completely the surface configuration. In detail, however, this is often only indirectly so. The field patterns are locally oriented with respect to the roads and, through them, to conditions of surface. In sections where the presence of a population group seems to be more immediately the effective agent of arrangement, that very fact links the pattern to that of surface either directly or through the element of the road pattern. The earliest settlements of the Pays du Gers were relatively isolated communities and, for a long period of time, they have been of a self-sufficient type. In many places they have opposed the advance in means of communication which would remove the necessity of that self-sufficiency. The early groupings of such communities for protection brought about a pattern of land use which still persists in a fragmentary way.

Grouped about the church or château, the houses capped the top of a prominent hill set in the midst of the forest-covered land. Clearings in the wider valley bottoms may have broken the extent of forest. Gradually the land around the settlement was cleared and the fields for immediate necessities were laid out. As the clearing of the land spread down the slopes to join with the natural grasslands of the valleys, more and more land was opened to cultivation. Fields were larger since there was a greater amount of land for each individual as the circle of cleared land spread. In the landscape of the present the concentric pattern, in which increasing size of field accompanies increasing distance from the settlement, is found to be present residually in the maturely dissected portion of the Pays du Gers (Pl. LXXXIV, Fig. 2). Associated with this pattern there is usually a specific zoning of crops. Encircling the buildings are the smallest fields, which are used as gardens or vineyards. Around them in the larger fields are the grain crops. And, farthest removed, are the lands given over to pasture. This is not invariably the arrangement, for frequently the fields close to the hamlet or village are used for pasture. Around the larger agglomerations this pattern, if it existed originally, has been considerably modified or destroyed by the gradual extension of the built-up area. With the increase in importance of roads arid with the decrease in self-sufficiency of small parts of the Pays du Gers, a new group of determining factors has arisen.

Where the road has become more significant than the population agglomeration and where settlement has spread along the roads either as small agglomerations or as isolated houses, the road itself is the axis of the pattern. Small fields line the highway on both sides. Back from the roads the size of the fields usually increases. Crops are grown in those nearest the roads while those farthest removed are in pasture.

The year in the Pays du Gers

Though the clear-cut decline of activity within the severe winter lands or within the lands of seasonal drought is lacking in the Pays du Gers, there is a very definite rhythm of intensity of life through the year. There are certain periods in which each kind of activity is at its height and other periods when it is practically dormant. The climatic position of the region is responsible for this rhythm, and it is to varying climatic factors within the region that most of the modification of this rhythm is related.

In the vicinity of Auch January and February are the months of least activity. The temperatures of this period of the year are sufficiently low to make undesirable the working of the land, but they are not low enough to force the removal of the animals from pasture. This condition leaves little that can be done about the farm other than the repair of implements. The lack of work results in an increased interest in the fairs and markets of the towns and villages. The Gersois peasant dearly loves a gathering of any sort,[51] and he makes the best of this opportunity. The roads are the living parts of the landscape. It seems as though every person in the land is on his' way to or from town.

With the coming of March there is a change. This is the beginning of the season of heaviest rains, and preparations are made to prevent damage to property. The increased precipitation causes a rise in river level, which is continued through April and May. Floods may cover all the lower land of the valleys and may endanger the lives of the animals if they are left in the customary pastures. They are brought to the farm and, if no neighboring land is suitable for pasture, they are fed and closely cared for. Then, too, the land is plowed before the heavier rains fall. Otherwise, the fields, particularly those on clayey soil, are quaggy and impossible to plow. The towns are forgotten. From the first noticeable rise of temperature in March the preparation of the land for crops is the sole end in view for the larger part of the population. In late April or early May oats are planted and shortly thereafter, maize is sown, and attention is given to vineyards. Wheat, planted the winter before, brings a green color to the whole land.

Continued farm activity accompanies the marked beginning of summer in late June. There is no further need of keeping the animals close to the farm for feeding. They are turned loose in pastures which have been refreshed by the short period of little use. The crops are well started by the time the rain begins to decrease in amount. With the coming of the dry, hot period of July and August the harvests begin. The wheat has ripened and it is cut and threshed. Throughout the region the constant coughing of the gasoline engines of wheat-threshing machines is to be heard. Some of the farmers still use the old method of driving the oxen round and round on a hardened earth threshing floor and then winnowing the grain in the hot blasts of the *vent d'autan*,[52] which is at its strongest at this time of year.

The wheat harvest lasts but a relatively short time. There is a hiatus in the farm work and, with almost clocklike precision, the towns take on the exaggerated importance of the January-February season. The land with its ripening crops is slighted. It is almost devoid of human beings.

Late August and September witness another reversal. In rapid succession come the grape, oat, maize, and fruit harvests. Everyone is pressed into service. The country hums and the villages and towns are silent.

Immediately the harvests are done the land is prepared and sown in wheat. The vineyards are looked after, pruned and sprayed, and wine is made. When November comes and the pressing farm work is done, there begins the manufacture of the one specialty of the region. The wine is distilled and made into armagnac. With the completion of this work the year is rounded out, and there comes again the season of increased social life for the whole area.

In all directions from the vicinity of Auch this rhythm of life is varied to a minor degree. The variance is primarily a recognizable function of the setting, although it is in part caused by differences in the distribution of population. To the south and west there is a greater amount of rainfall which results in the changed emphasis of utilization of the land. Likewise toward the south the winters are more severe and the summers are hotter and drier. The winter is sufficiently severe to necessitate the ration feeding of animals. This one item, coupled with a different distribution of population, decreases the importance of town gatherings in the winter life of the inhabitants. They are more completely tied to the farm. The climatic differences also make impossible the cultivation of some of the same crops. The increase in the amount of rainfall is particularly injurious to wheat while the lowered temperature of winter makes the vine a less satisfactory crop. Nevertheless, there is discernible the same type of rhythm of life as that near Auch. The movement of sheep to pasture on the plateau of Lannemezan during the summer months, though of greater magnitude, is essentially the same as the movement of cattle to new pasturage during summer in the center of the Pays du Gers.

CONCLUSION

The rural scene is the only important one and, though it varies from part to part of the region, it is only the result of necessity of detailed adjustment that brings about any difference. The same kind of people live in the same way in all sections. That way is distinct from those of adjoining areas. The way of living in the Pays du Gers is not like the agricultural life of the Garonne lowland, in which fruit cultivation is of primary importance. It is not like the corn-hog-vine economy of the Adour drainage basin to the west, nor is it like the Landes where pastoral life predominates. Likewise the pastoral life of the Pyrenean slopes contrasts sharply with it. Within the Pays du Gers all these various economies are blended to form a rural occupance of the type which lays equal stress upon agriculture and the animal industries. Specialization in commercial production is secondary to sustenance farming.

Thus it is that a small portion of the earth's surface with an associated group of natural phenomena stands out as distinct from the surrounding lands. And upon this small area the items of human occupance are arranged in such a way as to emphasize its individuality. The natural phenomena focus on the small remnant of the plateau of Lannemezan. The occupance phenomena focus upon Auch. The two have been inseparably welded through time to form the present phase of ever-changing landscape of the Central Pyrenean Piedmont of France.

UNIVERSITY OF MICHIGAN

[1] Map 22 shows place names mentioned in the text. No further reference to this map will be made.

[2] Vidal de la Blache, Paul, *La France* (Hachette, Paris, 1908); De Martonne, E., *Les Régions géographiques de la France* (Flammarion, Paris, 1921); Fèvre, Joseph, and Hauser, Henri, *Régions et pays de France* (Alcan, Paris, 1909).

[3] Gallois, L., *Régions naturelles et noms de pays* (Colin, Paris, 1908). See particularly Chapters I, II, XI, and XII.

A *pays* is an area which is popularly thought of in France as one of essential unity in both the forms of the fundament and those of the occupance. In many instances, though not invariably, this concept holds true. Pays are of several orders of magnitude as, for example, in Condomois, which is part of Haut Armagnac. The latter is, in turn, part of the larger pays of Armagnac and also part of the Pays du Gers. The limits of a pays are not always determined by exact criteria but, rather, by common usage. The names of many of the pays of France are so well recognized that their usage technically as well as popularly is common.

[4] Sorre, M., *Les Pyrénées* (Colin, Paris, 1928), pp. 138-141.

[5] De Launay, L., *Géologie de la France* (Colin, Paris, 1921), p. 291.

[6] The cause of asymmetry of the valleys of the Pyrenean piedmont has been a much-discussed problem for which no completely satisfactory solution has as yet been offered. See Laurant, Gustave, "L'Armagnac et les pays de Gers," *Ann. de géog*., 20: 145. 1911; Fabre, L. A., "La Dissymétrie des vallées et la loi dite de De Baer, particulièrement en Gascogne," *La Géog*., 8: 291-306. 1903; Réclus, É, *La France*, Vol. II in *Nouvelle géographic universelle* (Hachette, Paris, 1877).

[7] Fabre, L. A., "Le Sol de la Gascogne," *La Géog*., 11:257-284, 343-358, 413-434. 1905.

[8] Chaput, E. "Recherches sur l'évolution des terrasses de l'Aquitaine," *Bull., Soc. d'his. nat. de Toulouse*, 56: 17-100. 1927.

[9] Cavaillès, H., "La Houille blanche dans les Pyrénées françaises," *Ann. de géog*., 28: 450. 1919.

[10] Fabre, L. A., "Sur le déplacement vers Test des cours d'eau qui rayonnent du Plateau de Lannemezan," *Compte rendu Acad. sci. de Paris*, 127: 204. 1898.

[11] Fabre, *op. cit*., p. 203.

[12] Lemoine, Georges, "Essai sur l'hydrométrie du bassin de la Garonne," *Ann. de géog*., 5 : 368. 1895-96.

[13] One of the earliest accounts is included in Venatius Fortunatus, "De Egircio numine," *Venance fortunat*, translated by Charles Nisard and Eugène Rittier (Firmin-Didot, Paris, 1887), pp. 58-59.

[14] Cavaillès, *loc. cit*.

[15] Lemoine, *op. cit*., p. 371; Angot, Alfred, "Régime pluviométrique de la France (Deuxième partie. Régions sud-ouest et sud)," *Ann. de géog*., 27: 1-27. 1919.

[16] In terms of the Köppen classification the type is Cfb. For criteria see Köppen, W., *Die Klimate der Erde* (De Gruyter, Berlin and Leipzig, 1923), particularly pp. 120-121, 155-157, 262-267. In terms of the Thornthwaite classification it is BB'r. For criteria see Thornthwaite, C. W., "The Climates of North America according to a New Classification," *Geog. Rev*., 21: 633-655. 1931. See also a map of the climates of the world prepared and distributed by C. W. Thornthwaite at the annual meeting of the Association of American Geographers held at Ypsilanti, Michigan, in December, 1931.

[17] Bernhard, Hans, *Landbauzonen, ländliche Entvölkerung und landwirtschaftliche Einwanderung in Frankreich, mil besonderer Berücksichtigung der schweizerischen Ansiedlung in Südwestfrankreich* (Kümmerly & Frey, Bern, 1927), pp. 97, 99.

[18] Agafonoff, V., "Les Types de sols de France," *Annales de la science agronomique française et étrangère,* 2 : 97-120. 1928.

[19] See Stremme, H., Allgemeine Bodenkarte Europas (Danzig, 1927).

[20] A careful, though brief, statement of the present detailed character and distribution of the vegetation of the southeastern part of the area is included in Gaussen, H., *Végétation de la moitié orientale des Pyrénées* (Lechevalier, Paris. 1926), pp. 348-368.

[21] *Op. cit*., p. 348.

[22] All specific names used are those listed in Mouillefert, P., *Traité des arbrisseaux*, Part I, Librairie des Sciences Naturelles (Paris, 1892-1898). American usage has been followed with respect to the capitalization of specific names.

[23] Fabre, L. A., "Les Landes de Lannemezan," *Rev. de Comminges*, 13: 260. 1898.

[24] Laurant, Gustave, "Armagnac et pays du Gers," *Rev. de Gascogne*, 53d year, New Series, 12: 453. 1912; Fabre, L. A., "L'Érosion pyrénéenne et les alluvions de la Garonne," *Ann. de géog*., 11: 38. 1902.

[25] Burkitt, M. C., *Prehistory* (University Press, Cambridge, 1925), p. 11.

[26] Astre, Gaston, "Débris squelettiques d'une race néolithique de petite taille découverts à Vic-Fezensac," *Bull. Soc. d'hist. nat. de Toulouse*, 52: 117-132. 1924.

[27] Guilbert, Aristide, *Histoire des villes de France* (Claye, Paris [1844-48?]), II: 203.

[28] *Geography*, translated by Horace Leonard Jones (Heineman, London, 1923), 4, 2, 1.

[29] Bertrand, Alexandre, *Nos origins. La Gaule avant les Gaulois* (Leroux, Paris, 1891), p. 248.

[30] Williamson, James A., *Maritime Enterprise, 1485-1558* (Clarendon Press, Oxford, 1913), p. 208.

[31] Caziot, Pierre, *La Valeur de la terre en France* (Baillière, Paris, 1914), p. 332.

[32] Granat, O., *Géographie du Lot-et-Garonne* (Agier, Agen, 1929), pp. 44 and 45.

[33] Bernhard, *op. cit*., Pl. 32.

[34] *Résultats statistiques du recensement général de la population effectué le 7 mars 1926* (Impr. Nationale, Paris, 1928).

[35] Other phases of the question of the depopulation are discussed in Labat, Emmanuel, "En Gascogne. L'Abandon de la terre," *Rev. des deux mondes*, 80th year, 5th period, 58:635-668. 1910; and *idem*, "En Gascogne. À propos du problème de la natalité," *ibid*., 81st year, 6th period, 4: 62-95. 1911.

[36] *Annuaire administratif du Gers pour 1930* (Cocharaux, Auch, 1930), p. 57.

[37] *An VIII* in the calendar of the French First Republic corresponds to the period between Sept. 22, 1800, and Sept. 16, 1801, of the Christian calendar.

[38] Statistical data for the Pays du Gers as a whole are not available, and hence only for that portion which lies in the Department of Gers has it been possible to construct a detailed map of population distribution.

[39] Laurant, Gustave, "Armagnac et pays du Gers," *Rev. de Gascogne*, 53d year, New Series, 12: 289. 1912.

[40] *Ibid*., p. 300.

[41] De Casteran, Paul, "La Lande de Boc," *Rev. de Comminges*, 13: 246. 1898.

[42] Laurant, Gustave, "Armagnac et pays du Gers," *Rev. de Gascogne*, 54th year, New Series, 13 : 48-54. 1913.

[43] *Ibid*.

[44] See *Itinéraire d'Antonin* in Desjardin, Ernest, *Géographie historique et administrative de la Gaule romaine* (Hachette, Paris, 1885), Vol. IV,

[45] Fabre, "Les Landes . . .," p. 260.

[46] Guilbert, *op. cit*., II: 210. Auch was established previous to the Roman occupance of this region.

[47] The summer of 1930.

[48] De Casteran, *op. cit*., pp. 246-247.

[49] *Armagnac* is the name given to brandy which is distilled from the white wines of Bas Armagnac, Tenareze, and Haut Armagnac. Tenareze and Bas Armagnac are *pays* lying outside the Pays du Gers and to the west of Haut Armagnac, as the northwestern part of the Pays du Gers is called. See De Cassagnac, Paul, *Les Vins de France* (Hachette, Paris, 1927), pp. 192-193. See also Shand, P. Morton, *A Book of French Wines* (Knopf, London, 1928), p. 238.

[50] All the statistics mentioned in this section of the paper are from *Statistique agricole annuelle*, 1930 (Impr. Nationals, Paris, 1932).

[51] Caziot, *op. cit*., p. 331.

[52] The *vents d'autan* are Mediterranean in origin. See de Martonne, E., '"Note préliminaire sur le vent d'autan," *Bull. Soc. languedocienne de géog*., 30: 100-114. 1907; and *idem*, "Contribution à l'étude du vent d'autan (deuxième note)," *ibid*., 32 : 135-157. 1909.

PLATE LXXXI

FIG. 1. The plateau of Lannemezan, looking northward toward the dissected and forested edge

FIG. 2. One of the V-shaped valleys at the northern edge of the plateau of Lannemezan

FIG. 3. The middle valley of the Save River in August. The present stream is cutting below the level of the flat valley floor

PLATE LXXXII

FIG. 1. The gently undulating surface of the northern part of the Pays du Gers

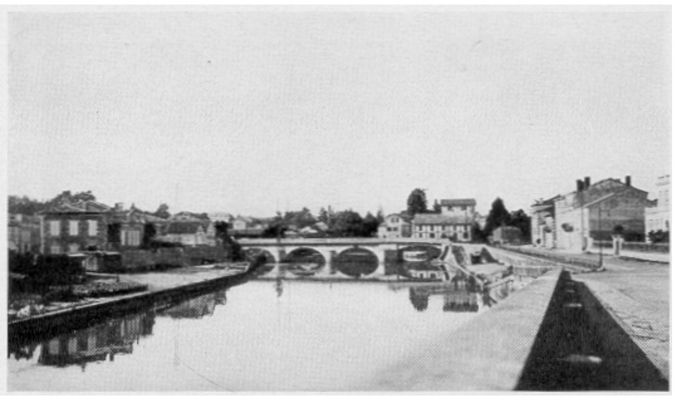


FIG. 2. The canalized Baïse River at Condom, looking north

FIG. 3. Tree and brush growth along one of the major streams

PLATE LXXXIII

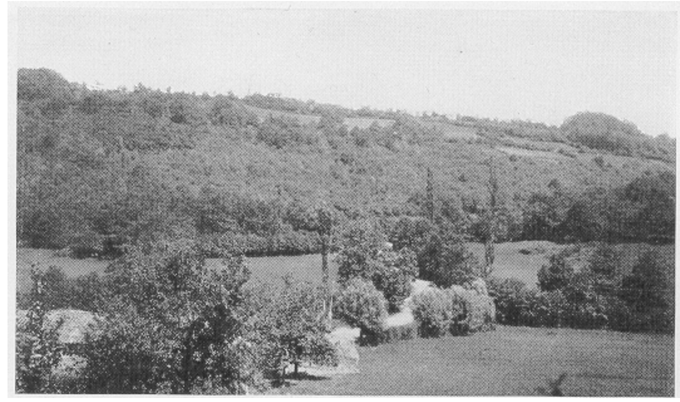


FIG. 1. The wooded eastern side of the upper valley of the Baïse River. The extent of the grassland in the valley bottom is very limited, and there are only a few clearings on the valley side

FIG. 2. Pastured woodland near the source of the Baïse River, on the plateau of Lannemezan

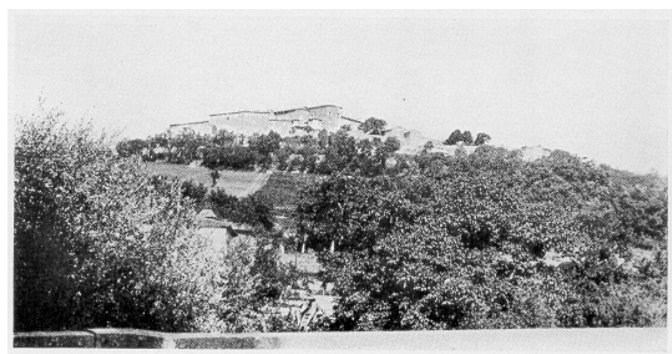


FIG. 3. The town of Lectoure

PLATE LXXXIV

FIG. 1. A *route nationale* in the northwestern part of the Pays du Gers

FIG. 2. Flamerens, a hilltop village in the northeastern part of the Pays du Gers

FIG. 3. Puymaurin, a town on the crest of the steep valley side, in the southern part of the Pays du Gers

PLATE LXXXV

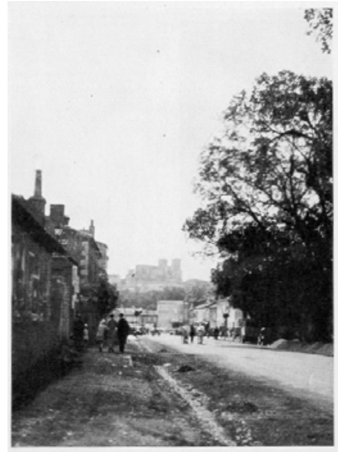


Fig. 1

Fig. 2

FIG. 1. The town of Auch. The cathedral in the background marks the original site from which the town spread down the valley side and across the flat valley floor

FIG. 2. The town of Lannemezan

PLATE LXXXVI

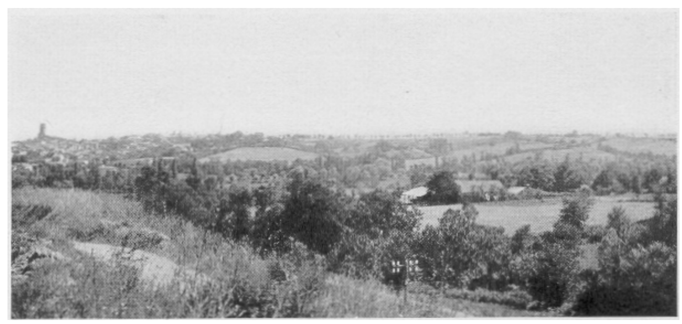


FIG. 1. The row of trees along the ridge in the background lines a main highway. The town is Gimont, which is about twenty-five kilometers east of Auch

FIG. 2. Pasture on the flat valley floor

FIG. 3. Cleared valley floor and wooded eastern valley side

NOTES ON THE ASSEMBLY OF AIRPLANE PHOTOGRAPHIC MOSAICS

HAROLD UNDERHILL

THE World War brought about the demand for and the initial development of photography from airplanes for purposes of military strategy and mapping. From that period to the present date various interested civilian groups organized for profit have sought to apply to our civil needs the knowledge gained by their war experience. Greatly improved cameras, the new extremely sensitive films, and better airplanes make possible the excellent air photography of today. The outstanding application of airplane photography to our civil needs is that of mapping.

When base data, such as lakes, streams, roads, cultivated lands, cities, and villages, are desired in the most minute detail, the air photograph is superior to ordinary maps. Larger areas than can be photographed upon a single print are mapped by assembling into a unit the overlapping photographs covering the desired area. Such a composite photograph is called a mosaic.

Here in Michigan we have found it convenient, through cooperation with the United States Geological Survey, to secure the services of trained United States Army pilots and photographers for the purpose of photographing from the air many of our hitherto unmapped counties. This work is being done in connection with our regular state program of topographic mapping.

Since our first county was photographed from the air in 1929 it has been the good fortune of the writer to be in charge of the filing of these photographs for the Geological Survey Division. About February, 1931, the Forest Fire Division, seeing the value of this new type of map as an aid in fighting forest fires, began the assembly of township mosaics, which now number 304 and picture approximately ten thousand square miles of territory.

During the past three years the methods used in the assembly of our mosaics have developed step by step, until a standard and an efficient routine has been attained. Future work along this line will yield new material for discussion. However, it is the purpose of the writer to record for the benefit of the novice our present procedure that he may profit by our experience. Conventional methods of mosaic assembly could not be used, for two reasons: first, lack of control, since our photographs covered unmapped areas; second, the prohibitive cost of scale changes by ratio printing, since by agreement the United States Army retains for a stated period the negatives from which our prints are made.

Our standard air photograph is a contact print made with a negative from a single-lens camera that uses a roll film 10 inches wide and 75 feet long. A contact print measures about 7 by 9 inches and is usually printed upon glossy single-weight paper. Some cameras are so equipped that a small number panel is photographed along the center of one side of each photograph. In the top of the center of this small panel is reproduced a rotary altimeter dial that records the altitude of the ship at the instant of exposure. Below the altimeter is the number of the photograph, shown on a small dial similar to the mileage dial of an automobile speedometer. To the right of this center group there are a circular bubble, to indicate the tilt of the camera, if any, and the face of a small clock giving the time of exposure. On the left side is a blank in which may be written for reproduction the date of flight and the name of the location of the job flown.

Few prints in our files, however, exhibit easily readable information in this number panel. The majority of them have been blacked out and the negatives numbered with ink in the laboratory after trial sets of prints have been laid out. This insures prints of a broken-flight strip getting consecutive numbers whether or not the entire strip was photographed on a single flight. Adjacent photographs overlap each other considerably; some contracts call for as much as 60 per cent side overlap and 50 per cent end overlap. This is necessary because the outer margins of a photograph are not on the same scale as the center portion, which was immediately below the camera at the time of exposure. Variations from normal in the position of the ship and the camera at the moment of exposure cause scale distortions in the photograph which may be so bad as to render it worthless. This type of wing-tilt off-scale print is difficult to detect in photographs of wilderness country, but when it occurs in those of farming regions with well-blocked-out road systems the opposite sides of a section will be shortened or elongated along the axis of tilt.

Commonly the most troublesome type of off-scale photograph is caused by variation in altitude of the ship. Weather changes often affect the barometric altimeter during a flight, or a change of ground elevation under the plane may be the disturbing factor. Either may cause a perfectly flown ship to produce off-scale photographs.

The happiest results, so far as photograph mosaic assembly is concerned, are obtained when the area to be flown is so small that it can be photographed on a single hop. A careful check of barometric pressure before each flight is the rule on large jobs and should produce uniformity of scale from day to day. However, the novice must be tolerant with the pilot and the photographer, who, when aloft, are two of the busiest men above earth, and should remember that as a matter of fact perfect scale photographs are generally sales talk.

Fully equipped laboratories have ratio printing machines by means of which both the altitude and the wing-tilt varieties of off-scale photographs may be corrected. Such a machine is essentially a vertical enlargement printer whose copy board may be tilted out of the horizontal plane to correct any tilt errors present in the negative. Prints made in contact with the negative are always more brilliant in appearance and show finer detail than prints made in such a restitutional printer or other enlargement camera.

There would seem to be every reason to invent and perfect an improved altitude meter that would give the pilot actual altitude above ground instead of altitude above sea level.

The altitude at which a pilot must fly to produce photographs of a given scale is easily arrived at. Given the focal length of the camera lens in inches and the desired ground distance to be represented by one inch on the photograph, a simple ratio provides the altitude. For example, if one has to determine the altitude necessary for a 12-inch focal length lens to produce photographs on a scale of 1 inch to 1000 feet on the ground, $^{1\text{ inch}}/_{1{,}000\text{ feet}} = {}^{12\text{ inches}}/_{12{,}000\text{ feet}}$. Again, on a scale of 1 inch to 400 feet on the ground, if one uses 8-inch lens. $^{1\text{ inch}}/_{400\text{ feet}} = {}^{8\text{ inches}}/_{3{,}200\text{ feet}}$.

A flight across a given area produces a series of overlapping photographs called a strip. Adjacent strips overlap and are generally flown in opposite directions, with the pilot usually making a nearly vertical bank at the end of the flight and reversing his direction for the return trip while the photographer snaps one or more shots with the camera shutter closed to indicate the end of a strip on the roll film.

In the laboratory, after the first set of prints has been laid out roughly to determine whether any gaps or "missouts" exist, a flight map or key map is prepared for the convenience of the customer, who receives it with his copies of the photographs. This flight map usually shows the beginning and the end of each separate flight by means of two rectangles inclosing the exact areas on the map covered by the first and last photographs of the flight. Each rectangle is given the number of the photograph it represents. The locations of intermediate photographs are generally omitted. However, the course of flight is sometimes shown by a line. If this map is too large for convenient filing it may be reduced in photostatic copies, on which adjacent strips are shaded with contrasting colored crayons and large numbers are inked in for visibility. Photographs may be located accurately and quickly from flight maps colored and renumbered in this manner.

A brief description of other and more important items of equipment used in the assembly of our air-photograph mosaics will be found in the Appendix to this paper.

The scale of the mosaic is probably the first consideration to come up after it has been decided to make an aërial photographic survey of an area. The use to which the map is to be put will govern the size of objects upon the photograph. "Scale" is the ratio of unit distance on the photograph to unit distance on the ground, i.e. if one foot of photograph portrays 12,000 feet of ground, the scale is represented by the fraction $^1/_{12{,}000}$. More commonly the scale is expressed by a statement of the relation of one inch of photograph to the actual ground distance it represents, such as 800 or 1,000 feet to the inch. It is also expressed in inches per mile. The following are different ways of expressing the scale of a single air photograph (all mean the same): $^1/_{12{,}000}$; 1,000 feet to the inch; 5.28 inches to the mile. This scale is standard in our photographs, namely, $^1/_{12{,}000}$. One county was flown on a $^1/_{12{,}000}$ scale, and it has been laid up in township mosaics, but the results do not compare with other areas mapped on the former scale, either for visible detail or for general appearance.

If the area to be mapped is large, the size of the individual mosaics is governed by the scale of the prints and the available sizes of mount. At 1,000 feet to the inch, our mosaic of a standard township, six miles each way, measures about 36 by 40 inches over all. This size is amply large for convenient handling and filing. We found the 24-inch mosaic from our one small-scale county a pleasant variation from the larger standard size. See Plate LXXXVII for this scale comparison.

The air photographs of a county to be assembled are put into plainly marked envelopes by flight strips and arranged in their overlapping order across the county. They are then deposited in a file for safe storage. Envelopes containing photographs of the township to be assembled are first removed from the file and arranged in a row on the back table in their proper order. The proper starting point is, of course, that place at which the location of the first few prints is established without doubt. Generally one side of the township is bounded by a well-known and mapped feature, cultural or natural, such as road, lake, stream, or timber-cutting line. In the absence of such information we must use the General Land Office plats for township-corner locations.

After the selection of the starting point the first print is fastened to the assembly board by four staples, without trimming, in a location that allows ample room for the complete assembly of the township. The mosaic is developed most naturally by strips across the board from the starting point. The direction of these strips may be vertical, horizontal, or diagonal, depending upon the direction in which the area was flown when photographed.

Assuming that the first print was laid in the upper left-hand corner of the board and also that the flights were made in an east-west direction, the first strip is laid from left to right across the top of the township. The second strip starts immediately below, overlapping upon the first print laid, and progresses from left to right, overlapping and matching the first strip. In this manner the entire township is developed, provided, of course, that the scale of succeeding strips is constant. Differences of the scale in two prints of adjacent strips may be too small to be noticed when regarded as individuals. However, small errors accumulate in the width of a township until the total is decidedly too great. Usable mosaics have been laid within which adjacent strips have differed in length by as much as one and one-half inches. Such an error is uncommon, however, and the assembler is rarely called upon to deal with errors totaling more than one inch across a township. All the resourcefulness of the workman is demanded when adjusting and fitting off-scale prints.

Sometimes, owing to off-scale photographs, it may seem impossible to complete the assembly of an area by the simple strip-after-strip method just described. In this case the quickest way out will probably be to remove the prints from the board by strips and stack them in orderly piles upon the back table. Starting out anew, the operator staples two or three prints in the first strip, as before. Next, he places the first one or two prints of the second strip and then the first one of the third strip. This method builds two adjacent sides of a township simultaneously, controlling the included corner angle by its triangular or fan-shaped development.

Another system of dry assembly which is more difficult to handle is the radial development which begins at the center of the board and grows from this point in all directions. This system is favored by some, but it is not so simple and, therefore, is less desirable than the strip or the corner method, and has been used in but one township mosaic assembly.

It is advisable to show only the center portion of any print because the edges are always more or less distorted and out of scale. Removal of the overlapping edges of successive prints entails trimming, probably the most important factor in a good assembly. In general, from the standpoint of minimum distortion, one half of any overlap should be removed. Any deviation from this "one-half" rule makes visible the undesirable distorted edge of the top or bottom photograph in question. It is seldom, however, that this rule may be applied literally, since the nature of the country shown on the photographs actually makes the overlap desirable or undesirable. Wooded country with few trails, streams, and such features is best torn by a wavy line, whereas cuts through cultivated fields are better straight. A straight cut across a print is more noticeable than a series of straight cuts connected by occasional offsets (for instance, cultivated land with offset sideways through a wood lot).

The road system of a mosaic is a most prominent feature, and cuts should be made well back of farm buildings if they are to receive the minimum of attention. Joints too close to roads or down their center may shrink upon drying and cause a double road. This cannot occur if roads paralleling a cut are trimmed off the overlaps.

Advantage must be taken of every feature on the photograph that will help conceal a cut. Wherever possible one should avoid joints through small lakes or other features such as wet marshes. The reflections of light from water surfaces cause a surprising change in the shade of lakes upon adjacent photographs. In fact, a lake is apt to be white in one and black in the next. The darker water areas are the best ones to show, since white water is often confused with sand or marl by the novice. Light reflections from water often work to our advantage in disclosing the course of small streams otherwise hidden by forest canopy.

Because land values are high in cities and because of difficulty in matching prints over such an area, these photographs are left intact when possible. Since errors of assembly occur at the joints, any valuable land, such as village, golf course, lake front, road front, or subdivision properties, is better left uncut if possible.

When there is need to cut a print, it is laid upon the trimming board, and the exact path of the proposed tear is cut lightly through the emulsion with an even pressure of the penknife point. The undesired part of the photograph is so placed as to overhang the edge of the trimming board. The tear is accomplished by pressing the scrap downward and forward away from the operator. When this is properly done the tear will start in the photograph and follow the knife cut across it as the hand grasping the scrap piece moves away from the operator. After the tear, the scrap should display a white fringe of beveled paper from one eighth to one fourth of an inch wide along the full length of the tear. If this evidence of proper feather edge upon the photograph is lacking at any point the desired result must be obtained by inverting the photograph and beveling with the penknife where necessary. A spiral shaving of paper indicates proficiency here. Scraping with a razor blade or finishing with fine sandpaper is recommended by some to insure a more nearly perfect feather edge. In practice, however, the average torn edge, beveled, if necessary, with the knife along the edge of the trimming board, is sufficiently thin to give good camera copies.

The pair of small holes caused by fastening with paper-stitcher staples should be made, if possible, under an overlapping photograph. They are not so big, however, that they will be noticeable from a short distance, should it be necessary to make them where they will occur upon the finished mosaic. A staple in each of three hidden corners is the rule in fastening a print upon the dry assembly board. If insufficiently stapled, the photographs may curl badly overnight, or slip out of position.

A careful check of the finished dry assembly is essential to detect errors in alignment of straight railroads, highways, power lines, and other features, and poor matching of prints. It is sometimes necessary to pull photographs of a short strip apart somewhat. The check of the final dry assembly should bring out any too noticeable cases of "twins" from this source. "Twin" is a laboratory term for an object such as an isolated tree or farm building that, owing to separation of prints at a joint, is allowed to appear in duplicate. As a rule, judicious trimming will remedy a too obvious case of twinning.

If the township is shown to be of regular dimensions upon the best available maps of the area, the mosaic will probably be square when completed. Correct tilting of the film in the camera at the time of copying often produces a square copy from an off-size or distorted original. If this hint is understood at the time of assembly, much detail may be preserved in the longer strips that would ordinarily be telescoped in an attempt to square up the original. The experience of our field men who map soils and cover directly upon mosaic copies has been that it is better to sacrifice the scale of a mosaic, if necessary in order that no country be lost by compression of a large-scale strip. "Twins" are evident, but lost areas are not self-explanatory to the mosaic reader.

Dry assemblies are often torn apart and reassembled several times before the best possible arrangement is found. This branch of the work is by far the most important step in the making of a mosaic, and it should not be hurried. All but the smallest scraps of photographs used are carefully put away for possible future use.

After completing the dry assembly the big question is whether or not we shall be able to reassemble the prints with mucilage, preserving their original arrangement. Our present transfer system has worked 100 per cent efficiently since its adoption. The first method we used for this transfer of photograph location consisted in tracing the roads, lakes, and prominent features visible through tracing paper and transferring these base data to the mount by means of carbon paper. The photographs were then mounted over this network. However, though this method served, we were forced to find something better when the country changed from farm lands with well-developed road systems to wilderness, few features of which were visible through the tracing paper.

The needle bar, as described later, was developed and now, instead of pencil work upon the tracing, which is stretched over the completed dry assembly, the twin needle points are pressed through the tracing and each individual photograph in the assembly. The pair of holes so made are easily relocated by a pencil line ruled along the bar at each operation. The township and the outer limits of the mosaic, which are as generous as the photographs allow, are outlined with soft pencil upon the tracing after each photograph has been pierced with the needle bar points. The best way to remove the tracing is to cut it off the board with the penknife, scoring the photographs for later trimming. This produces a correctly shaped tracing which may be laid upon a sheet of artificial wood three sixteenths of an inch thick as a template to determine the size and the shape of the mount. About three inches additional height is allowed for a title panel across the top.

The process of transfer is usually interrupted at this point long enough to cut with a handsaw the correct piece of mount and to apply upon each side, by means of mucilage, a cover sheet of Kraft wrapping paper, an operation discussed under "wet assembly." The freshly covered mount is set aside to dry while the underlap of the photographs is trimmed off. To hasten drying it may be stood with an edge presented to the blast of an electric fan.

The underlap is that portion of a photograph hidden by an overlapping print. Early experience showed that loose edges frequently resulted from the weak bond between the glossy emulsion on the underlap and the print cemented to it. Contraction due to drying causes edge looseness where the underlap is excessive. This looseness is prevented by discarding all but about one half of an inch of the underlap, thus providing each print with a maximum area of contact with the Kraft paper-covered mount underneath. The looseness just mentioned must not be confused with edge curling due to unequal drying at the time of assembly.

When one begins the dismantling of the dry assembly, about one-half inch of the tip of a china-marking crayon is inserted underneath the feathered edge of the last print in the final strip and a black line is traced around it upon the photographs below. This operation is repeated with each print in the last strip before any are removed for trimming. The marks so made insure that a safe margin of underlap will be left in all cases. The photographs thus marked are removed and the excess areas are trimmed off along the black crayon lines just traced upon them. Care is taken in tearing off waste portions to produce a good feather edge, since a square edge here will be noticeable through the overlap as an abrupt bump upon the surface and is very apt to cause a light reflection, seriously affecting the value of the copy mosaic. Boundary prints are also trimmed at this time along the knife marks made when the tracing was cut from the board. As the prints are trimmed they are laid face up in an orderly pile upon the back table.

When the paper-covered mount is dry the tracing is fastened upon it with a few small pieces of "Scotch tape," a rubber base adhesive tape made of heavy crêpe paper and used by draftsmen in place of thumb tacks to secure drawings to the board.

The needle bar or bars used before are again pressed through the tracing in the identical holes made by the first operation. The mount is dense and care must be taken not to break off a needle point. As each location is transferred it should be marked with a pencil check. When it is certain that no photograph position has been neglected the tracing is removed and discarded.

At the starting point the first photograph is relocated in its proper position by means of the needle bar, and its outline is traced upon the mount with a soft lead pencil.

The remaining prints in the order of their sequence are relocated with the needle bar, and those edges that do not overlap any preceding print are outlined upon the mount. When all the photographs have been outlined the wet assembly may be started.

The covering of paper on both sides of the wall board, described for use on mount in the Appendix, is necessary to control warping, which would occur if only one side of the board were covered. The front surface is covered to make the pin holes from the transfer operation visible, as well as to cover up the oily surface of at least one brand of board used, thereby improving the glue bond between board and prints. The back paper is always added afterward to balance the shrinkage stresses and to prevent warping of the mount.

The transfer tracing was used as a template to obtain the correct size of the board to be used as a mount. This board now serves as a pattern for three pieces of paper, which are cut to a size approximately three fourths of an inch less each way than the board itself. This under-sized paper will equal the size of the mount when wet. One sheet is rolled up and saved for backing the board after the assembly has been made. The other two are wetted thoroughly on both sides and mucilage is spread evenly on the paper rather than upon the board itself. The inclusions of air under the paper are removed by lifting the corners and smoothing with a cloth progressively from the center to the corners of the large sheet. After the paper is smoothed on both sides of the board the edges are bound with gummed paper tape one and one-half inches wide and the board is set up on edge so that both surfaces may dry evenly.

The wet method of applying prints to the mount entails the soaking or floating of them, together with a certain amount of trimming at assembly of undesired portions and constant manipulation of the whole mass while wet, to arrive at a desired assembly. The excess glue is removed by wiping and cleaning with a damp sponge after the mosaic has dried. It is obvious that during such a wet assembly the prints will be fully expanded with moisture, and this is one of the things our present semi wet system avoids.

The number one print of the dry assembly is also the first print to be glued into its place upon the mount. The front and back sides of the first print are sponged in rapid succession upon a linoleum or other suitable surface. It is then laid face down upon a pad of paper towels, where thinned mucilage is applied with a brush evenly over the back surface. It is next quickly placed face up in its proper position on the mount and smoothed from the center toward its edges in all directions with a damp sponge to force out all entrapped air bubbles and is then dried in like manner with a soft dry cloth. Its correct location is shown by its penciled outline upon the mount, and any necessary adjustments must be made without delay because the mucilage acts as a lubricant only while wet and its moisture is quickly absorbed into the Kraft paper beneath. All freshly laid edges are carefully pressed and dried with the cloth-covered finger tips before passing on to succeeding operations. A photograph applied as described above adheres strongly to the mount in about two or three minutes.

The second print is wetted on both sides and placed upon a clean paper towel for application of the mucilage. The paper towels are discarded after being used once to prevent the front surface of the print from becoming excessively sticky. In smoothing out and drying this and successive prints in their places care must be taken not to rub against an edge with the sponge or wiping cloth. Such a movement would surely displace the fine feather edge and probably split it so as to cause separation of the emulsion from the paper. No harm results if the wiping action is with and not against the overlap. It is important that the edges of newly laid prints, especially the overlapping edges, should be pressed out firmly to expel the excess mucilage, thus permitting the edges to adhere before the evaporation of moisture from the emulsion side causes edge curl. The commercial arabic mucilage used is heavy and viscous and should be thinned with about equal parts of water to facilitate the edge-squeezing operation, thereby guarding against unwelcome edge curl. A roll curtain was first used to retard edge evaporation. This prevented the trouble, but its use interfered with the assembly work and the thinning of the mucilage, which proved adequate, was adopted in its stead. In this way the entire assembly is completed, with a place for each print and with each print as near as may be in its place. Expansion sometimes forces the prints off their outlines, but the penciled control is still useful in keeping the assembly uniform, if large, and the result is good.

A strip of Kraft paper is glued across the top of the assembly and the title is located and mounted in the center of this panel. The mosaic is then turned over and a second back paper, saved from the previous mount-covering operation, is applied to the back. We now have two sheets of paper on the back balancing one sheet and a mosaic of photographs on the front. This symmetrical treatment will insure that the finished board will remain flat.

Gummed paper tape is again used to bind the edges of the mount, care being taken this time to display a uniform width of tape around the front borders of the mosaic. The length of the one-mile diagrammatic scale on the mosaic title is one sixth of the measurement between the top township corners, if the township is found to be of regular size on the General Land Office plat. Although the original Land Office plat may depict a township as a square, the same township as built up in mosaic form is often far from square. This is due to variation in scale of the photographs and is allowed because experience has taught us to show as nearly 100 per cent of the area as possible and then to try in the process of photographic copying to correct the shape of the mosaic.

In the title there should appear along with the scale such items as north point, township, county, state, name of agency which took the photographs, and the year the pictures were taken (see Pl. LXXXVII).

If water surfaces occurring in an area have mirrored the sun's rays into the camera lens, the water body will appear dead white, while normally the dark under-water vegetation and muddy bottoms will give such bodies of water an almost black color. The artist's air brush (see Pl. LXXXVII), filled with black water color, is used upon these light water areas until all lakes and large streams are of a uniform gray or black color. Excess color around the margins of a lake may be wiped up with a little cotton on a small wooden applicator (see Pl. LXXXVII). Shoals and submerged sand beaches are not covered with color if their presence is known. After water surfaces have been retouched they may be sprayed with a transparent fixative or lacquer to prevent accidental scratching of the delicate water color film; this procedure, however, is not practiced at present.

Water features are next labeled with white ink, which is used for names of lakes, large rivers, and bays. All land features are in black ink. Mountains, points, islands, and cultural features such as towns are included in this group, as well as section numbers and county boundary names.

The assembly man signs each mosaic in the lower right-hand corner and writes upon a small piece of note paper any special instructions that will aid the photographer in making a good reduced copy of the mosaic. This note is attached to the mosaic by means of "Scotch tape." The scale appearing in the title is always to measure two inches on the copy, and, unless there is a statement to the contrary, the township should appear square and regular upon the reduced copy.

Our regular semimatte finished paper is the most popular and is usually cloth-backed and provided with a hinge on the left-hand edge (see Pl. LXXXVII). Glossy and dead-matte papers are also furnished. The glossy paper gives maximum brilliance of detail and the dead matte permits pencil work upon the print. This last finish is used by field parties in mapping soils and cover with colored pencils and ink directly upon the copy mosaics.

When the original mosaic and prints are returned from the photographer the copies are filed in a loose-leaf binder and the originals placed vertically in a special file by counties to facilitate easy removal of individual mosaics for reference.

APPENDIX

The following notes on the equipment used by the Geological Survey of Michigan are added for the benefit of persons interested in the making of airplane photograph mosaics.

Assembly board. — The assembly board rests at an angle upon a vertically adjustable wall rack or easel. The wall rack is hung from a strong metal picture groove in the wall by two light-weight window-sash cords. These are threaded around grooved shives on a pair of overhanging arms; thence they are wound upon a light-weight crank shaft near the bottom of the rack. This shaft is locked by a sliding bolt (see Pl. LXXXVIII, Fig. 1).

The overhanging arms cause the top of the wall rack to press firmly against the wall at all times. To accommodate different loads the length of these overhanging arms is made adjustable by means of a series of holes through any one of which a removable pin fixes the position of the outer shive. A 4-inch shelf along the base of the assembly board provides a convenient place upon which to lay small tools between operations.

The variable height of this wall rack is a boon to the assembly man who would, without some such device, spend many tiresome hours each day reaching over the edge of a flat-topped table. Such a working posture is poor because air photographs may not be accurately matched and fitted unless the workman's line of sight is normal to the working surface. This reason alone justifies the use of some form of wall rack, tilting drawing table, or easel.

A pair of letter files standing side by side make an acceptable substitute easel, upon the slightly opened lower drawers of which the assembly board is rested.

The assembly boards shown (see Pls. LXXXVIII-LXXXIX) measure about 42 by 45 inches. They are amply large to accommodate our standard township assembly of 36 square miles on a scale of 1,000 feet to the inch. They are ordinary soft insulating wall board of a brown color, from which the tiny wire staples used in the dry assembly may be easily withdrawn with the finger nail, an important detail.

Since the accompanying photographs were taken a new type of nonsuspended wall rack has been designed. It consists of an assembly-board carriage that runs upon a portable wall frame. The wall frame is made of one-inch pine, four feet wide by seven and one-half feet high. Its top corners press against the wall through two felt-covered adjustable bearing blocks, and any tendency to tip away from the wall is checked by means of two projecting feet securely bolted to the broad bottom ends of the vertical side members. The assembly-board carriage is equipped with small flanged wheels, which run upon the exposed edges of the two vertical side members of the wall frame. These members are narrow at the top and wide at the bottom, thus forming an inclined track which, through gravity, operates to keep the carriage seated securely at all times. The hand crank, which is installed upon the wall frame, does not travel with the carriage, and because the flanged wheels are mounted at the extreme corners of the carriage the stability thus gained permits the use of the staple-driving machine upon the outer edge of the dry assembly board. Because the carriage rests squarely upon the rigid wall frame it needs but one supporting rope attached on its center line; the rails keep it square at all times.

There is a full-length tray 6 inches wide supported by metal arms in a position between the operator and the movable carriage and on the same level as the back table. Thus the tray does not move with the assembly board. In short, the new units are portable; the hand cranks and working trays do not travel with the assembly board, which is held square by its flanged wheels between the side rails, and it is much easier to operate.

Table. — We use a special back table resembling a flat-topped desk; it is 38 inches high and provided with a drawer and some open shelves on one side and a special pocket for safe storage of original General Land Office maps so essential in the assembly of wild-land photographs. This table has a brown linoleum top and is ideal for wet jobs such as this.

Stool. — The stool is adjustable for height and the seat rotates like that of a swivel chair. By pivoting upon this stool it is often possible to perform related operations between back table and assembly board.

Stapler. — The stapler is a device similar to the common paper stitchers found in many offices for fastening two or more papers together with a clinched wire staple. The small wire staple is not clinched, but is driven straight into and flush with the surface of the photographs on the assembly board. Staples may be removed from the recommended insulating board with the finger nail or from a pine drawing board by means of a pointed and bent lifter furnished with each machine (see Pl. LXXXVIII, Fig. 2).

Trimming board. — Two 8-inch squares of thin wall board (described under "mount" in this Appendix), with the rough side of the board beveled off to leave a clean sharp edge all around, are glued with smooth sides outward to opposite ends of a 4-inch wooden spacer block (see Pls. LXXXVIII, Figs. 1-2; LX.XXIX, Fig. 1). The 4-inch height of the spacer block is specified to prevent assemblyman's knuckles from striking the table top when a print is torn along the edge of the trimming board.

Knife. — A small penknife with a sharp point is necessary for scribing and beveling prints. A few pieces of 000-size sandpaper will keep it sharp. Crocus cloth polishes the edge quickly. It is essential that the knife be sharp at all times.

Straightedges. — One long steel straightedge is required for alignment of straight roads and similar features, and a short one of wood, or a large triangle of celluloid, or both, are handy for short projections and comparisons.

Scales. — A 5-foot narrow steel tape, in a round metal case smaller than a man's pocket watch, which reels itself up at the press of a center button, is recommended for accurate measurements (see Pl. LXXXVIII, Fig. 1). An engineer's triangular celluloid-edged scale, 12 inches long, is necessary for laying out the average mile in the title block under "scale."

Needle bar. — The term "needle bar" is applied to a brass bar $^{3}/_{16}$ of an inch square and from 1½ to 5 inches long, having a pair of needle points inserted into drilled holes at either end and fixed with solder. A kettle knob, brass ring, or straight piece of self material may be fastened to the center of the bar on the top side for use as a handle. The points should not protrude more than $^{3}/_{16}$ of an inch. The longer bars produce most accurate results, but short bars are necessary for occasional small bits of photographs in an assembly (see Pl. LXXXVIII, Fig. 2).

Mount. — The mount is a thin hard wall board $^{3}/_{16}$ of an inch thick, of golden brown color. It comes in all standard lengths up to 12 feet and is 4 feet wide. The finished surface is very hard and smooth; the reverse side bears the imprint of a fine wire screen. It weighs about one pound per square foot. A smaller size of the same kind of board, ⅛ of an inch thick, is lighter but less rigid. Since there is danger of the prints becoming loose through the flexing of the mount, this size is not recommended for mosaics larger than 2 feet square. The thicker board is successfully used for mounts as much as 4 feet square.

Larger mosaics must be laid upon thicker boards obtainable in 6-foot widths. Loosely bonded boards designed primarily for insulating value are not suitable. At least one surface should be fairly smooth.

Mucilage. — Good glue or mucilage is important. A quick-setting library paste is unsuitable, for each photograph must be adjusted after it is applied. It must be soluble in water, since sometimes the assembly must be reworked. Any mucilage containing water causes photographs to expand. The ideal bonding medium, therefore, would cause a minimum of expansion. Rubber cement deteriorates in time and permits edges to curl. A heavy commercial mucilage made of gum arabic seems to work as well as anything we have tried (see Pl. LXXXIX, Fig. 2). Various formulas call for from one to two or more pounds of gum arabic to one gallon of water. The mucilage we are using successfully is heavier in body than that made in either of the proportions of gum and water just mentioned. In addition, it has a pleasant odor and does not become rancid with age and hot weather. A foul-smelling mucilage is a nuisance around any office.

Glue pot. — From the original container, which may be a one-gallon jug or a one-quart bottle, our mucilage is transferred in small quantities to a specially constructed square metal dish. Heavy gauge copper is recommended for the material, since our first dishes made of galvanized steel have begun to rust within a year. The dish, about 1½ inches deep by 4 inches square, is provided, near the front edge, with a crossbar over which the brush is wiped or upon which it may be rested (see Pl. LXXXIX, Fig. 2).

Brush. — A 2-inch varnish brush is used to spread the mucilage evenly and thinly. Such a brush (see Pl. LXXXIX, Fig. 2), with the bristles vulcanized in rubber, costs about 25 cents.

Paper towels. — The dampened photographs are laid face down upon paper hand towels during the operation of applying the adhesive. In actual wet assembly work about one third of the mucilage used is discarded with the spent towels. Upon first thought this may seem an unnecessary waste. However, if the face of the photograph is not kept free from adhesive in the first place, the same waste mucilage must be sponged off the mosaic surface later, a messy operation which can be avoided through the use of paper towels (see Pl. LXXXIX, Fig. 2).

Sponges. — Good sponges are absolutely essential to good work upon air-photograph mosaics. Only the best quality of small-sized wool sponges should be considered, and before being used they should be thoroughly washed out to remove bits of sea shell and grit. The emulsion on a photograph is very tender when wet and a soft wet sponge cannot be excelled for sponging and cleaning.

Basin. — An 8-inch aluminum basin with flat bottom will hold sufficient water for sponging purposes.

Wiping cloths. — Mention should be made also of the soft cotton wiping cloths so useful for rough-drying the wet surfaces of photographs and as pen wipers. After use they are stiff with mucilage and should be thoroughly laundered from time to time. The adhesive recommended is easily rinsed out in hot water. Discarded sugar bags are excellent.

Lettering guides. — Ownership of or access to a set of mechanical lettering guides and pens is very desirable for the finishing of a mosaic. The ordinary draftsman's instruments also will be useful from time to time, especially the bow pen and the ruling pen.

Air brush. — Compressed carbon dioxide gas is used to operate the artist's air brush (shown in Pl. LXXXVII) employed for touching up water areas.

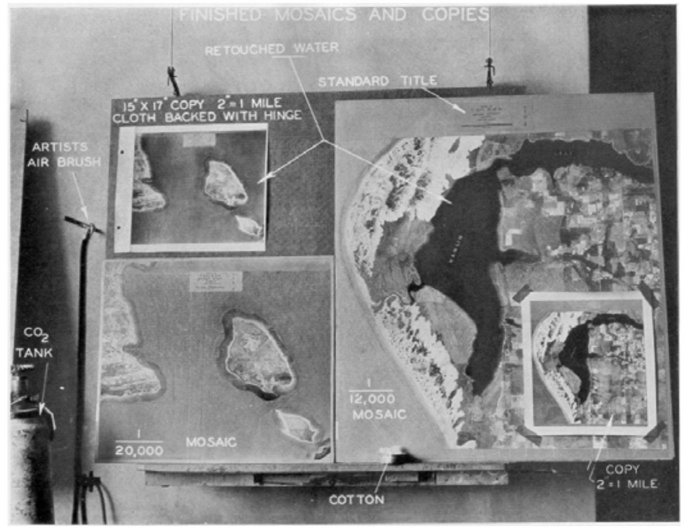
Crayon. — A china-marking crayon in black makes legible marks upon glossy prints that may be wiped off completely with a dry soft cloth without injury to the photograph.

Miscellaneous. — Other items of equipment might include suitable envelopes for sorting and filing photographs by strips, a quantity of manila Kraft wrapping paper for use as a mount cover, gummed paper tape 1½ inches wide, and quantities of clear celluloid for grids. From time to time the ingenuity of the assembly man will produce special items of equipment, such as celluloid templates for locating the section numbers.

The items of equipment discussed above are important. Good tools are important on any job, and the difference between good and poor results in any work often rests in the tools employed rather than in the ability of the workman. At all events, a workman using good equipment cannot blame his tools for poor results.

DEPARTMENT OF CONSERVATION
LANSING, MICHIGAN

PLATE LXXXVII



Representative samples of work

PLATE LXXXVIII

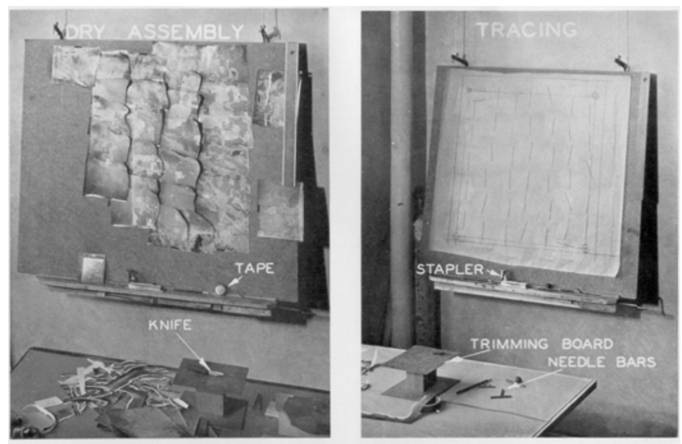


FIG. 1. Dry assembly in progress

FIG. 2. Transfer operation

PLATE LXXXIX

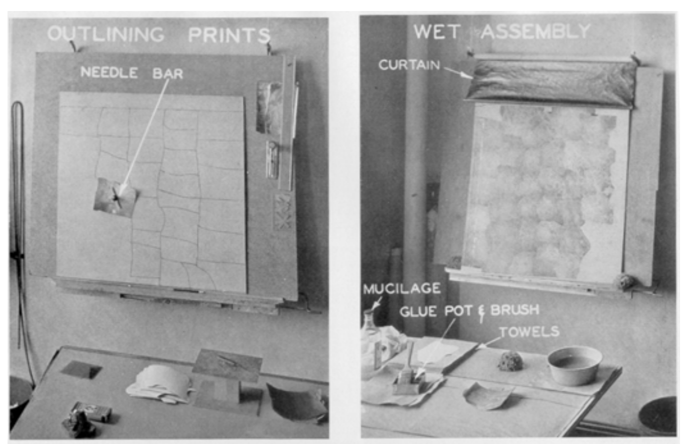


FIG. 1. Relocating photographs

FIG. 2. Wet assembly in progress

ABANDONED CHANNELS ON THE LOWER HURON RIVER, MICHIGAN

JAMES WILLIAM BAY

INTRODUCTION

THE Huron River is one of the major drainage lines contributing to the flow of the Great Lakes system between the head of the St. Clair River and the southwestern end of Lake Erie. Its entire valley in Washtenaw, Wayne, and Monroe counties[1] has resulted from mouthward extension of the river over land previously occupied by the Huron-Erie lobe of Late Wisconsin glaciation and the subsequent glacial lakes of the Lake Huron and Lake Erie basins. Between the lowest of these glacial-lake shore lines (that of Lake Elkton) and the present drowned shore of Lake Erie there is a network of distributary channels which the river has abandoned. This is the Lower Lake Plain section of the river. Its channels tell the story of the descent of lake waters in this area from the Elkton level to that of Lake Erie.

The features of the Lower Lake Plain section of the Huron River valley are shown on Map 35, together with the distributary channels of the Detroit River which connected Lake Rouge and Lake Erie.[2] In order to prevent confusion in their description the Huron River distributaries are numbered. Channels 13, 16-18, and 20-23 are shown on the maps of the "Detroit Folio,"[3] but are there undifferentiated from the present valley floor. The others have not previously been mapped.

TOPOGRAPHY OF THE CHANNELS

The Huron River distributaries cover an area about ten miles in length and four miles in maximum width. For the most part they are flat-bottomed channels measuring from forty or fifty feet to a quarter of a mile across and from five to ten feet in depth. The majority of them are dry. Some are occupied by streams, mostly of the intermittent type, too small to have cut the broad depressions in which they now flow. The Silver Creek channel is a single exception, but the headwater portion is dry and shows channel characteristics so distinctly that it must be regarded as having the same origin as the others. Elevations on the flat floors of these features range between 575 and 612 feet above sea level, with those channels farthest from the center of the system at the highest levels. Many of the lower channels have cut across the heads of the higher ones, so that there is a definite ascent from one to the other. The present river occupies a course which nearly bisects the whole system longitudinally.

Channel 1 is occupied for most of its length by Silver Creek. At its headward end it appears to have drawn water from Channel 7 and east of the present site of Rockwood, from several of the Detroit River distributaries. Near the headwater portion it has cut deeply into a high sand ridge. The extreme head stands higher than Channel 7.

On the south side of the river Channels 2-6 constitute a group which carried a large portion of the water and which appears to have been abandoned relatively early. Channels 7-11 on the north side of the river seem to have had a similar history. Channel 2 is about 612 feet in elevation one and one-half miles south of its head and 586 feet at its mouth. It is the largest of the channels. Channel 3 served as a connection between number 2 and those to the north. The elevations in Channels 5 and 6 range from 604 to 606 feet above sea level; in Channels 7-9, from 601 to 603 feet. These were two parallel lines of flow with a possible connection by way of Channels 6 and 8. The present river flows along the southern of these two lines and has cut into it, leaving the upper end of Channel 5 as a terrace on the south side of the valley. Channels 11 and 12 carried water from 7 and 17. Near their junction with Channel 1 they were connected with the Detroit River distributaries west of Rockwood.

In the vicinity of Flat Rock a group of distributaries which were cut lower than those just described indicates that in the later part of the development the river waters had been concentrated in a group of channels toward the center of the system. This is also true near Rockwood and South Rockwood. The Flat Rock group consists of Channels 13-17, and possibly 12, which range from about 585 to 593 feet above sea level. The second group is composed of Channels 18, 20, and 21, at about 579 to 580 feet elevation.

Channel 19, which appears to have been formed by overflow from Channel 2, did not function long enough to cut back by headward erosion to the latter. Therefore, it must have been abandoned relatively early.

SUMMARY AND INTERPRETATION

The pattern and close articulation of the Huron River distributary channels indicate that the descent of water from the Lake Elkton level to the Algonquin stages of Lake Erie was extremely rapid, possibly more rapid than the transition between any of the other glacial lakes of the Lake Erie basin. Instead of the gradual mouthward extension of a single channel, which took place over most of the area upstream, the river waters seem to have divided into a braided system upon a newly uncovered surface of only slight relief. At first the flow of waters was through the entire network, but as the cutting continued the waters concentrated in the channels nearest the center of the system, so that these were cut lower than the outer ones.

Channel 1 had its beginning as soon as the lake waters had lowered so that cutting could begin on the sand ridge at its headward end. This channel appears to have been the first to be discontinued because Channel 7, which was abandoned relatively early in the series, is cut beneath it at their junction. There is additional evidence of this conclusion in the lower part of Channel 1 at its intersection with the Detroit River distributaries east of Rockwood. These channels, which were believed to have been formed by overflow from the main channel to the north and which were among the first of the Detroit River series to be discontinued,[4] have the same level as Channel 1 at the junctions.

Channels 2-11 seem to have been the next to be abandoned. They stand at higher elevations than the channels nearer the center of the system, and distinct breaks of slope occur between 7 and 16 and between 4 and 14. The relation of Channel 12 to the others is uncertain. Its head is level with Channel 17, but the connection with 11 is obscured by recent erosion and a roadway.

The group composed of Channels 13-18, 20, and 21 were the last to become dry. The cause of this was possibly one of the two low stages of Lake Erie during Lake Nipissing and Lake Algonquin times.

The present valley bottom is from four to five feet below the lowest channel floors between Flat Rock and Rockwood. The valley is drowned upstream as far as South Rockwood, and a small delta covering an area of about two square miles[5] has been deposited in it.

The evidence at hand indicates that the Huron River distributary channels were abandoned by down-cutting to a low base level. Whether this was the low stage of Lake Erie during Lake Algonquin or Lake Nipissing time or both is at present indeterminable.

WAYNE UNIVERSITY
DETROIT, MICHIGAN

[1] The distance from Base Line Lake at the Livingston-Washtenaw county line to Lake Erie is fifty-six valley miles.

[2] For the description and interpretation of the Detroit River distributaries see F. Leverett and F. B. Taylor, *The Pleistocene of Indiana and Michigan and the History of the Great Lakes, U. S. Geol. Surv., Mon. 53*: 487-496. 1915.

[3] Sherzer, W. H., "Detroit Folio," *Geol. Atlas of the United States*, No. 205. 1916. Maps of Areal Geology of Romulus and Wyandotte Quadrangles.

[4] Leverett and Taylor, *op. cit*., p. 491.

[5] Sherzer, W. H., "Geological Report on Wayne County," *Mich. Geol. and Biol Surv*., Publ. 12, Geol. Ser. 9, p. 117. 1913.

VALLEY-TRAIN DEPOSITS IN THE NORTHERN PENINSULA OF MICHIGAN

STANARD G. BERGQUIST

IN A recent paper dealing with the glacial geology of Iron County, Michigan, the writer made special reference to the widespread distribution of glacio-fluvial sediments in the major valley ways (Pl. XC, Figs. 1-2) of the area (see Map 36). Attention was called likewise to the general occurrence of very fine silt which is spread out as a thin mantle over the surface of the gravel trains and is interspersed through the adjacent interfluvial till plains.[1]

More detailed studies, made recently, of the Pleistocene section exposed in numerous mine caves within the till-plain area in the vicinity of Iron River have revealed a succession of geologic events which are not readily recognized on the surface. Four distinct episodes of Pleistocene activity are recorded in the formations which overlie the pre-Cambrian floor. These events are associated with various stages of glaciation, extending from pre-Wisconsin into late Wisconsin.

PRE-WISCONSIN DRIFT

Basal till sheet

Resting directly upon the pavement of the pre-Cambrian complex in the vicinity of Iron River is a sheet of till which ranges from twenty to forty or more feet in thickness (Pl. XCI, Fig. 1). It seems to be confined largely to the preglacial upland areas and is noticeably absent in the rock-sculptured valley floors. The drift here is composed largely of bouldery till, definitely unassorted but somewhat compacted. Polished and faceted pebbles, cobbles, and large erratics, consisting in the main of quartzite, granite, and other acidic rocks, together with dark slate and an abundance of more basic types such as diabase and basalt, are embedded in the ground mass of distinctly weathered clay, silt, and sand.

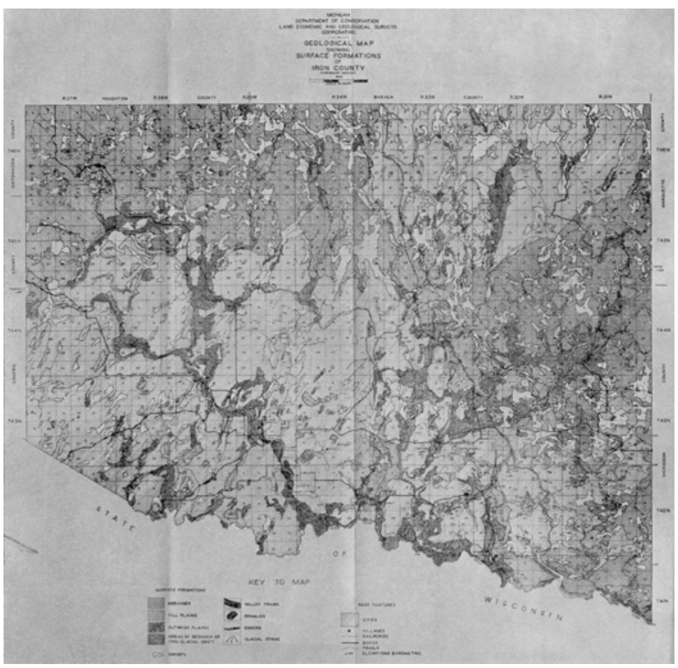
South of the village of Iron River, in the Berkshire cave, near Gaastra, the drift is of a rust brown and contains a considerable quantity of comminuted limonite, apparently of local origin. A pebble count of a characteristic sample of the basal till in this cave exposure reveals the presence of the following material:

Material	*Percentage*
Quartzite and quartz	26
Granite and aplite	8
Limonite (weathered)	12
Slate (dark-colored)	10
Basalt and diabase	44

The larger fragments are dominantly basalt and diabase, with quartzite and quartz together forming a considerable portion of the total content. Some of the larger pebbles and fragments of the basalt and diabase show but a very small degree of weathering. The smaller fragments, on the other hand, seem to have undergone appreciable decomposition and they possess an outer thin zone of weathered limonite. The finer matrix in this till is made up essentially of more or less rounded, frosted, and translucent particles of quartz. These are generally coated with a fine dusting of limonitic powder, which also accounts for the color of the formation as a whole. No calcareous fragments were observed in the sample and no reactions for carbonate were obtained, conditions which may be attributed to the greater age and the more profound weathering of the drift in this section.

Three miles to the north, in the Davidson (No. 1) mine cave, in the SW. ¼, SE. ¼, Sec. 14, T. 43 N., R. 35 W., the exposed basal till is a decidedly lighter or a cinnamon brown, and contains much less of the intermixed iron ore. In this section the older till resembles more the younger surface drift, in composition as well as in color. In a characteristic sample of the drift from this locality there was found the following material:

Material	*Percentage*
Quartzite and quartz	36
Granite and aplite	14
Schist (much weathered)	3
Limestone and dolomite (fresh)	6
Slate (dark-colored)	15
Basalt diabase and diorite	26



MAP 36

Although the stratigraphic relations of the basal till in the Berkshire and Davidson mine caves are identical so far as bedrock and overlying gravel deposits are concerned, still there is a substantial difference in composition and likewise in the degree of weathering. In the basal till of the Davidson cave the larger pebbles and cobbles are somewhat smoothly polished and some are definitely faceted. They are composed essentially of quartzitic and basaltic fragments with a predominance of the former. The smaller pebbles, those below the size of a small pea, are angular to rounded and seem to lack the smoothly polished surfaces which characterize the larger fragments. The finer-textured portion of the drift is made up largely of angular to rounded frosted grains of quartz, with a subordinate assemblage of intermixed fragments of fairly fresh basalt, diabase, and dark-colored slate. The sample contains also some unweathered limestone and dolomite pebbles, together with scattered minute weathered fragments of the same material, and yields a liberal amount of effervescence with dilute HCl. It is apparent from the calcareous character of the basal drift in the Davidson mine cave that weathering has not progressed to the same advanced degree as in the Berkshire cave. This may be due to one of several circumstances, or to a combination of them, among which may be cited: (1) the relative age of the deposit in the two localities; (2) the possibility of more rapid burial of the gravel plain in the Davidson cave area owing to a sudden abrupt readvance of the ice before much weathering had been effected; and (3) the variations in the source of material included.

On the premise that there is a decided difference in the age of the material of the deposit in the two areas, it may be inferred that the rate of retreat of the ice sheet which contributed the till was extremely slow.

EARLY WISCONSIN DRIFT

Glacio-fluvial sediments

Immediately above the basal till sheet in the upland interfluves and lying more or less directly in contact with the rock floors of the intervening valley ways there is a formation composed essentially of stratified glacio-fluvial sediment. This deposit, ranging in thickness from fifteen to forty or more feet, is made up of alternating beds of gravel and sand of varying degrees of texture (Pl. XCI, Fig. 2). Subangular to rounded grains of quartz comprise the bulk of the constituents in the finer material, although subordinate amounts of basalt and slate are also intermixed. The pebbles and cobbles of the coarser fractions are fairly well rounded, and many exhibit distinct triangular faceting.

This intermediate formation of stratified drift is well exposed in both the Berkshire and the Davidson caves, where it rests upon the basal till. A pebble count was made of characteristic samples of the deposit from each of these localities, and the comparative results are given in the accompanying table. It will be seen from the tabulation that quartzitic, granitic, and basaltic constituents predominate in each of the samples. It is noteworthy that the dark-colored or basic rock fragments appear not to have undergone a great amount of weathering, for they are as fresh as the light-colored constituents.

Material	Berkshire Cave Percentage from 100 pebbles	Davidson Cave Percentage from 200 pebbles
Quartzite and quartz	27	35
Granite and aplite	21	17
Gneiss	1	0
Schist (fresh)	1	1
Schist (weathered)	7	0
Limestone and dolomite (fresh)	9	6
Sandstone	2	2
Basalt, diabase, and diorite	23	30
Slate (dark-colored)	9	8
Lignite	0	0.5
Banded jasper	0	0.5

It is questionable whether this intermediate bed of stratified material is associated with the ice invasion which is related to the older basal till or to that which developed the overlying surface sheet. The mineral and rock fragments, however, more nearly correspond in composition and degree of weathering to the younger rather than to the older drift. In all events it lies between the two till sheets and is intermediate in age.

That the stratified deposit is of widespread and extensive occurrence is recognized by its presence in various caves, shafts, and drill holes scattered through the area. It appears to form a more or less continuous feature below the surface cover throughout the greater portion of the till plain.

MIDDLE WISCONSIN DRIFT

Surface till sheet

In the upland areas which form the divides between the adjacent valley ways there is superimposed upon the stratified formation a younger till sheet which in the exposed portions ranges from twenty to thirty-five feet in thickness. It is undoubtedly much thicker in certain areas. This till sheet was laid down by a tongue of ice located directly west of the Green Bay lobe, referred to by Weidman[2] as "the Langlade lobe." It deployed across the area in a generally northeast-southwest direction. The numerous drumlins which are distributed over the surface of the till plain in the vicinity of Iron River are more or less parallel in their alignment and strike in a direction which varies from S. 5° W. to S. 40° W. This is in accord with the trend of the glacial striae which are found on the rock pavement in various localities. The drift in this plain is composed of bouldery clay intermixed with a considerable amount of gravel and cobble, which may have been derived either by incorporation of material from the gravel plain which the glacier overrode or through glacio-fluvial activity within the advancing ice sheet.

The constituents of the surface till plain are largely fragments of quartzitic, granitic, and basaltic derivation. Quartz predominates, however, in both the coarser and the finer fractions of the drift, although the more basic materials are likewise important. The fragments of rocks and minerals, whether of basic or of acidic nature, do not show evidence of excessive weathering and appear relatively fresh in the mixture. Intercalated with the coarser till and at times attaining a thickness of several feet in the surface depressions and pockets is a finely comminuted siltlike material which in composition and physical character bears a very close resemblance to the fine fluvial flour which mantles the surface of the adjoining valley-train deposits. It seems quite probable that this finer sediment was carried on to the till-plain area from the valleys by wind activity and is thus of aeolian development.

LATE WISCONSIN DRIFT

The late Wisconsin drift of the area is associated intimately with the activities of the Superior lobe, which moved into the Lake Superior basin from the northeast and advanced southward across a small portion of the Northern Peninsula. The terminal moraine which is associated with the activities of this ice tongue lies directly to the north of the till plain of the Middle Wisconsin invasion; it has been described in some detail in a previous paper.[3]

Extending southward from the terminal moraine of the Superior lobe the glacial valleys are fairly well filled with glacio-fluvial sediments. These were deposited as valley trains by melt waters issuing from the dissipating ice border during the waning stages of glacial activity. The valley-train deposits (Pl. XCII, Fig. 1) are composed of alternating layers of coarse and fine sediment and contain a predominance of smoothly polished and faceted fragments of quartz, quartzite, and granite, with scattered basic materials such as diabase, basalt, and diorite and occasional dark-colored slate. The various gradations of texture developed in the stratified sediments of the valley ways is indubitable evidence that the velocity and volume of the water fluctuated from time to time during the process of sedimentation.

A section through the valley-train deposits shows stratified material to be more or less persistent down to the floors of the valley in which deposition took place. The basal portion of the well-sorted material is intercalated with boulders and large erratics, which are undoubtedly the concentrated remnants of the oldest till. Occasional scattered erratics are found also in the higher levels of the deposit and may represent the concentrated residuals of the younger till sheet. The apparent absence of finer till in the lower part of the valley-train deposits seems to harmonize with the view that in the early stages of deglaciation by the Langlade lobe protracted melting continued to supply an abundance of melt water as the glacier retreated slowly northward to lay down its load of till plain. The ensuing streams occupying the partly filled depressions proceeded to scour out the finer portions of the basal till and left the coarser and heavier residuals as concentrates on the rock floors.

The closing chapter of Pleistocene activity in Iron County is related to the deposition of a layer of silt which forms a comparatively thin mantle over the surface of the gravel in the valley trains (Pl. XCII, Fig. 2). This deposit of fine material was undoubtedly carried into the valley ways as glacial flour by slowly moving melt waters which issued forth from the margin of the last remnants of the waning ice in the Superior lobe. It represents the product of final deglaciation within the area and is unquestionably associated with fluvial activity. The silt is not uniform in depth throughout the valley trains, but ranges from merely a few inches to six or more feet. It rests directly upon the gravel and marks definitely an abrupt change in the transporting ability of the streams which occupied the valleys.

The fine surface fluvial flour of the valley trains is composed essentially of subangular to rounded particles of quartz interspersed with a small amount of minute fragments of granite, gneiss, and dark-colored, more or less basic, rock. The predominance of quartz seems to substantiate the opinion that acidic rocks rather than those of basic character contributed largely to the material. The basic rock constituents which are scattered through the mixture are not unlike the quartz in texture and structure. Although fragmented by mechanical wear, they still retain their original properties and show no more evidence of weathering than do the associated quartz particles.

The view has been advanced by several podologists that the surface mantle of silt in this area is merely the weathered product of underlying parent gravel and that weathering has progressed rapidly to form the finer mantle because of the predominance of included basic rock fragments. Microscopic examination of the material reveals, however, that although quartz is the predominant mineral there is also a relatively large amount of unweathered basic constituents. If the ordinary processes of weathering have been able to change coarse gravel composed in large measure of quartzitic and granitic pebbles into a fine rock flour in a region so recently deglaciated, it seems logical to expect similar relationships, but on a much broader scale, to exist in the Southern Peninsula, where the surface has been exposed to weathering agents for much longer periods. The theory so commonly held by podologists, that surface soils should be related to the underlying parent material through the simple process of weathering, does not seem to hold true in this area. Other geological factors besides weathering must necessarily be brought into the picture to account for the succession from very coarse to very fine textures as developed in the materials of these valley trains.

Podsolization has played an important role in the development of a distinct profile in the surface silts. But, unlike the vertical changes ordinarily found in a podsolized soil, there appear here to be two definitely bleached horizons. Invariably, in the upland silts as well as in those of the valleys, the surface-bleached podsol is underlain by a dark brown illuvial layer with a heavy concentrate of iron oxide. Then follows a second bleached zone, not quite so light in color as the surface podsol but, nevertheless, much lighter than the overlying brown layer. This bleached horizon is underlain by a second brown subsoil, which in turn may be followed by either a darker or a lighter zone before reaching the gravel floor. The lower bleached horizon is of geologic significance in that it probably marks the position of a former surface in which weathering had progressed sufficiently to initiate a podsol condition. But before the process was very far advanced there was a renewal of sedimentation, which may have resulted in a complete mantling of the older soil, with consequent termination of the bleaching activity.

In the upland interfluves of the till-plain topography the fine silt may be traced for some distance back from the valley ways. Here it is thinly spread out in patches over the surface or intermixed with the material of the till plain. In areas where the accumulations are of appreciable thickness they resemble very much the deposits in the valley ways in both mineral composition and profile.

On the basis of their horizonal and textural similarities it seems plausible to assume that the upland silts are genetically closely related to the valley silts. The writer is of the opinion that the fine flour which occupies the surface of the till-plain area was translocated by wind from the adjacent valley-train deposits during intervals when only a small amount of water flowed through the valleys. Then the finer material of the valley flats situated above the channels had an opportunity to become thoroughly desiccated and was lifted into the atmospheric circulation and transported, sometimes for considerable distances, before finally settling. There is a strong suggestion that the lower bleached horizon in the upland rock flour deposits may represent a former surface exposed to weathering during the interval when fluvial activity was finally restored in the valley ways. The last melt waters which flowed into the valleys were capable of transporting merely the finer silts, although occasionally the velocity was increased sufficiently to move fine pebbles, which became intermixed in the mantle. While the depressions were occupied with slow moving waters, translocation by the wind was minimized. Hence at the time of renewed fluvial deposition in the valleys the upland deposits were subjected to weathering, with the result that a weak podsol layer was developed. When finally the ice sheet retreated northward to the point where melt waters could no longer find access to the train-filled valleys, desiccation again became an effective process and the finer silts were subjected to renewed atmospheric shifting. They were then in part carried out of the depressions and on to the adjacent uplands, where they were spread out over the podsoled surface. Eventually the encroachment of vegetation caused the soils to become more or less fixed, and then followed the natural sequence of weathering activities and the development of an upper podsol horizon in both the lowland and upland deposits.

Thus, in conclusion, it may be inferred that fine sediments in the valley-train deposits are definitely of fluviatile origin. On the other hand, the mantle silts of the uplands, although originally water-laid, were subsequently transferred by the wind and deposited eventually as loessial material.

MICHIGAN STATE COLLEGE
EAST LANSING, MICHIGAN

[1] Bergquist, S. G., "Glacial Geology of Iron County, Michigan," *Pap. Mich. Acad. Sci., Arts and Letters*, 16(1931): 368. 1932.

[2] Weidman, Samuel, "The Geology of North Central Wisconsin," *Wis. Geol and Nat. Hist. Surv*., Bull. 16, Ser, 4, p. 492. 1907.

[3] Bergquist, *op. cit*., pp. 365-367.

PLATE XC

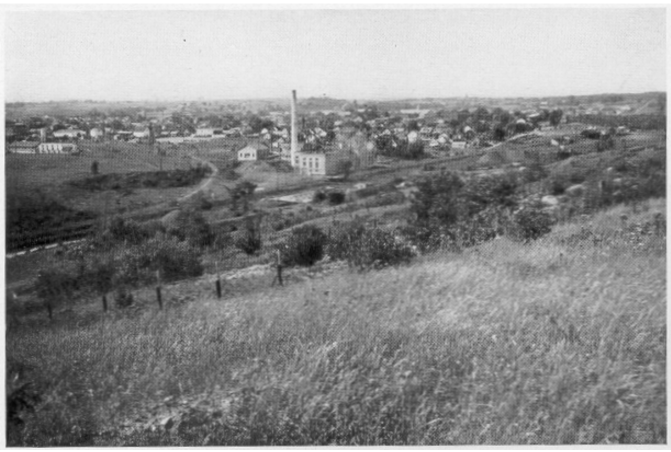


FIG. 1. Valley of Iron River, in the vicinity of the village of Iron River

FIG. 2. View from Stambaugh Hill, looking south across the Valley of Iron River

PLATE XCI

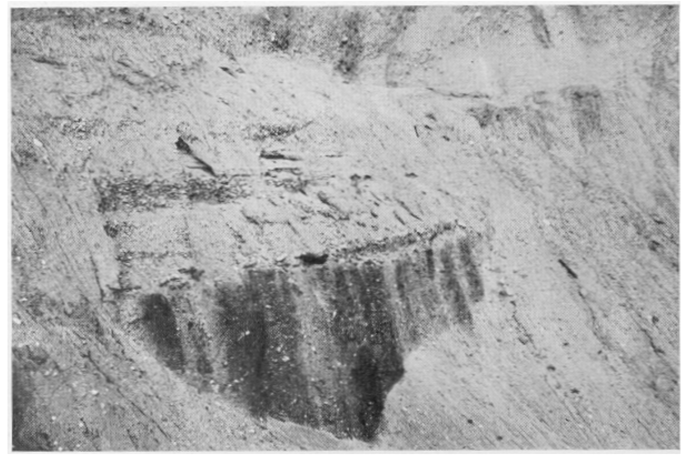


FIG. 1. Basal pre-Wisconsin till with overlying glacio-fluvial deposit, near the bottom of Berkshire Cave

FIG. 2. Alternating beds of gravel and sand in glacio-fluvial deposit immediately above basal till, Berkshire Cave, near Iron River

PLATE XCII

FIG. 1. Gravel bed showing faceted and polished pebbles, in valley train of Paint River Valley, near Crystal Falls

FIG. 2. Surface fluvial silt resting directly on stratified gravel of valley-train deposit, Champion gravel pit, near Beechwood

DISCOVERY OF *ELEPHAS PRIMIGENIUS AMERICANUS* IN THE BED OF GLACIAL LAKE MOGODORE, IN CASS COUNTY, MICHIGAN

ERMINE C. CASE, IRVING D. SCOTT, BYRNE M. BADENOCH, AND THEODORE E. WHITE

IN 1929 the Museum of Paleontology of the University of Michigan received word of the discovery of large bones in a marl pit near the small village of Union in Cass County, Michigan. Investigation revealed that these were the bones of an elephant. Since such remains are relatively scarce in Michigan, the material was carefully preserved and is now mounted in the Hall of Evolution in the University Museums Building.

The skeleton was found during the excavation of a marl bed in the northwest corner of Porter Township, Cass County, Section 32, Township 7 S., Range 13 W. Mr. George Wagner, the owner of the pit, most generously donated the specimen to the University and aided materially in its recovery.

The position of the specimen gave an opportunity for a more accurate dating than any previously discovered, and so the help of Professor I. D. Scott and certain of his advanced students was enlisted to determine what could be made out from the associated glacial and physiographic features concerning the time of burial. The following is a report of the combined findings of ail engaged in the study.

The specimen consisted of the major portion of the skeleton of an adult individual. The skull and tusks were not found, but all four of the cheek teeth were recovered in good condition. These teeth were determined by Dr. H. F. Osborn, of the American Museum of Natural History in New York, as those of *Elephas primigenius americanus*, the woolly or hairy mammoth of the American continent.

The humerus measures 3 feet 11 inches in length, which indicates a height of 10 feet 6 inches at shoulders, and a length of over 13 feet from the base of the tail to the base of the tusks, somewhat larger than the Indian elephant commonly seen in the circus or zoölogical garden. Because of the absence of tusks, which reach a large size in the male, it is believed the skeleton is that of a female.

The skeleton lay upon a yellowish, clayey sand which formed the bottom of the lake in which the marl developed. Above the specimen lay 8 feet 8 inches of undisturbed marl, mostly white, but with bands of a brown and bluish color. The marl is an almost pure calcium carbonate, formed from the shells of fresh-water invertebrates and by direct precipitation from the water. According to a personal communication from Mr. Calvin Goodrich, curator of molluscs in the Museum of Zoology, the abundant shells of lamellibranchs and gastropods preserved in the marl are indistinguishable from those of living forms. The undisturbed condition of the marl beds shows that the cadaver was deposited before the marl was formed and did not sink down through all or any part of it at any subsequent time. The condition of the bones, some badly injured by decay and the skull almost entirely destroyed, indicates that they lay partly exposed to the air for some time before burial. These are important points, since they date the deposition of the specimen at the beginning of the formation of the lake.

The examination of the physiographic evidence by Professor Scott and two of his advanced students, Mr. B. M. Badenoch and Mr. T. E. White, leads to the following considerations.

The glacial deposits of the region south of the Saginaw-Grand lowland were formed by the Wisconsin ice sheet. The Kalamazoo-Mississinawa morainic system may be taken as characteristic. It consists of three parts, a western part with a northeast-southwest trend formed by the Michigan lobe, a central part with a northwest-southeast trend formed by the Saginaw lobe, and an eastern part with a northeast-southwest trend formed by the Huron-Erie lobe. It will be seen from the map (Map 37) that these three sections form a large rectangular reëntrant.

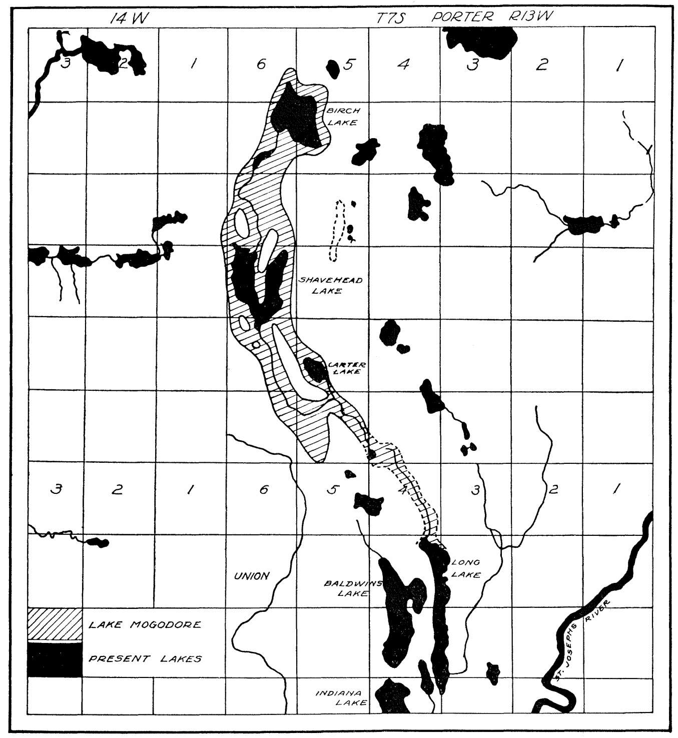
The Kalamazoo-Mississinawa morainic system marks the first great halt of the receding ice front. Three earlier minor halts are indicated by the Lagrange, Sturgis, and Tekonsha moraines which, although not continuous, have a northwest-southeast trend and therefore were deposited by the Saginaw lobe. It is important to note that there was a readvance of the ice to form the Tekonsha moraine and that the Lake Michigan sector covered the western ends of the Lagrange and Sturgis moraines.[1] This advance was sufficient to cover the basin in which the skeleton of the elephant was found and for which the name "Lake Mogodore" is proposed. This name was apparently used first by Mr. John Eby, a former resident of the region, who probably derived it from the earlier name of Chapel Hill school-house near the find of elephant bones, and from the local name, Mogodore Valley, applied to the lower end of the depression formerly occupied by an extension of the lake.

MAP 37. Southern Michigan and northern Indiana, showing the moraines

The borders of Lake Mogodore are identified by a well-defined offshore terrace, often consisting of marl, and in places by low, wave-cut cliffs. The terrace stands between thirty-five and forty feet above the present level of Shavehead Lake and at about the same height above Carter Lake. At Birch Lake, however, the terrace is only about six feet above the present lake level. At its greatest extent Lake Mogodore had a total length of about six and one-half miles and a maximum width of about one mile. It was irregular in shape and contained several islands, some of which were topped by wave action. It covered nearly all of Sections 7, 18, 19, 30, 32, the southwest part of Section 5, the southeast part of Section 6, the northeast part of Section 31, the southwest part of Section 29, and the west half of Section 8, all in Township 7 S., Range 13 W. (See Map 38.)

The present drainage starts with Birch Lake, which is the highest in the Mogodore Basin. It discharges southward into the western arm of Shavehead Lake. The outlet of the latter lake takes a southeasterly course and is joined by the drainage of Carter Lake at the head of the Mogodore Valley. The stream continues to the south and east into Long Lake and thence into the St. Joseph's River. The drainage of Lake Mogodore followed approximately the same course.

From the explanation given above it is evident that Lake Mogodore came into existence after the recession of the ice from the Tekonsha moraine. The condition of the bones necessitates postulating a rise in the level of the lake to its maximum stage but, unfortunately, no physiographic evidence of this was found.



MAP 38. A portion of Cass County, Michigan, showing the site of glacial lake Mogodore and the find of *Elephas primigenius americanus*

The date of burial of the elephant is uncertain. It surely postdated Tekonsha time and must have been previous to the draining of the lake, the date of which is not known. Assuming burial to have taken place during the time between the formation of the Tekonsha and Kalamazoo moraines, the following glacial history ensued: The Kalamazoo-Mississinawa system was followed by the Salamonie, the Wabash, and the Fort Wayne moraines, all of major importance. The recession of the ice from the Fort Wayne moraine initiated a series of glacial lakes with Maumee, Arkona, Whittlesey, Warren, Algonquin, and Nipissing as the main stages.

It is impossible to state with any certainty the duration of this time in terms of years, and any attempt must be in the nature of an estimate. Our best clock is Niagara Gorge, which was started in Algonquin time. According to Dr. Frank Leverett in a personal communication, it has taken Niagara River approximately 18,000 years to carve the gorge. The same authority places the Tekonsha moraine at somewhat less than 35,000 to 40,000 years ago. Thus the elephant must have lived in southwestern Michigan at some time less than 35,000 years ago, but how much later the genus survived in the state is still a question.

UNIVERSITY OF MICHIGAN

Frank Leverett, personal communication.

THE LOWER CHEEK TEETH OF THE FOSSIL HARE *PALAEOLAGUS HAYDENI*

LEE R. DICE AND DORA S. DICE

THE lower cheek teeth of the fossil hare, *Palaeolagus haydeni* Leidy, exhibit numerous changes during the life of the individual, and the teeth of young animals differ greatly from the teeth of old animals. The changes in teeth during growth are so considerable that specimens of this one species have been assigned to four genera and to three different subfamilies of the Leporidae.

Leidy[1] in his original description of *Palaeolagus* noted that some changes in the teeth are correlated with age. Troxell[2] also has described briefly some of the stages of wear on these lower teeth. By bringing together a large number of specimens from several museums we have been able to make a more detailed study of these age changes. Since Troxell has described in some detail the age changes in the upper teeth, we have confined our attention to the lower series.

Among the material which we have examined for this study are one hundred and ten fragments of lower jaws kindly loaned from the collections of the United States National Museum. These specimens were collected in the years 1886-88 by J. B. Hatcher, and are from the White River Formation, probably in the Hat Creek Basin, Sioux County, Nebraska. George F. Sternberg has courteously allowed the examination of the types of *Protolagus affinus* and *Archaeolagus striatus*, which were collected in Central Wyoming. The Peabody Museum of Yale University has generously loaned over four hundred parts of lower jaws, most of which are from the Oligocene (probably Brule clay) of Nebraska, but a few are from localities in Colorado and Wyoming.

A small amount of variation occurs between different specimens of the same tooth at comparable ages, but there is, nevertheless, a great deal of similarity in the series of specimens at hand, and we believe that all the material here described belongs to the single species *Palaeolagus haydeni*. It is probable that several races or subspecies are represented, for much of the material lacks precise data of locality and formation. Some of the specimens from the Peabody Museum which we have used in this study have been labeled by Troxell as belonging to the subspecies *Palaeolagus haydeni agapetillus* and *P. h. intermedius*, though most of them are assigned to the typical subspecies. Since these three subspecies are separated by Troxell only on the basis of size, we have treated them together in considering the effects of age and wear on the characters of the teeth.

The figures of the teeth were made by Grace Eager. The enamel pattern of each tooth was drawn separately with a camera lucida from a point of view parallel to the length of the tooth.

The youngest teeth in the lower jaws which we have examined are the third and fourth deciduous molars. No trace so far has been found of either the first or the second deciduous lower molars.

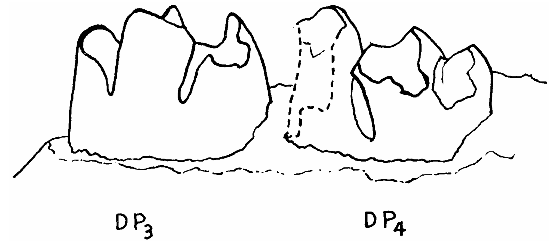
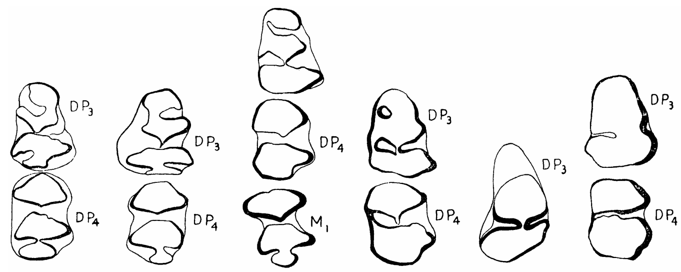


FIG. 7. *Palaeolagus haydeni*. DP_3 and DP_4 from inner side, X 12; anterior cusp of DP_4 somewhat broken. Peabody Museum. No. 13790

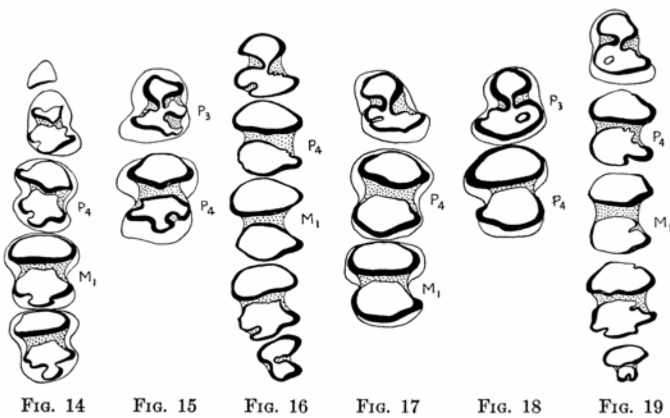


FIGS. 8-13. *Palaeolagus haydeni*. Enamel patterns of lower deciduous molars, X 6. Peabody Museum, Nos. 13791, 12075, 13793, 12071D, 13794, 13795

The most anterior milk tooth (DP_3), when first erupted, is made up of three principal transverse cusps, all of which rise into sharp crests (Fig. 7). Enamel surrounds all the cusps. On the inner surface of the posterior lobe there is a small reëntrant angle of enamel (Fig. 8). With wear the anterior cusp and the middle cusp become joined together near the middle of the tooth by a neck of enamel (Fig. 9). At about the same time, sometimes earlier and sometimes later, the posterior and middle cusps also become joined near the middle of the tooth (Fig. 10). With still further wear the posterior cusp and the middle cusp become joined by enamel on the inner surface of the tooth, and thereby cut off an island of enamel (Fig. 11). At this time the anterior cusp has almost entirely disappeared, being represented only by an enamel island toward the inner edge of the tooth, and by a shallow reëntrant angle on the outer edge of the tooth. A somewhat different angle of wear on DP_3 is shown in Figure 12 where the anterior cusp has entirely disappeared, and the posterior and middle cusps are joined in the middle of the tooth. In a slightly later stage of wear (Fig. 13) both reëntrant angles are much reduced, though enamel still completely surrounds the tooth. In very late stages of wear (Pl. XCIII, Figs. 1-2) DP_3 has entirely lost the internal reëntrant angle, but the external reëntrant angle still persists. In this very late stage of wear enamel occurs only on the outer border of the tooth and in the reëntrant angle.

The roots of the anterior deciduous molar (DP_4) penetrate deeply into the jaw, almost coming into contact with the root of the incisor. When the crown of this deciduous molar has disappeared the roots remain in place for a short time. The strong anterior root of DP_3 is directly in front of P_3 (Pl. XCIII, Figs. 3-4; text Fig. 14) and on casual inspection might be mistaken for a more anterior tooth. The posterior root of this milk tooth lies toward the outer side of the jaw between P_3 and P_4.

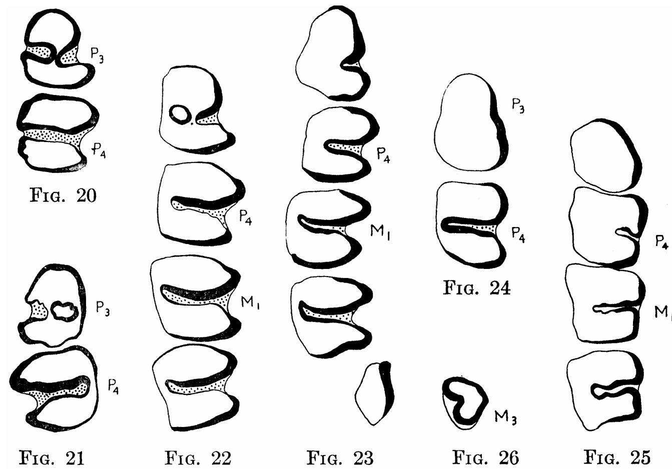
The fourth deciduous molar (DP_4) at its first appearance (Fig. 7) is made up of two principal transverse cusps, which rise into sharp crests. A strong posterior lobe is attached to the posterior cusp (Fig. 8). Enamel surrounds all the cusps. With wear the two main cusps become joined by enamel on their outer borders, and the tooth then has a rounded outline with an external reëntrant angle extending completely across (Fig. 11). At this stage the enamel of the two pillars comes into very close contact in the middle of the tooth and gives an appearance almost of fusion, but in none of the specimens which we have examined is there an enamel connection at this place. In a late state of wear (Pl. XCIII, Figs. 1-2) the large external reëntrant angle of DP_4 is much reduced and extends only about halfway across the tooth. In this stage of wear enamel is present only on the reëntrant angle and on the outer surface of the tooth.



FIGS. 14-19. *Palaeolagus haydeni*. Enamel patterns of lower cheek teeth, X 6

FIG. 14. Right P_3, P_4, M_1, M_2. U. S. N. M., No. 13558. In front of P_3 appears the broken anterior root of DP3
FIG. 15. Left P_3, P_4. U. S. N. M., No. 13559
FIG. 16. Right P_3, P_4, M_1, M_2, M_3. Type of *Protolagus affinus* Walker. Coll. of Geo. F. Sternberg, No. 26
FIG. 17. Right P_3, P_4, M_1. U. S. N. M., No. 13560
FIG. 18. Left P_3, P_4. U. S. N. M., No. 13561
FIG. 19. Right P_3, P_4, M_1, M_2, M_3. U. S. N. M., No. 13562

The two deciduous molars show a surprising correspondence in the details of their enamel patterns with the premolars which replace them. The enamel pattern on the face of P_3 during a mature stage of wear is characterized by strong internal and external reentrant angles which nearly meet in the middle of the tooth. Its milk tooth (DP_3) has a similar shape during one period of its wear. In its mature condition P_4 has a strong external reëntrant angle which extends completely across the tooth. Its milk molar (DP_4) has similar characters during a part of its wear, and the milk molar even has for a time the posterior lobe on the tooth which is so characteristic of the early stages of wear on P_4.



FIGS. 20-26. *Palaeolagus haydeni*. Enamel patterns of lower cheek teeth, X 6

FIG. 20. Right P_3, P_4. U. S. N. M., No. 13563
FIG. 21. Left P_3, P_4. U. S. N. M., No. 13564
FIG. 22. Right P_3, P_4, M_1, M_2. Peabody Museum, No. 13789
FIG. 23. Right P_3, P_4, M_1, M_2, M_3. Type of *Archaeolagus striatus* Walker. Coll. of Geo. F. Sternberg, No. 27
FIG. 24. Right P_3, P_4. Peabody Museum No. 13796
FIG. 25. Right P_3, P_4, M_1, M_2. Peabody Museum, No. 13797
FIG. 26. Left M_3. U. S. N. M., No. 13565

At the age when the two milk molars are still in place, though much worn, the first two true molars are already in position (Pl. XCIII, Figs. 1-2), but the third molar has not yet erupted. The fourth premolar erupts before the third, and may show considerable wear before the third deciduous molar is lost (Pl. XCIII, Fig. 3).

The third lower premolar, when it first erupts, consists primarily of two large transverse pillars, one anterior to the other and connected broadly in the middle of the tooth by cement (Fig. 14). When it is first erupted a line of enamel extends around each pillar and is thickest on the posterior border of the pillar. The anterior pillar at its tip is invaded from in front by a broad shallow valley (Pl. XCIII, Fig. 3), which does not descend much below the summit of the cusp, and which therefore disappears shortly after wear begins on the tooth. With only a small amount of wear the two pillars making up P_3 become connected in the middle of the tooth by an isthmus of enamel (Fig. 15).

A small reëntrant angle develops on the inner surface of the posterior pillar of P_3 soon after wear begins on the surface of the tooth (Fig. 14). This reëntrant angle enlarges with further wear (Fig. 15), but soon again diminishes (Fig. 16). The tooth at this stage has two internal reëntrant angles. At the next stage of wear (Fig. 17) the neck of the more posterior internal reëntrant angle has become constricted (Fig. 17), and the last stage of the angle is represented only by an island of enamel (Fig. 18), which soon disappears (Fig. 19). The whole process is passed through very early in the life of the tooth, and in all the later stages of wear on P_3 there is no trace on the posterior pillar of an internal reëntrant angle.

In some young specimens of P_3 there is a small indentation of the enamel on the posterior-exterior border of the posterior pillar (Pl. XCIII, Fig. 6), and this indentation, together with the internal reëntrant angle which is on the posterior pillar at this stage, produces a posterior lobe on the tooth similar to, but smaller than, the posterior lobes on P_4, M_1, and M_2 in their early stages of wear.

On one unusual specimen of P_3 a small lobe is attached to the anterior face of the anterior pillar (Pl. XCIII, Fig. 6). This lobe does not extend far down the tooth, and would disappear after a brief period of wear.

The general shape of P_3 during a considerable period of middle life is that of a compressed hourglass (Fig. 19). With further wear the neck of the main internal reëntrant angle begins to constrict (Fig. 20), and then closes off at the edge of the tooth, leaving an island of enamel (Figs. 21-22) to mark the former position of the reëntrant angle. With still more wear the island disappears and the external angle becomes reduced in depth (Fig. 23). In very old age all the reëntrant angles are gone and the tooth is roughly ovoid (Figs. 24-25).

On the older specimens of P_3 the enamel is much thicker than during the earlier stages of wear. On the other molariform teeth also there is a similar thickening of the enamel in old age. In the very oldest specimens of P_3 enamel is lacking on the inner surface, though it is still present as a thick plate on the outer surface.

The fourth premolar erupts before the third, and its face shows a small amount of wear at the time when the third deciduous molar is lost (Pl. XCIII, Figs. 2-3). At its first appearance P_4 is made up of two independent transverse pillars, one anterior to the other (Fig. 14). The two pillars are connected only by cement. There is a posterior lobe on the hinder edge of the posterior pillar and this lobe is set off mainly by two posterior reëntrant angles, the inner one of which is the deeper. With continued wear the posterior lobe becomes more prominent (Fig. 15), mainly by the deepening of the outer one of the two reëntrant angles setting it off. However, this posterior lobe exists during only a brief period of wear, for in the stage of wear represented by Figure 16 it has entirely disappeared.

Each of the two pillars making up the slightly worn P_4 is surrounded by enamel, which is quite thick along the posterior edges of the pillars. In older ages the enamel becomes thicker, but in the oldest (Figs. 22-24) it is lacking on the inner surface of the tooth.

The two pillars of P_4 maintain their distinctness over a long period of wear (Figs. 15-20). Finally they become joined by enamel on the inner border of the tooth (Fig. 21), and the tooth then has a somewhat rounded shape, with a deep external reëntrant angle. The external reëntrant angle, when first formed, extends completely across the tooth. With further wear it becomes shortened (Figs. 22-24), and in the oldest specimen which we have seen (Fig. 23) it extends only about one third of the way across the tooth.

The history of the first and the second true molars is very much like that of P_4. Both M_1 and M_2 are in position and are very slightly worn at the time of the eruption of P_4. At their first appearance each of these molars is made up of two transverse pillars, one anterior to the other and connected only by cement. When but slightly worn each of these teeth has a conspicuous posterior lobe (Pl. XCIII, Figs. 1-4). With wear the posterior lobes on these molars soon disappear (Figs. 16 and 19); the lobe on mi goes before the one on M_2. The two pillars forming each molar eventually become united by enamel, so that, as in P_4, the teeth come to have deep external reëntrant angles. With wear the depth of these reëntrant angles is reduced (Figs. 22-24). In the oldest specimen at hand (Fig. 25) the reëntrant angles of M_1 and M_2 extend only about halfway across the teeth. Throughout early and middle life enamel completely surrounds both mi and M_2, but in the oldest stages of wear enamel is lacking on the inner border of these teeth (Figs. 22-23, 25).

The third lower molar (M_3) erupts at about the same time as P3 (Pl. XCIII, Figs. 3-4), and at its first appearance it is made up of two pillars, one placed before the other in position, and each surrounded by enamel (Fig. 19). An exceptional specimen of M_3 (Pl. XCIII, Fig. 5) has a posterior lobe like that of the other molars. With wear the two pillars of M_3 become joined by a neck of enamel, so that there results a tooth (Fig. 16) with an external reëntrant angle of enamel extending nearly across and nearly meeting a small internal groove. At a later stage of wear M_3 is rounded and has a moderately deep external reëntrant angle (Fig. 26). At this age enamel still completely surrounds the tooth. In the oldest stages of wear M_3 consists of a single flattened plate with enamel only on its outer edge (Fig. 23).

The order in which the several teeth erupt is not exactly uniform in the different lower jaws which we have examined. Thus in Figure 19 a stage of slight wear on M_3 is associated with a more advanced stage of wear on the other teeth, whereas in Figure 16 an advanced stage of wear on M_3 is associated with a less advanced stage of wear on the other teeth.

The very considerable changes which have been described above as occurring in the characters of the teeth of *Palaeolagus haydeni*, during the growth of the animal, have misled paleontologists into describing a number of species, genera, and even subfamilies from specimens which we believe belong to this one species.

Cope[3] based his genus *Tricium* on the presence of the third posterior lobe on certain of the molars. *Tricium avunculus*, *T. leporinum*, and *T. annae* seem all to be synonyms of *Palaeolagus haydeni*.

Walker[4] based the subfamily Protolaginae on the presence of a second reëntrant angle on the inner face of P_3. We have been allowed by George F. Sternberg to examine the type of *Protolagus affinus* Walker, on which the subfamily Protolaginae is based; the enamel patterns of the lower teeth of the type are drawn in Figure 16. The minor internal reëntrant angle on P_3 of the type is only a temporary structure, for it extends but a short distance down the tooth beyond the present stage of wear. With a slight additional amount of wear this reëntrant angle would disappear, as was noted by Walker himself. All the other characters of the teeth mentioned by Walker are those of a young specimen of *Palaeolagus*, and the specimen fits exactly into the series of growth stages of *Palaeolagus haydeni*. Furthermore, the skull shows no characters which would distinguish it in any way from an excellent skull of *Palaeolagus haydeni* which one of us has previously described.[5] It seems necessary, therefore, to regard *Protolagus affinus* as a synonym of *Palaeolagus haydeni.*

The species *Archaeolagus striatus* Walker[6] is based on a very old specimen, as is shown by the greatly worn teeth of the type, which is illustrated in Figure 23. None of the characters of the teeth of this specimen distinguish it from very old specimens of *Palaeolagus haydeni*, nor do there seem to be any characters of the skull which are distinctive. *Archaeolagus striatus* must, therefore, also be placed as a synonym of *Palaeolagus haydeni*.

UNIVERSITY OF MICHIGAN

[1] Leidy, Joseph, "On the Extinct Mammalia of Dakota and Nebraska, Including an Account of Some Allied Forms from Other Localities," *Journ. Acad. Nat. Sci. Phila*., Ser. 2, 7: 331-334, Pl. 26, Figs. 17-20. 1869.

[2] Troxell, E. L., "Palæolagus, an Extinct Hare," *Am. Journ. Sci*., 1: 345-348. 1921.

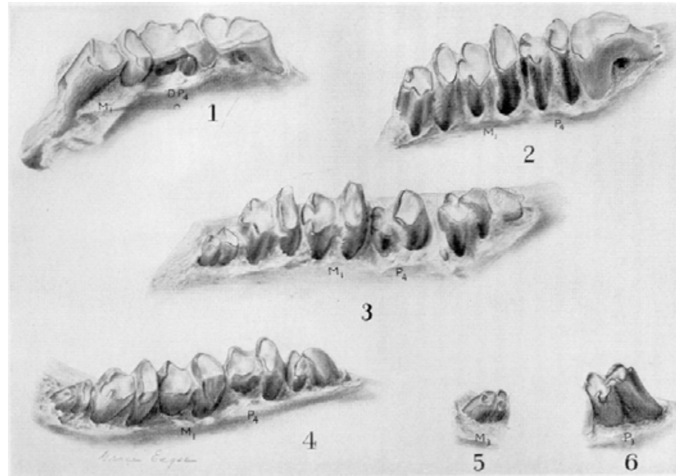
[3] Cope, E. D., "Third Notice of Extinct Vertebrata from the Tertiary of the Plains," *Palaeontol. Bull*., No. 16: 4-5. 1873.

[4] Walker, M. V., "Notes on North American Fossil Lagomorphs," *The Aerend, Kansas State Teachers Coll. Quart.* (Hays, Kansas), 2, No. 4: 238. 1931.

[5] Dice, L. R., "Some Characters of the Skull and Skeleton of the Fossil Hare, *Palaeolagus haydeni*" *Pap. Mich. Acad. Sci., Arts and Letters*, 18 (1932): 301-306. 1933.

[6] Walker, *op. cit*., p. 236.

PLATE XCIII



Lower cheek teeth of *Palaeolagus haydeni*, X 6. Peabody Museum, Nos. 13646, 13647, 13785, 13787, 13786, 13788

A STUDY OF THE BAYPORT CHERT

FRED DUSTIN

FOR twenty-five years I have collected the cultural remains of the people who once occupied our state of Michigan, and my home county, Saginaw, has yielded over three thousand arrow points, with hundreds of drills, perforators, scrapers, leaf-shaped blades, and knives. As the collection grew and interest increased, I observed that nearly all these artifacts were of a characteristic mineral in which the lines of growth or deposit were concentric. The gathering of perfect pieces led to the saving of "rejects," turtlebacks, flakes, and fragments of odd form or showing hollows and crystalline cores. From this it was but a step to the study of the material and to the wider field of its geological genesis and distribution.

Chert, which mineralogists generally define as an impure flint, is of widespread occurrence; where certain types of limestone are found it exists either in concretions or in veins, sometimes merging into agate, chalcedony, true flint, or other form of silica. It is usually gray, although occasionally black, becoming the basanite of the literature on gems, or, rarely, green, when it is called plasma. It may be red, blue, pink, white, yellow, or brown; sometimes it is mistaken for jasper, although its true conchoidal fracture distinguishes it from that mineral, which shows an uneven surface when broken and carries a considerable percentage of elements other than silica.

In a previous article[1] I have described certain materials used by the Indians in their lithic arts. This paper is a more particular description of the Bayport chert found in the limestone most prominently exposed near Bayport in Huron County and in Arenac County, or on islands in Saginaw Bay. In his geological paper on the Lower Peninsula, and on the map which accompanies it[2] Dr. Carl Rominger defines this rock as "carboniferous limestone." It lies beneath the coal measures, around which it forms an outward rim bounded by a line having near it Alabaster, West Branch, Reed City, Grand Rapids, Bellevue, Jackson, Holly, Otter Lake, and Caseville. A later map[3] based on increased information somewhat modifies the area as given by Rominger. Dr. R. A. Smith, the present state geologist, defines the formation as "the Upper Grand Rapids or Bay Port (Maxville)"[4] and gives a somewhat detailed account of its occurrence, which he summarizes as follows: "The Bayport limestone is the upper member of the Grand Rapids group of the Mississippian system. It underlies a belt around the central Coal Basin excepting in the southeast where it has been largely removed by erosion. The chief areas of exposure are in the vicinity of Bayport in Huron County, in Arenac County, and near Bellevue, Eaton County. In Jackson County the Bayport limestone forms a capping on many of the pre-Coal Measure hills."

In Arenac County there are several exposures of the Bayport limestone, beginning at Point Au Gres, where it forms a ledge along the shore rising to a height of seven or eight feet. From here the formation extends northwest along a low ridge, outcropping in eleven or twelve sections for a distance of eleven miles or more; it is sandy or cherty and contains many fossils. About halfway between the villages of Omer and Au Gres the new paved highway, M-23, crosses a quarry site with good exposures of the rock. In places the perpendicular face is from six to eight feet in height, thus giving a fair section. The opening south of the road is about two hundred by three hundred feet; the one north is smaller and not so deep. In some of the layers hundreds of chert nodules can be seen, many of fantastic forms; there also appear to be limestone concretions which have perhaps formed in the same manner that the chert has. The rock is much shattered, partly from frost, and many of the chert nodules are broken and seem also to have deteriorated by weathering. A visit to this place in the fall of 1933 gave me a good idea of the great supply of material for those artifacts which have been collected in the great Saginaw district and surrounding territory.

The more important outcrops in Huron County are found in the vicinity of Bayport, where it is exposed along the shore, on the islands west and northwest, and also at the Bayport quarries southeast, where the overlying soil is thin and where extensive operations have been conducted for nearly fifty years.

At Charity Island there is a large exposure. In Tuscola County two or three miles below the Grand Trunk Railroad bridge across the Cass River south of Cass City another outcrop appears which, though small, is of considerable interest. From these places the aborigines secured their supplies of chert on which this study is based.

In 1820 Henry R. Schoolcraft said in his *Narrative Journal*:[5] "In crossing the bay [Saginaw] we landed a few moments on Shawangunk [Charity] island which is found to be based on compact limestone, and contains embedded masses of Chalcedony and calcareous spar. I also picked up, during the short period we remained, a lump of the argillaceous oxyd of iron, and some detached fragments of a coarse striped jasper."

Winchell states[6] that this limestone formation is seen under the water a long distance southwest of Little Charity Island, and that it outcrops on its northern, western, and southern shores, "but more extensively on the north side of Great Charity Island, where it rises about five feet above the water."

Rominger[7] describes the several strata exposed on the larger of the two islands, which is now officially known as Charity Island. (The smaller one is now called Little Charity Island.) He notices the numerous flint (chert) nodules and names the most important fossils.

Lane,[8] who has reported at considerable length on the geological formations observed in Huron County, states that some of the limestone layers are filled with chert nodules and others with fossils, including corals and fish teeth. He also says that on the shore of Charity Island facing Little Charity "there are low paving-slab outcrops of brown brittle dolomite with cavities, and the surface is strewn with chalcedony and other geodes, which have evidently been left by solution of the limestone that enclosed them."

Harlan I. Smith,[9] the noted archaeologist, made many observations in the Bayport region. He says: "At the western limit of Wildfowl Bay is North Island, on the northern or highest part of which chert implements were found in all stages of manufacture, from the nodular masses occurring in the substratum of the entire island to the finished chipped points for spears, arrows, knives and similar objects. Here were also found chips, flakes and other discarded fragments of the same material, — the waste from the processes of manufacture, — indicating the site of an ancient workshop." He notes similar conditions on "Heisterman" or Stony Island.

Dr. R. A. Smith[10] reviews previous reports and summarizes the available information, including that of Professor W. M. Gregory, whose *Geological Report on Arenac County, Michigan* (1912),[11] with its accompanying maps, has been useful in the preparation of this paper. Dr. Smith also describes the Bayport quarry; he gives a vertical section showing its several beds.

Gregory's *Report* mentions several quarries in the limestone in Arenac County, with data on its appearances and commercial uses, whereas the sections given by Winchell, Rominger, Lane, and Smith have interesting details on the general character of the formation in the vicinity of Saginaw Bay, which are adequate for the purposes of the archaeologist.

Winchell states in regard to the chert near or at Bayport: "The flint nodules in layer D,[12] are bluish, of a fine, homogeneous structure and strike fire with steel, with great readiness. They exist in large quantity." Rominger and Lane repeatedly mention "numerous nodules of chert," and R. A. Smith adds some facts on the "cherty limestone" in his "Treatise."[13]

This study is based on selected specimens, on which serial numbers have been placed. They have been presented to the University of Michigan Museum, and may be of use to the archaeologist.

In July, 1924, I visited the Bayport quarry; from my notes taken that day, together with later information, I give a brief description.

The operations, in which was employed the best machinery for quarrying, transporting, and crushing the limestone, covered many acres of ground. Steam shovels removed the overburden of soil, which was not thick; pneumatic drills pierced the rock for charges of dynamite, which broke it up to be lifted by a steam shovel into cars in which it was transported by a locomotive to the crusher, by which it was broken up and assorted into commercial sizes.

My examination covered only a few hundred feet of the north face of the quarry, which was from ten to twelve feet high. The rock first exposed (marked 1 in the series) is a sandy limestone about three feet thick, at the bottom of which there are one or two layers of limestone two inches in thickness, filled with simple fossil corals, which look like sections of calamus root, most of them lying parallel with the bedding. The replacement mineral of these fossils has the appearance of calcite, and the broken sections stand out in marked contrast to the yellow-gray matrix. A more careful examination indicates that many of these corals are silicified, and when subjected to the hardness test and examined with a pocket lens are seen to be almost pure chalcedony. Immediately below this fossiliferous layer is the cherty limestone containing thousands of chert nodules, or, as the quarrymen call them, "stones," some very compact with a glimmering luster when broken, others porous and of less purity. Many are embedded in the broken rock; fair samples are the specimens 3-A and also 3-B, which is a small nodule in its limestone matrix. Specimen 3 shows masses of brown rhombohedral crystals which I supposed to be calcite, but which later proved to be that form of magnesite called brown spar. Calcite crystals do occur, however, and there seem to be variations in the crystalline secondary deposits, much silica in one locality and magnesia and iron in others, with occasional pockets of pyrite, zinc blende, or pure calcite crystals. At the Bayport quarry there seems to be much brown spar, together with small masses of lean iron ore, probably limonite.

At the base of the cherty limestone formation and resting on the shale beneath, a layer of very fine grained compressed limestone is seen which, when first exposed to the air, is of a warm gray color showing a decided umber tinge. It breaks with a subconchoidal fracture; as it weathers, it grows lighter in color until it has the appearance of chert even under the lens. Since this is a valuable building stone, it is unfortunate that this layer is only ten or twelve inches thick. For this reason it is not saved for building purposes unless there is a special order for it. Specimens 4 are of this rock.

The gritty shale under the compressed limestone, specimen 5, is a rather bright green, but that color does not seem to penetrate it more than a quarter of an inch; it may be due to iron, for throughout the limestone proper there are iron stains and ochery patches of mineral.

The chert nodules seen were not large. A great percentage of them were four inches or less in diameter; those of six inches and upward were very rare, and a quarryman of eight years' experience stated that eight inches was the limit. As a rule, most of the concretions from the Bayport quarry are globular, while those at the Arenac quarry are frequently of eccentric shapes, resembling a pear, a heart, an hourglass, or other curious figures; some nearly round ones, collected on village sites, have been so deceptive in appearance as to be mistaken for tennis balls; larger ones have been called cannon balls by persons who have been deceived by their regular spherical outlines.

I collected from Saginaw County village sites two hemispheres, one eight and one-half inches in diameter, the other eight, both very compact in texture. A third, measuring six inches across, had six large flakes struck off, which, with the remaining unbroken piece, constituted two thirds of the original nodule; the seven portions were lying together where they had been buried in the earth on a village site, where flood waters brought them to light.

My collection of nodules from prehistoric sites numbers twenty-five unbroken specimens, with an equal number slightly or considerably flaked.

As to their formation, there seem to have been two processes of growth. In the first there was a gradual filling of a cavity in the limestone by the deposit of silica on the lining, with the nodule generally becoming purer toward the center; not infrequently it has a core of translucent chalcedony or a small mass of transparent quartz crystals, but sometimes it leaves a hollow or vug, as though the siliceous solution had been exhausted. In the second it would seem that the deposit began around some nucleus, organic or inorganic, and that a simultaneous process of dissolving out the limestone and formation of the nodule occurred, both growing together, with the cavity and its counterpart having the same form. Occasionally fossil casts are found in the chert, also real fossils, such as coral of several varieties, especially the simple forms.

The chert in the vicinity of Bayport is the type of mineral from which at least ninety per cent of the arrow points, drills, perforators, scrapers, and cutting blades collected in the Lower Peninsula were made. The color, texture, and concentric lines of formation, with certain other "earmarks" known to the close observer, indicate plainly their origin. There are variations from this type due to local conditions such as the presence of limonite in small quantities. Years ago I discovered a cache of leaf-shaped blades with distinct markings of an ocher shade. Later I found on a sand knoll swept bare by high winds a pile of flakes and chips, together with a hammer-stone that had evidently been used to strike off the flakes from nodules. This waste material was from the chert of which the blades in the cache had been made, the yellow stains, texture and lines of formation being identical.

Occasionally an artifact is collected of ashy black or of a dull bluish cast, but none originating from the Bayport limestone have been observed that were either a true black or a deep blue, although a number of both types in my collection were secured locally. Like the copper knives and beads from Isle Royale and the Upper Peninsula, the catlinite pipes from Minnesota, or the little cowry shells from the Florida coast, they are the fruits of travel or exchange, and are probably from Ohio or farther south.

Rarely a fine nodule, artifact, or flake will be found in which the ground mass is a pleasing gray, with almost pure white concentric layers alternating, thus giving a true agate somewhat like the gray Brazilian agates which the German lapidaries dye and polish and palm off on the unwary as naturally colored.

At a point on the Cass River near the line between Frankenmuth and Bridgeport townships, at the lower end of a high, steep bank, the aborigines had a canoe landing. In the bed of the river at this place I have collected at low water a pipe, a celt, a partly flaked nodule, and three or four of these gray agates; some distance back on the high ground of a village site two or three others were found which had been chipped. Aside from its archaeological interest, one is a most beautiful mineral specimen; its delicate and intricate lines seem more like the handiwork of an artist than a work of nature. I have presumed that these agates gathered from the river bed with the artifacts were lost in an accident, such as the overturning of a canoe or other casualty, and my good fortune in finding them was perhaps the ending of a story in which comedy or tragedy might have had a part.

Chalcedony geodes from Charity Island have been mentioned and nodules of that material are not infrequent although, so far as noticed, they are not large; they furnish material for the smaller sizes of artifacts. A few show delicate lines of formation, and are true agates, often with gray or white centers somewhat opaque. Silicified fossils have been found on the Charity islands: one, a bivalve with valves closed, seems to have been agatized; another, a small mass of cup corals, with the remains of other creatures, has an outer coloring of dark red, and shows drusy cavities in which the tiny crystals are also colored.

At Point Lookout (Gravelly Point on the older maps) concretions of this nature are picked up; perhaps they had their origin in the reefs of the Charities, from which they were conveyed by ice or other natural agencies. On the other hand, this point was the landing place for canoes crossing the bay from the eastward, and prehistoric remains are plentiful in the near vicinity, so some of the nodules and other products of the limestone may have been brought by human beings.

Concerning the outcrop on Cass River, Dr. Rominger makes the following statement:[14] "Another locality where these lower beds of the carboniferous limestone series can be observed is on Cass River, 30 miles south of Caseville, in Town. 13, R. 11, Sect. 16 ["16" is probably a misprint; it should be 6]. At the farm-house of Mr. W. H. Brown, situated close by the river bed, the water flows in rapids over the oblique edges of rock beds dipping at a moderate angle down stream. Here we find a coarse-grained whitish sand rock. . . . Only a few steps below Mr. Brown's house, the sand-rock ledges are overlapped by a bluish argillaceous limestone of a dull, earthy fracture and moderately soft. It was from this rock that the Indians used to carve their smoking-pipes. It contains numerous nodular concretions of Zincblende, or Druse cavities filled with this mineral, or with Brownspar or Dolomitspar. The Zincblende is mistaken by the inhabitants for Galena, and the same mistake occurs on the old maps of surveyors, lead ore being indicated as occurring in the vicinity of Cass River." He further speaks of several beds of limestone above this, and says: "A hard, calcareous bed with flint concretions overlies them."

Many years ago I collected a large piece of chert approaching chalcedony in purity: it had a peculiar metallic appearance and was yellow-brown. Later it was shown to a mining engineer who pronounced it "sphalerite or zincblende with chert" and, on testing it for streak, obtained the characteristic brown powder of that mineral. Since that time a few other pieces have been collected, so that it is probable that these blende-impregnated flakes came from the deposit studied by Rominger.

As for the galena, it is not impossible that it occurs sparsely with the blende, as it does in some of the Mississippi River localities. I have a small lump of this lead ore, also one of the blende, found not far apart near the bank of the Cass River at the same village site where the gray agates were collected. They show the crystallization and the streak peculiar to those minerals, and in each the masses of crystals of the metallic ores are intermixed with other substances very similar to one another, perhaps indicating that they originated in the same rock formation, so that it is possible that a grain of truth may be buried in the lead legend of the Cass, which has been variously related and fantastically embellished. Late in 1933 there appeared an article in a Saginaw paper[15] that reported "gold, zinc, lead and copper" as well as graphite to have been discovered by two local citizens of the "lead" neighborhood, one of whom was said to have smelted fifty pounds of rock and to have obtained "six pounds of a mixture of zinc, copper and lead, the zinc predominating." It is quite possible that the "gold" is pyrite and the copper (if any) a drift specimen or an oxidized artifact of prehistoric times. A little knowledge of the genesis of graphite might be of use in determining the identity of a supposed deposit of that mineral.

Another type of chert is that which is strongly colored by an iron oxide. A short distance west of the town cemetery in James Township, Saginaw County, there is an area of two or three acres strewn with flakes, chip's, rejects, and occasional arrow points or other artifacts, nearly all of a yellow-brown color, some darker than others, but all from the same lot of nodules. It would seem that a canoe load of the raw material had been landed there and worked up into the finished weapons and implements. This area, together with many acres around it, has been a prolific collecting ground, and the sandy soil is dotted with the fragments and refuse of manufacture but, with the exception of the brown chert mentioned, nearly all are of the common gray mineral. The outer surface of the brown nodules is in no way different in color from that of the gray nodules, whereas the contrast of the interiors is striking.

At the junction of the Tittabawrassee and Shiawassee rivers there is a low flood plain that is occasionally covered by the high waters of spring. This tract has been a fine collecting ground for local archaeologists, and of hundreds of chert artifacts secured a large portion are marked with dendrites from iron or manganese, the mossy figures being much the same as those of the moss agates from Wyoming. If the material were a translucent chalcedony instead of an opaque chert the resulting gem would be a fine one. These dendritic markings must have been acquired from repeated soakings of river water carrying iron or manganese, or from the wet soil itself.

Some archaeologists have stressed the existence of "workshops"; that such existed there can be no doubt, but every village site of more or less permanent residence that I have seen was a workshop where arrow points and all other articles of chert were made. We can picture the Indian of the Saginaw country making a trip in his canoe to Au Gres, to Charity Island, to Bayport, or to the reefs of the Cass, gathering his cargo of nodules with perhaps some curious fossils and beautiful crystals or such shining minerals as pyrite or blood-red jasper; then in his little bark returning to the home wigwam where the rivers meet.

Here he buries the rounded stones of flint, for he well knows that moisture facilitates their working, and later, in his leisure hours, he digs out a few and with his hammerstone strikes off flakes of suitable size. If time permits, he chips them into leaf-shaped blades and again buries them until necessity requires; when they are again unearthed, the chipping tool comes into play, and arrow point, drill, or blade is fashioned with speed and skill.

Perhaps disaster overtakes our red worker or death comes, and his hoard of blades is forgotten. Many generations come and go and a new race possesses the land. Some of these newcomers are sneering; some are indifferent; some mildly curious, but finally one comes whose visions of the past are tinged with reverence for those who have gone before. From time to time his feet tread upon their ashes, and he gathers from their long-deserted haunts the pipe and the stone hatchet, symbolizing their peace and their war. On the edge of that sand knoll which the wind has bared he sees a little pile of chipped blades and soon uncovers the cache so long hidden. He has come to the end of the story.

SAGINAW, MICHIGAN

[1] Dustin, Fred, "Materials of the Indian Lapidary in the Saginaw District, Michigan," *Pap. Mich. Acad. Sci., Arts and Letters*, 8 (1927): 11-22. 1928.

[2] Rominger, C., *Geology of Lower Peninsula* (1876), *Geol. Surv. Mich*., 3, Part I, 102, and map in pocket.

[3] Leverett, Frank, and Taylor, Frank B., *The Pleistocene of Indiana and Michigan and the History of the Great Lakes, U. S. Geol. Surv., Mon. 53* (1915).

[4] Smith, R. A., *Mineral Resources of Michigan . . . for 1915 and Prior Years. With a Treatise on Limestone Resources* (1916), Publ. 21, Geol. Ser. 17, pp. 162-185.

[5] *Narrative Journal of Travels through the Northwestern Region of the United States; extending through the Great Chain of American Lakes to the Sources of the Mississippi River. . . . In the Year 1820* (1821), p. 99.

[6] Winchell, A., *First Biennial Report of the Progress of the Geological Survey of Michigan, . . . Lower Peninsula* (1861), p. 101.

[7] See page 119 of work cited in note 2.

[8] Lane, Alfred C., *Geological Report on Huron County, Michigan* (1900), *Geol Surv. Mich*., 7, Part II, pp. 105-112.

[9] Smith, Harlan I., *The Saginaw Valley Collection*, Suppl. to *Am. Mus. Journ*., Vol. 7 (1901), No. 12.

[10] See page 226 of work cited in note 4.

[11] *Mich. Geol. and Biol. Surv*., Publ. 11, Geol. Ser. 8, pp. 47-58.

[12] See pages 101 and 102 of work cited in note 6.

[13] Cited in note 4.

[14] See page 104 of work cited in note 2.

[15] *Saginaw Daily News*, Wednesday, November 22, 1933.

A STUDY OF UNDERGROUND WATERS BEARING ON THE SOURCE OF "BIG SPRING," SCHOOLCRAFT COUNTY, MICHIGAN

O. FLOYD POINDEXTER

"BIG SPRING" is located in Schoolcraft County, Michigan, on the west side of Indian Lake about eight miles in a northwesterly direction from the city of Manistique. It is reached by means of a good gravel road (M-149) intersecting U.S.-2 at a point approximately eight miles west of Manistique and running north and east for about four and one-half miles to the site of the spring. In 1929 the Palms Book Land Company of Detroit deeded to the state the 40 acres upon which the spring is located, together with an adjoining lot comprising 49.40 acres. The indenture provides that this grant is "to be forever used only as a public park bearing the name Palms Book State Park." Additional descriptions adjacent to this gift, deeded to the state through tax delinquency, amount to 327.40 acres, bringing the total acreage of state-owned land surrounding the spring to 417.30 acres, with a frontage of 3,000 feet on Indian Lake.

Big Spring (see Pl. XCIV) is a roughly oval pool, the surface dimensions of which are stated to be 300 by 175 feet. The sides of the depression slope abruptly to a depth of 40 feet, where the water enters under strong hydrostatic pressure, roiling the sandy bottom so much that a pronounced boiling effect plainly visible from the surface is obtained. The spring has a scenic location at the edge of a coniferous swamp, with the verdant growth adding much to the charm and beauty of the surroundings. The water is of an unusual emerald green, due probably to the luxuriant growth of aquatic vegetation clothing the sides of the pool and draping the submerged trunks of fallen trees.

According to legend, the Indians named the spring Kitchitikipi, in memory of the young chieftain of that name who went to his death in the icy waters in an attempt to satisfy the vain caprice of his ladylove, who insisted as a test of devotion that he catch her as she jumped into the canoe from an overhanging bough. Indian lore naturally held the "great spring" to be a manifestation of the power of "Gitchi-Manitou," the "Great Spirit," who caused the crystal waters to well up from unknown depths.

Old residents tell one that the source of Big Spring is Lake Superior, but, since the spring lies at a higher elevation than the great lake to the north, this theory is obviously not in accord with natural observed phenomena, nor is it necessary to assume such a vast reservoir as Lake Superior in a search for the ultimate source of this scenic wonder. The great swamp of the Manistique River (Seney Swamp) and the numerous lakes in the Hiawatha National Forest region furnish to the underground drainage sufficient quantities of water under ample hydrostatic pressure to form any number of springs similar in character to Big Spring. Many lakes in northwestern Schoolcraft County and in adjoining parts of Alger and Delta counties have no surface outlet, but contribute their surpluses to the subsurface flow.

In the fall of 1932 a water well was drilled in the Palms-Book State Park about one hundred feet northwest of the spring. This well was put down because of an unsatisfactory test of the water of the spring for drinking purposes. Later it was found that the spring had been sampled at the edge, where it was exposed to contamination. Subsequent tests taken from the center of the pool proved that pure drinking water could have been obtained by piping from the deeper parts.

The driller's log and samples furnished by Richard Kiney, well contractor, imparted valuable information regarding the character of the formations penetrated by the drill. From the surface to a depth of 29 feet soft clay was encountered; below this 8 feet of hard-pan consisting of a mixture of gravel, sand, and clay was reported, followed by 10½ feet of quicksand and hardpan, with fine sand and gravel at a depth of 55 feet 8 inches. At this depth the water enters very freely and rises to a height of 48 feet in the pipe. When examination of the well samples and leg showed the water in the well to come from a bed of sand and gravel at a depth of 55 feet 8 inches, it was considered probable that the water forming the spring is derived from the glacial drift and that it comes down under the thick lake clays known to underlie the Seney Swamp. The record of the well, which gives 29 feet of clay at the surface, would lend support to such a theory.

PLATE XCIV

View of the "Big Spring," Palms Book State Park, near Manistique, Michigan. (Photograph by Department of Conservation, State of Michigan)

The depth at which water was encountered in the well and the amount of head present suggest that the well taps the same stream of water that forms the spring. Chemical analyses of samples from both the well and the spring confirm this suggestion, since the characteristic feature of both samples is the presence of relatively large amounts of calcium sulphate. The sample from the well contained 1,180 parts per million of SO_4, and the sample from the spring showed a sulphate content of 532 parts per million. This large discrepancy in amount of sulphate was at first puzzling, since waters obtained from the same source at so close an interval should be very nearly similar. This difference is, however, logically explained by the fact that the spring sample was obtained near the edge of the pool, where the normal waters arising from the bottom are diluted by the soft water draining into the spring from the surrounding swamp. Mr. John Hepler of the Michigan Department of Health suggests that there may be stratification of water in the pool, owing to variation in specific gravity.

Results of analyses of water from the spring and from the well at the pavilion are even more striking when compared with those of waters from other sources. Sixteen samples collected by S. G. Bergquist, from Michigan State College, from as many different lakes, streams, and rivers in various parts of Schoolcraft County, indicate a maximum sulphate concentration 56.8 parts per million at the south end of Indian Lake, but the average sulphate content of these samples was only 17.8 parts per million (Table I). Similarly, nine samples from wells drawing their water from the glacial drift gave a maximum 864 content of 54 parts per million and an average of 15.5 parts per million (Table II). Shallow waters in the Niagaran limestones were not greatly dissimilar; seven samples had an average SO_4 content of only 8.3 parts per million (Table II, Anal. 11-17).

In the city of Manistique there are many flowing wells which form the original water supply of the city, the depths of which indicate that the water probably comes from the lower part of the Niagaran Series. The sulphate content of these wells, varies from 425 to 480 parts per million (Table II, Anal. 18-20). One deep well at Whitedale showed 870 parts per million (Table II, Anal. 21).

TABLE I

ANALYSES OF RIVER, LAKE, AND SPRING WATERS IN SCHOOLCRAFT COUNTY *

(Samples collected by S. G. Bergquist)

Source of sample	SiO_2	Fe_2O_3	Ca	Mg	Na+K	Cl	SO_4	HCO_3	Total solids	Hardness as $CaCO_3$
Big Spring	17.6	...	230.5	21.0	3.4	6.5	532.0	130.0	878	700
Driggs Lake	2.4	0.23	24.0	5.6	Tr.	4.0	4.9	89.5	88	80
Driggs River	5.6	0.74	19.5	5.0	5.0	4.0	4.9	85.0	82	70
Fox River, West Branch at Seney	6.4	1.02	16.5	4.5	4.3	4.0	7.2	72.0	78	60
Gulliver Lake	8.8	...	30.0	13.8	3.2	4.0	10.5	149.5	154	130
Indian Lake, South End	15.2	Tr.	47.0	10.0	2.3	3.0	56.8	122.0	214	168
Indian River at M–94	8.8	Tr.	45.0	9.3	4.1	3.5	56.0	118.0	188	150
Indian River, Sec. 34, T. 44 N., R. 17 W.	12.8	...	27.0	7.1	5.7	4.0	6.5	113.5	124	95
Intake Park	7.2	0.31	41.0	8.2	Tr.	4.0	43.2	107.0	162	135
Lake Michigan	5.6	...	33.5	11.2	8.0	5.0	15.1	135.0	154	130
Manistique River Sec. 24, T. 45 N., R. 13 W.	8.0	0.34	28.0	6.6	8.9	4.0	25.0	93.5	134	100
McDonald Lake	4.8	0.23	29.0	11.9	Tr.	4.0	15.8	123.0	132	120
Murphy River	7.2	...	27.0	8.2	2.7	3.0	14.8	107.5	116	100
Ross Lake	4.0	0.45	18.5	5.2	Tr.	4.0	4.0	72.5	76	68
Smith Lake	4.0	0.34	5.0	1.5	4.3	4.0	6.5	20.0	36	18
Thompson Spring	6.4	...	21.5	13.8	9.6	4.0	5.9	125.5	133	110
Thunder Lake	4.0	...	21.5	7.3	7.6	4.0	8.8	99.0	106	82

* Analyses by Miss Alice Exworthy, Michigan Department of Health.

TABLE II

ANALYSES OF WELL WATERS FROM SCHOOLCRAFT COUNTY *

(Parts per million)

Analysis	SiO_2	Fe_2O_3	Ca	Mg	Na+K	Cl	SO_4	HCO_3	Total solids	Hardness as $CaCO_3$
Drift waters										
1	3.2	....	31.5	8.8	Tr.	4.0	21.0	108.5	128	112
2	29.6	19.4	32.5	7.5	12.2	3.0	4.9	157.0	186	110
3	12.0	1.3	64.0	15.7	16.9	20.0	54.0	215.0	304	220
4	2.4	Tr.	4.5	2.2	Tr.	4.0	8.9	5.5	28	25
5	9.6	0.34	15.5	7.2	31.7	11.0	1.3	113.5	156	68
6	4.8	....	52.5	16.8	Tr.	4.0	12.8	224.5	204	200
7	4.8	0.34	16.0	11.2	3.0	20.5	25.7	14.5	270	98
8	7.2	Tr.	14.0	10.5	25.3	5.0	3.6	148.5	142	78
9	4.8	0.63	21.5	8.4	Tr.	3.5	7.5	95.0	98	90
10	15.2	1.83	366.0	100.0	14.0	11.0	1180.0	134.0	1752	1300
Limestone waters										
11	4.0	0.74	54.0	30.0	Tr.	4.0	9.9	293.0	268	258
12	5.6	Tr.	45.5	21.2	2.9	5.0	5.2	234.5	184	200
13	7.2	0.63	42.5	21.6	Tr.	4.0	9.9	219.0	194	195
14	8.0	0.51	45.5	22.0	1.4	3.5	6.6	239.0	208	204
15	6.4	....	40.0	20.0	9.2	3.0	4.6	235.0	194	182
16	7.2	....	43.0	20.4	3.9	3.0	5.3	232.0	198	190
17	5.6	0.34	45.5	19.9	9.6	10.0	17.0	204.5	232	195
18	11.2	1.2	173.0	62.0	46.8	100.0	425.6	249.0	960	680
19	6.4	....	126.5	54.8	20.2	6.0	440.0	144.5	726	540
20	8.8	0.17	170.5	59.6	43.8	75.0	480.0	192.0	928	668
21	9.6	Tr.	340.0	44.8	Tr.	5.0	870.0	157.0	1346	1050
22	8.8	0.51	560.5	43.2	5.5	16.5	1368.0	172.5	2160	1580

* Analyses by Miss Alice Exworthy, Michigan Department of Health.

A well 117 feet deep in Blaney Park encountered the following materials: sand, 15 feet; hardpan, 35 feet; clay, 10 feet; limestone, 20 feet; "black rock," 10 feet; and blue shale, 25 feet.

Analysis of this water indicates a sulphate content of 1,368 parts per million (Table II, Anal. 22), and the water is said to come from the shale. Since the Niagaran of the Upper Peninsula is entirely devoid of even thin shale beds, it is probable that the shale corresponds to that logged as Cataract in the record of the well drilled for oil at Seul Choix Point. The drill cuttings at this depth are shale and shaly dolomite, which contain abundant calcium sulphate in the form of brownish anhydrite. It is not impossible, however, that the shale in the well at Blaney marks the top of the Ordovician, which, as shown by the samples of the Seul Choix well, contain even more abundant reddish gypsum and anhydrite.

The marked difference in mineral composition of the samples obtained from the Big Spring and the adjacent well and of those obtained from surface waters, drift wells, and shallow rock wells, as opposed to the similarity of the State Park waters to those of the deeper formations, suggests that Big Spring may have its source of supply at or very near the base of the Niagaran, if not in Cataract or Ordovician strata. The Lower Niagaran strata could, possibly, obtain a sulphate content through waters circulating at the base of the series in contact with Cataract strata. No gypsum or other sulphates are present in the Niagaran section from the well at Seul Choix, nor can any be observed in a set of samples from one of the old water wells at Manistique.

An argument against the Lower Niagaran rocks as a source of supply for Big Spring is the fact that no flowing wells are found in Niagaran strata outside the area covered by the outcrop of the Manistique formation, although numerous flows in this belt extend across Schoolcraft County from Hunt Spur in Mackinac County to the village of Thompson.

It appears that the dense, platy, and cherty dolomites of the Manistique formation may act as the confining cap rock for the Lower Niagaran aquifer, and, furthermore, it is probable that there is a loss of head in passing northward toward the Niagaran escarpment, since the surface elevation increases about one hundred feet and the lower beds of the Niagaran are truncated by the great preglacial valley to the north, probably at a considerably lower elevation. On the other hand, the Cataract and Cincinnatian rocks forming belts to the northward and underlying a continually rising surface undoubtedly have the requisite artesian conditions, as is proved by the well at Blaney.

Aërial photographs show a cluster of six or more sharply defined depressions about one mile south of Big Spring. These have not been visited on the ground, but their appearance under the stereoscope is very similar to that of many of the sink holes of Presque Isle County.

It is probable that the glacial drift at Big Spring is not much thicker than the 55 feet 8 inches penetrated by the well. A well drilled on the shore of Indian Lake about three and one-half miles southeast of the spring found bedrock at 70 feet, and a well about two and one-half miles southwest encountered rock at 20 feet. Scott[1] reports an outcrop of limestone about one mile north of the south end of Indian Lake, but at Parker's resort at the south end of the lake it is 103 feet to rock.

It has been suggested by several geologists that the spring was formed as a result of a cave or fault in the underlying limestone formations. In view of the fact that there are no pure limestones in the lower part of the Niagaran or in the formations below the Niagaran, it is possible that cave-ins may have resulted from the solution of beds of gypsum in Cataract and Cincinnatian strata. Slumping of the overlying strata would then form an avenue of easy and rapid passage of the calcium sulphate waters rising under hydrostatic pressure, with the shales at the top of the Cataract formation constituting the cap rock to complete the requisite artesian conditions.

MICHIGAN GEOLOGICAL
SURVEY LANSING, MICHIGAN

[1] Scott, I. D., *Inland Lakes of Michigan, Mich. Geol. and Biol. Surv*., Publ. 30, p. 281.

GEOLOGY OF THE HART OIL FIELD

C. HAROLD RIGGS

THE Hart Oil Field is a small producing area near the center of Oceana County about thirty miles north of Muskegon, Michigan. Though the field is not of great commercial importance, some of its features are of geological interest. Oil occurs in dolomitic cavities near the top of the Traverse limestone. Accumulation is due primarily to differences of perviousness in the reservoir rock and, to a lesser extent, to small structures.

HISTORY AND DEVELOPMENT

The first well was drilled in August, 1932, by Edward DuVall on the Oscar Weirich property in the NE. ¼ of SE. ¼ of Section 31, T. 15 N., R. 16 W. Oil was encountered in the top of the Traverse limestone at approximately 1,900 feet. The oil filled up rapidly in the hole and flowed into tanks under considerable pressure. When shut in, the well showed a pressure of 50 pounds to the square inch at the casing head.

During the next few days the well flowed by heads, making from 40 to 80 barrels of oil at each flow. The Napth-Sol Refining Company of Muskegon agreed to purchase the oil. A total of 329 barrels was produced before the well was shut down because of legal difficulties over the title of the property.

Excitement over a new oil discovery ran high in Hart and Muskegon, and leasing costs were more than later developments warranted. However, the next two wells drilled northwest and southeast of the Weirich well encountered water and no oil in the Traverse limestone. The first of these wells, the A. S. Cochran Hannum No. 1, was drilled to the "Dundee," where water was encountered at 2,407 feet and the well was abandoned.

In March, 1933, Flanigan and Voorhees started a well on the E. Mitchell property in the SE. ¼ of SE. ¼ of Section 36, T. 15 N., R. 17 W., one mile west of the discovery well. "Pay sands" were encountered in the Traverse limestone from 1,904 to 1,907 feet, and oil filled up 1,500 feet in the hole. The well was treated with Dowell acid and produced approximately 25 barrels of oil daily. A second acid treatment failed to increase production (Fig. 28).

Meanwhile the Oscar Weirich well had been reopened. It was found that there was 1,100 feet of salt water in the bottom of the hole, with heavy viscous oil on top. When this water was bailed down to 800 feet the well made a small flow of oil. After each flow the water would fill up in the bottom of the hole and the well could be made to flow only by keeping the water bailed down. The well was put to pumping soon afterward. It has since made a little oil and much water.

In July, 1933, the E. Mitchell well was treated with acid for the third time. When reopened it flowed and soon filled all available storage. A week later, when more tanks had been installed, it produced 711 barrels of oil on a 24-hour test. Development has proceeded rapidly since then and at the present time (March 1, 1934) there are 14 producing wells, 8 dry holes, and 5 uncompleted wells in the general area.

STRATIGRAPHY

The surface formations at the Hart Field are glacial moraine and outwash plain. The moraine tends northwest to southeast through the western part of the field. Surface elevations vary from 860 feet above sea level on top of the moraine to 710 feet on the comparatively flat outwash plain. The glacial drift is from 400 to 500 feet thick and consists of alternating layers of clay, sand, and gravel. The wells drilled around the base of the moraine encounter artesian water in the top of the second sand layer. Evidently this sand layer has a connection with surface waters to provide a head somewhere in the moraine. Clay underlying the sandy outwash plain forms a seal above the water-bearing horizon.

The field lies almost wholly within the belt of Marshall outcrop, but close to the contact with the Grand Rapids series to the southeast. One well drilled in the southeastern part of the area encountered eight feet of shale and gypsum, presumably of the Grand Rapids series. The Napoleon sandstone in this well is thinner than in other wells to the west, and the occurrence of the Grand Rapids series here may be due to its deposition in a channel of erosion in the top of the Upper Marshall formation.

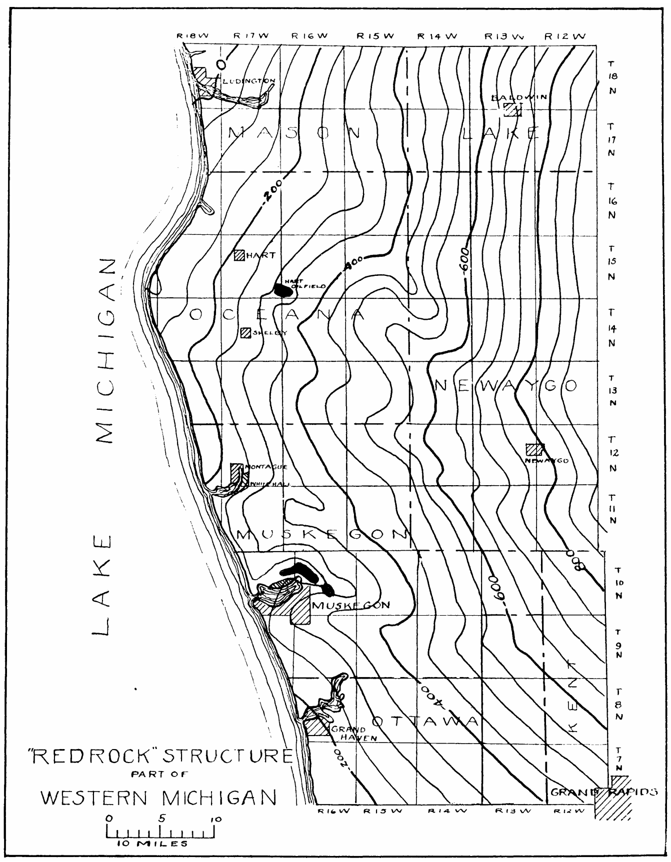
The Napoleon sandstone is composed of medium to fine light gray sandstone, with an occasional bed of gray shale. Thickness varies from 50 to 85 feet, increasing to the southeast in the direction of regional dip. The sandstone is abnormally thick in the southwestern corner of the area, where hills probably stood out in the preglacial land surface.

The Lower Marshall formation is composed of fine dark red sandstone and sandy shale. The absence of some of the lower beds in the western part of the area suggests an overlap with deposition on an irregular land surface. Thickness varies from 40 to 70 feet.

The Coldwater formation consists of light gray shales and argillaceous limestones. About 250 feet below the top of the formation is a calcareous zone with beds of argillaceous limestone grading laterally and vertically into shale. Locally these limestones are dolomitic or contain gypsum. From 500 to 550 feet below the top of the formation there is another calcareous zone. The top of this zone is marked by a thin bed of red calcareous shale called "Red Rock." Below the top bed occur several layers of reddish limestone.

The shales below these limestones have been termed "Ellsworth."[1] They do not differ much from those above, but grade downward into shale of a more greenish cast. There have been sandstone layers encountered in different wells throughout the area. Locally these sandstones are called "Berea," although they are evidently sandstone lenses in the shale and may represent reworked Berea material. The interval between these sandstone layers and known horizons varies greatly, and it is probable that they are not the same bed, but occupy different stratigraphic positions. A dolomitic sandstone from the southeastern part of the field is very dense and fine grained and contains small quantities of oil.

Interpretation of well logs may indicate an erosional unconformity separating the Antrim from the overlying dark shales. It is possible that irregularities in thickness may be due to lateral gradation at the base of the Ellsworth. The upper part of the Antrim is soft, light brown shale; the lower part is dark brown to black and is more calcareous. The base of the Antrim is marked by a slight unconformity. Pyrite concretions near the base of the Antrim may have been a residual deposit from weathering of Traverse shales.

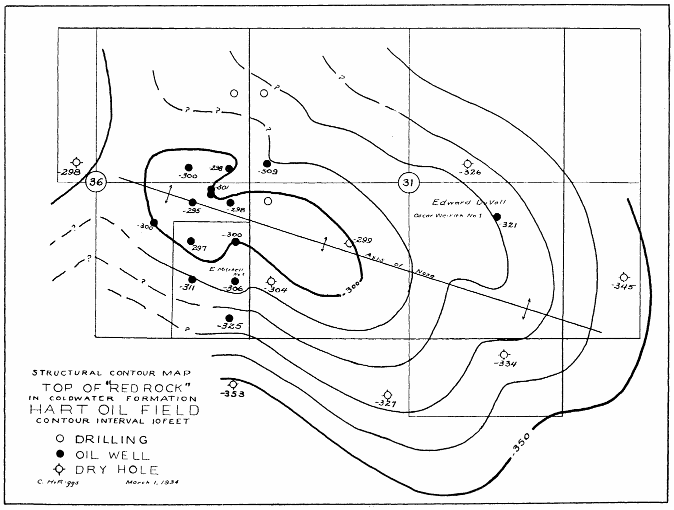


MAP 39

The top of the Traverse formation is a gray shale containing considerable pyrite. The shale becomes more calcareous with depth, grading into limestone from 40 to 80 feet below the top of the formation. Pore spaces in the top of the limestone contain oil above low folds and water on their flanks. From 40 to 50 feet below the top of the limestone there is a water-bearing zone, which probably corresponds more nearly with Upper Traverse pay horizons elsewhere in western Michigan.

STRUCTURE

The Hart Oil Field is located near the western rim of the Michigan Basin where the rocks dip southeast twenty to thirty feet per mile. It lies at the head of a broad syncline between a pronounced fold to the northeast and a suggestion of a fold in the southern part of Oceana County (Map 39).



MAP 40

Detailed structure contour maps of the field show two important features: a modified nose tending NW.-SE. and smaller echelon folds with axial directions N. 35° W. (Maps 40-42). There is some evidence to indicate that the nose may have been formed prior to Marshall deposition. This evidence is listed as follows:

1. Total thickness of the Lower Marshall is less over the nose and increases off-structure;

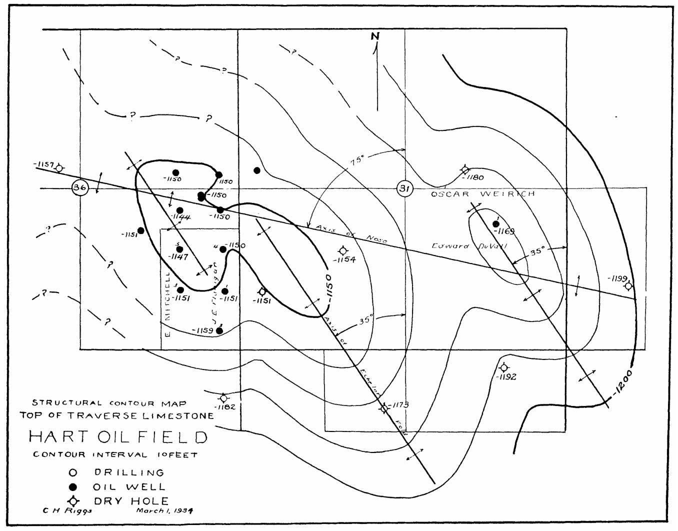
2. Lower beds of the Marshall are absent on top and west of the fold (evidently some topographic feature acted as a temporary barrier to westward encroaching seas);

3. Structure on the top of the Lower Marshall formation does not correspond to nose structure of lower beds;

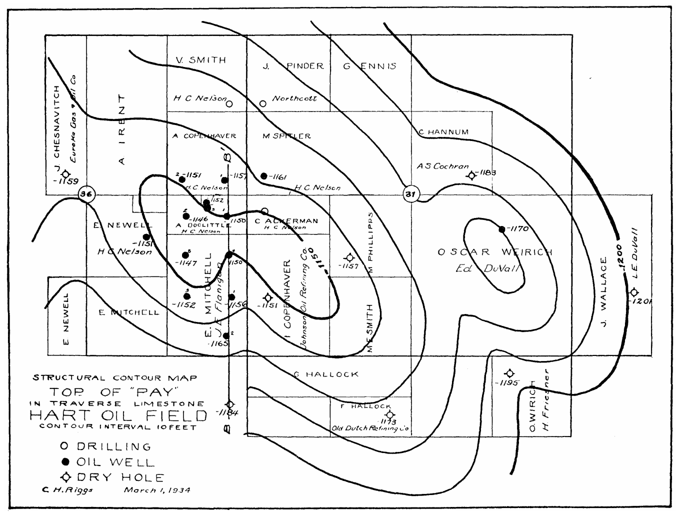
4. A nose is shown when the structure on top of the Lower Marshall is subtracted from that of the lower beds (structure of the lower beds would indicate deformation due to both periods of folding, whereas structure on top of the Lower Marshall would show only folding of the later period).

That this folding of the nose may be due to differential settling over deep folds or coral reef is suggested by a thickening off-structure of the upper part of the Coldwater formation.

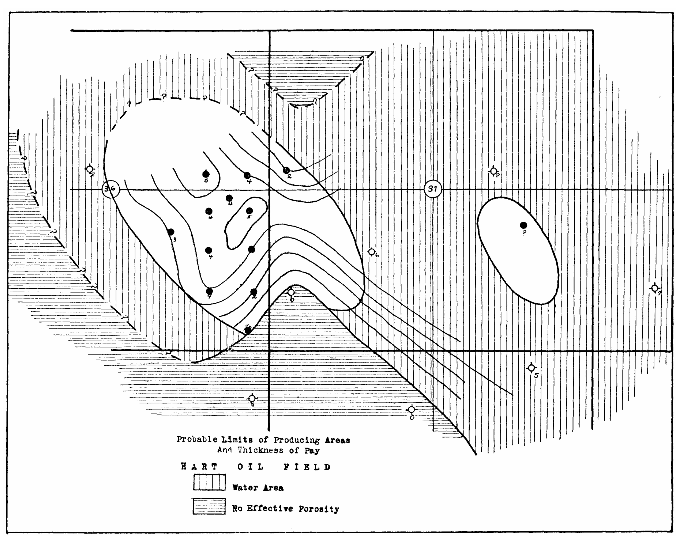
The axial directions of echelon folds shown by contours on the lower formations correspond in general with the folds of the Marshall formation. These folds were probably caused by post-Marshall movements effective over most of Lower Michigan.



MAP 41



MAP 42



MAP 43

RESERVOIR CONDITIONS

Though the nose and the small folds seem to govern the local distribution of oil, their size and extent do not appear to be sufficient to have been the primary cause of accumulation. Rather it is more probable that up-dip migration of oil above salt water was halted by a lack of perviousness in the reservoir rock. Wells show a decrease in the amount of perviousness and thickness of pay from east to west across the area (Map 42). The limit of the area of no effective porosity to the west of the producing area is rather indefinite owing to lack of information. Its existence is indicated by a thinning of pay to the west and by the absence of pay in a well drilled one mile west of the field.

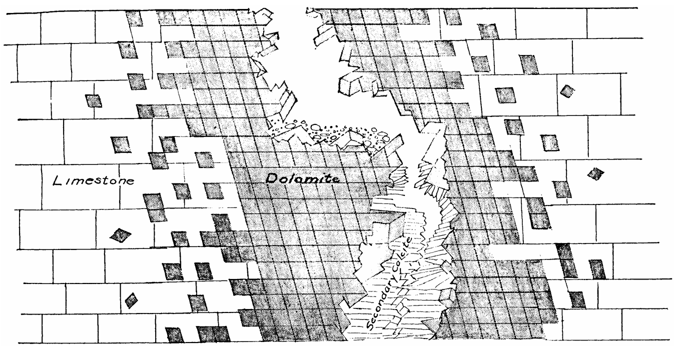


FIG. 27. Section to illustrate nature of dolomitic cavities

The thickness of the porous zone containing oil seems to vary with the proportion of dolomite to limestone in the section. The pore spaces and small cavities are probably related to the formation of the dolomite. In a section along the line B-B' (Map 42) the thickness of dolomite and the thickness of pay increases above the structure, but this relationship does not exist throughout the area. Map 43 shows the area of no effective porosity up on the side of the structure. Wells off structure east of the field indicate an increase rather than a decrease in perviousness, and water fills up rapidly in the hole. The dolomite seems to be concentrated near the top of the Traverse limestone and porosity in the lower water-bearing zone is evidently not due to dolomitization. There is no evidence to indicate that the dolomite is interbedded with the limestone. It probably exists as nests, chimneys, or zones in the limestone.

Figure 27 illustrates the author's conception of the nature of these dolomitic cavities. No cores of the pay have been taken, and our knowledge, based only on drill cuttings, must necessarily be very incomplete. It is probable that these cavities are not very large, although the larger cavities and crystals would be broken up by the drill. Drill-cuttings show rhombohedral crystals of dolomite lining the openings. Rarely these cavities are lined with black carbonaceous material. Sometimes they are partly or completely filled with crystals of secondary calcite. Crystals of pyrite are associated with the secondary calcite. Sometimes the cavities are partly filled with sand and other clastic material. Back from the edge of the openings the material is coarsely crystalline dolomite. Samples from just above and just below a dolomitic zone reveal sharp rhombohedrons of dolomite in dense limestone. No fossils have been found in the limestone or dolomite. It is assumed that these cavities are more or less connected and form the reservoir in which oil has accumulated. Probably the greatest effect of acid treatment is to remove the secondary calcite and to open channels between cavities.

It would seem probable that this material was deposited as calcium carbonate with a small amount of magnesium carbonate. The overlying shales and undolomitized limestones below contain varying amounts of magnesium. Leaching of calcium carbonate by downward-moving acidic waters would increase the proportion of magnesium carbonate to a point at which dolomite could be precipitated. Worm trails or cavities left by the solution of shells by organic acids may have provided the avenues of migration. The absence of fossils in the limestone as compared with the overlying shale could be explained more easily by their subsequent solution than by a supposition that the fauna did not exist during limestone deposition, but suddenly appeared with the argillaceous sediments. The leaching of calcium carbonate would enlarge preexisting avenues of migration. Smaller, disconnected openings may be due to the decrease in volume accompanying dolomitization. It may be assumed that dolomitization would commence at the openings and work outward. The extent of this action would then depend primarily upon the perviousness of the original material. It has been noted that the limestone associated with the dolomite is less dense than undolomitized portions. Calcium carbonate removed by leaching would be carried downward into preformed cavities and deposited as secondary calcite. Close association of secondary calcite and secondary pyrite would seem to indicate that they were precipitated from the same solution under similar conditions. It is supposed that leaching commenced while the material was still unconsolidated on the sea bottom. The concentration of dolomite near the top of the Traverse limestone and its association elsewhere with gypsum or anhydrite suggest that the original dolomitization took place in shallow water where deposition was irregular. Later concentration of dolomite may have occurred during elevation and erosion.

DRILLING AND PRODUCING PRACTICES

Drilling in the Hart Oil Field is done with either standard rigs or drilling machines. Drilling time varies from twenty to forty days. The common practice is to drill one well to each ten acres in the proved area, but this practice is not always followed. The thick drift (400 to 500 feet) makes the driving of pipe difficult. Some wells drilled on the moraine have encountered boulders, necessitating skidding of the rig. Ten-inch drive pipe is landed on top of the Marshall formation to shut out fresh water and caving sands. Brackish mineral water is encountered in the Marshall formation and is shut out of the wells with eight and one-quarter inch casing set in the top of the Cold water shale. Six and five-eighths casing is usually set in the calcareous shales above the Traverse limestone to prevent caving from above.

A few wells have flowed by natural pressure when drilled into the pay formation near the top of the limestone. The volume of gas in the wells is small, and it would seem that water pressure behind the oil is the greatest force causing the wells to flow. With low perviousness and without uniform porosity it is assumed that the wells nearest the oil-water contact would show the greatest pressure. Production records of two edge wells tend to verify this assumption.

Tubing is usually set on packer above the pay horizon and the wells are treated with 1,000 gallons of Dowell acid. Because of the tight pay considerable pressure is required to force the acid back into the formation, where it will open channels between cavities. Sometimes two or three attempts are made before the well is successfully treated. The acid treatments increase production from 10 to over 1,000 per cent (Fig. 28). Drilling and treating costs average close to $5,000.00 a well.

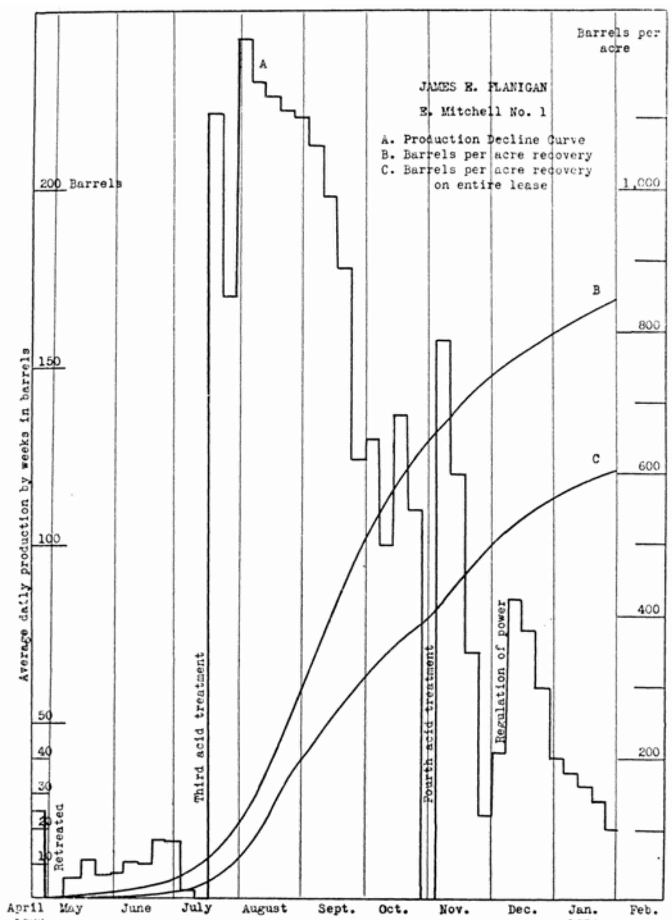


FIG. 28. Production curves of Hart Wells

After acid treatment the wells are usually swabbed and cleaned out to remove insoluble residues. They are put to pumping soon afterward. Whenever possible wells are pumped from central powers to reduce lifting costs.

When the field was opened the wells were produced nearly to capacity with little back pressure. The oil from the Hart Field contains a large percentage of gasoline, but little kerosene, and a large percentage of heavy oils. The reduction in pressure at the well permitted escape of the volatile constituents and caused precipitation of paraffin in tubing and casing. It is now necessary to remove this paraffin periodically by mechanical or chemical means and at considerable expense. Reduction in pressures at the wellheads also caused encroachment of edge water. All wells now produce some water. In most cases this water may be drained off, but in some cases the oil must be steamed or treated with chemicals. Lifting costs vary from 20 to 35 cents per barrel, with an average close to 30 cents per barrel. The Napth-Sol Refining Company and the Old Dutch Refining Company, both of Muskegon, purchase the oil.

ESTIMATES OF TOTAL PRODUCTION

Map 43 shows the probable producing area of the Hart Oil Field. There is evidently only a small area of thirty-five or forty acres surrounding the original well. The larger area to the west may approximate two hundred and fifty acres.

The variable nature of the reservoir rock in the Hart Oil Field would make it impossible to estimate recovery on the basis of volume content. Production records from Upper Traverse wells in the Muskegon Oil Field indicate an average yield close to 1,000 barrels per acre. Figure 28, Curve B, shows the barrels per acre recovery from the Flanigan Mitchell No. 1. Curve C on the same figure shows the barrels per acre recovery from the entire Mitchell lease — five wells on fifty acres. These and other production records, which are now available on the Hart Oil Field, would not tend to increase recovery estimates beyond 1,000 barrels per acre. The total production of the Hart Oil Field will probably not exceed 300,000 barrels. To February 1, 1934, the field had produced approximately 52,000 barrels of oil or an average of 400 barrels per acre from the 176 acres drilled and producing.

STATE DEPARTMENT OF CONSERVATION
MUSKEGON, MICHIGAN

[1] Newcombe, Robert B., *Oil and Gas Fields of Michigan, Geol. Surv. Mich.*, Publ. 38, Geol. Ser. 32.