STATE OF MICHIGAN
DEPARTMENT OF CONSERVATION
GEOLOGICAL SURVEY DIVISION

Water Investigation 1
RECONNAISSANCE OF THE GROUND-WATER RESOURCES OF ALGER COUNTY, MICHIGAN

by

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ABSTRACT

Alger County, in the east-central part of the Upper Peninsula, is sparsely populated. The county is underlain by deposits of unconsolidated clay, sand, and gravel of glacial origin, which mantle limestone, dolomite, and sandstone of Paleozoic age. Beds of glacial sand and gravel and various strata in the Paleozoic formations yield water to wells. Most of the county is underlain by several aquifers. Some areas, however, are underlain by only one aquifer. The aquifers yield 5 to 20 gpm (gallons per minute) of good water in most of the county, will yield 20 to 50 gpm in much of the county, and several hundred gpm in local areas. The water produced from wells generally is satisfactory for most uses. It ranges from soft to very hard, but locally contains objectionable amounts of iron. The iron content and hardness can be reduced by commonly used home water-treatment equipment. Locally in the northwestern part of the county, the Jacobsville Sandstone yields salty water. The salt content (principally sodium chloride) increases with depth. In most "salt water" areas, fresh water can be obtained from wells tapping the uppermost beds of the Jacobsville or aquifers in the overlying glacial drift.

Alger County is rich in water resources. Lake Superior, the surface streams, and locally the ground-water reservoirs can be tapped to supply large quantities of water, which should be sufficient for any foreseeable or anticipated economic growth.

INTRODUCTION

The purpose of the study in Alger County was to determine the general occurrence, availability, quantity, and quality of ground water in the area. This information is needed for planning and stimulating industrial, recreational, and general economic growth of the region. This report is the sixth of a series summarizing ground-water information in the Upper Peninsula of Michigan.

The cooperative ground-water investigations in Michigan are directed jointly by O. M. Hackett, Chief, Ground Water Branch, U. S. Geological Survey, Washington, D. C., and W. L. Daoust, State Geologist, Michigan Department of Conservation, Lansing, and are under the direct supervision of G. E. Hendrickson, District Geologist, U. S. Geological Survey.

Acknowledgments

Special thanks are given to the well drillers and residents of Alger County and to the State, County, and Municipal agencies whose cooperation made this report possible. Appreciation is expressed also to personnel of the Michigan Geological Survey, especially to members of the Geologic Names Committee, and to members of the Michigan Basin Geological Society, who furnished much valuable advice and assistance.

Previous Investigations

In the early part of this century the U. S. Geological Survey made an investigation of flowing-well districts in the Northern Peninsula. The report of this study (Leverett, 1906) provides some information on ground water in Alger County. A later study of Leverett (1929) provides additional information on the geology and shorelines of ancient glacial lakes in the county. A more detailed study of the surface geology of Alger County was made by Bergquist (1936). In 1949 the U. S. Geological Survey studied the probable hydrologic effects on adjacent aquifers of proposed canals extending from Lake Superior to Lake Michigan and Lake Huron through the eastern part of the peninsula. Many data collected during that study are included in this report. A study of the Cambrian sandstones in the Northern Peninsula of Michigan by Hamblin (1958) provides considerable stratigraphic information pertinent to this study.

Various phases of the geology and hydrology of the Northern Peninsula are described in other reports. A rather comprehensive bibliography of these works, which date back to 1821, is included in the report on Chippewa County by Vanlier and Deutsch (1958a). Further information on Alger County is contained in the publication entitled "An Index of Michigan Geology" by Martin and Straight (1956).

Information concerning the geology and ground-water resources obtained in other counties in the eastern part of the Northern Peninsula provide an important background for the study of Alger County. The following table lists the previous reports of the reconnaissance study:

Progress Report	County	Reference 1/
17	Chippewa	Vanlier and Deutsch, 1958a
19	Mackinac	Vanlier and Deutsch, 1958b
21	Luce	Vanlier, 1959
22	Schoolcraft	Sinclair, 1959
24	Delta	Sinclair, 1960

1/ See "Reference Cited" at end of report.

Well-Numbering System

The well-numbering system used in the report indicates the location of wells within the rectangular subdivisions of the public lands, with reference to the Michigan meridian and base line. The first two segments designate the township and range; the third segment designates both the section and the number assigned to the well within the section. Thus, well 49N 15W 2-1 is well number 1 in section 2, Township 49 North, Range 15 West. The 40-acre tract in which each well is located is listed in the well records (table 2).

Methods of Investigation

This study included a review of all pertinent literature concerning the geology and water resources of Alger County. Files of various State agencies are searched also for useful data. Much of the time in the field was spent checking data collected during previous years. Some additional data were obtained from well drillers and local residents. Bedrock outcrops were examined to determine the nature of the openings in the rock. Samples of water were collected from wells, springs, and streams for chemical analysis. Samples of glacial sediments and bedrock formations were collected and analyzed to determine permeability and other physical characteristics.

GEOGRAPHY

Alger County is in the central part of the Northern Peninsula of Michigan (fig. 1). It has an area of about 910 square miles and includes several islands in Lake Superior, the largest of which is Grand Island in Munising Bay. The shoreline along Lake Superior, excluding the shoreline of the islands, is about 80 miles long. The city of Munising, on the shore of Lake Superior (fig. 2), is the county seat.

The county is served by U. S. Highway 41, State Highways 28, 67, 77, and 94, and the Duluth, South Shore and Atlantic Railroad, the Lake Superior and Ishpeming Railroad, and the Minneapolis, St. Paul, and Saulte Ste, Marie Railroad.

Population and Economic Development

The population of Alger County in 1960 was about 7,500. A slight decrease in population had been recorded during the previous two decades.

The county is largely forested, and includes many inland lakes and rivers, as well as several large swamp areas. The economy is related primarily to forest resources and the tourist industry. The forest industries include the manufacture of paper at Munising. Gravel and crushed dolomite are produced for road metal and construction aggregate. The many beautiful lakes, streams, and the Lake Superior shoreline attract many tourists to the county each year and the fish and wildlife resources also attract hundreds of hunters and fishermen.

State and local governmental units are considering means of improving the economic and recreational potential of the county. Among the plans being considered is a scenic highway along the south shore of Lake Superior, which would be part of the around-the-lake scenic highway, some of which in Canada has already been completed.

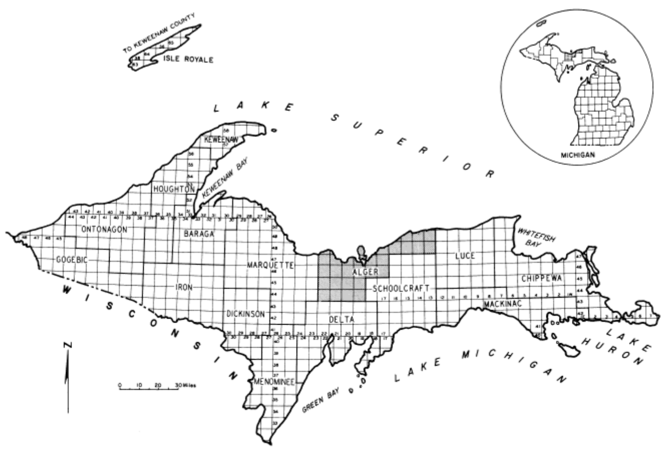


Figure 1. Index map showing location of Alger County, Michigan.

Physiography

During the Pleistocene glacial epoch Alger County was covered by thick sheets of glacial ice and inundated by a series of glacial lakes (fig. 3). As a result, the topographic features of the county are related, in large part, to the erosional and depositional processes associated with the glaciers and the glacial lakes. Some of the principal topographic features, however, relate to the configuration of the underlying bedrock surface.

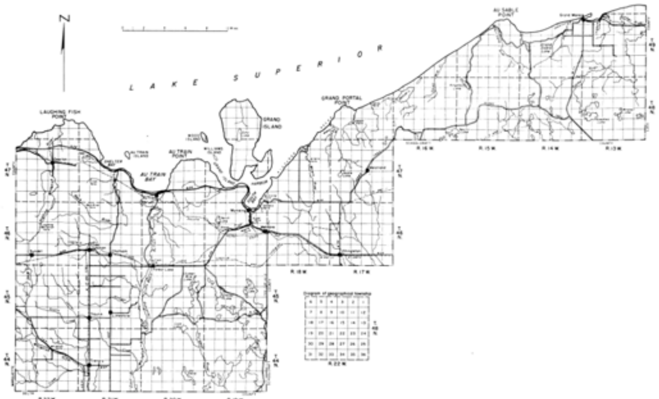


Figure 2. Map of Alger County

The most spectacular topographic features are the rock escarpments along the shoreline of Lake Superior. The best known exposure of this escarpment is the Pictured Rocks area east of Munising (fig. 4). Other sections of the escarpment are exposed at many waterfalls. Over much of the county the bedrock escarpments are mantled by glacial drift. The large hills in the Munising area are part of a glacial moraine that overlies bedrock highland.

The Munising moraine forms a belt of rugged hills extending from the area south of Grand Marais to the Whitefish Valley south of Au Train (fig. 2). Other prominent physiographic features related to glacial deposition include the Wetmore and Kingston outwash plains. These plains are pitted with rather large depressions, many of which are filled with water and form most of the numerous lakes in the county. Au Train and Beaver Lakes occupy bays of ancestral Lake Superior. These lakes were formed when bars, beaches, and dunes were built up across the mouths of the bays.

The southwestern part of the county is a gently undulating plain called the Trenary till plain (fig. 4). This plain stood above the waters of the glacial great lakes, and the minor glacial features of the plain such as eskers and drumlins were not obliterated by wave erosion or buried by lake deposits. The drift deposits on the plain generally are quite thin, and bedrock is exposed at some road cuts and along the bottoms of many of the streams crossing the plain.

Bars, beaches, and wave-cut terraces mark the shorelines of extinct glacial lakes which at one time covered much of the county. Some of these features are many miles inland from Lake Superior. The area south and east of Shingleton is a large swampy, lake plain, which is part of the Seney Complex (Bergquist, 1936, p. 125).

Dunes and small deposits of windblown sand are scattered throughout the county. Most of the inland dunes are small and are associated with the shorelines of ancient glacial lakes. These old dunes are forested and inactive. Many of the dunes along Lake Superior are active -- that is, they are presently being moved by the wind. The largest active dune area is the Grand Sable dune area a few miles west of Grand Marais (Bergquist, 1935). This dune system covers about 5 square miles.

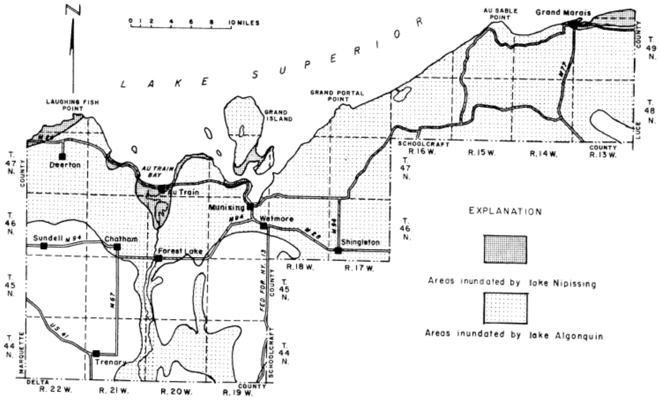


Figure 3. Areas inundated by glacial lakes (after Leverett, 1929, pl. 2)

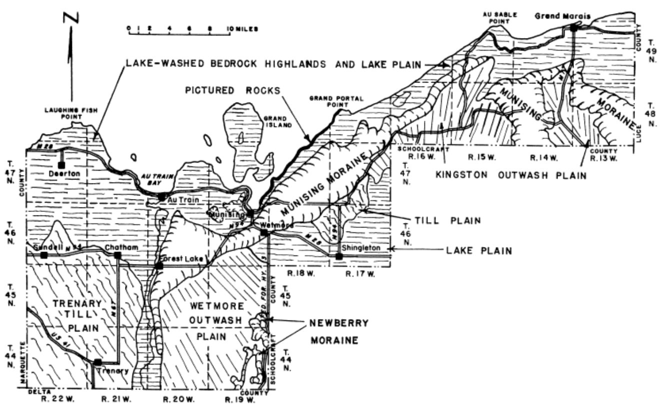


Figure 4. Major physiographic features of Alger County.

Relief

Two highland areas in the county reach altitudes of 1150 feet above mean sea level. One lies west of Highway M-77 in the center of T. 48 N., R. 14 W.; the other is a few miles north of Sundell in the extreme western part of the county. Several other highland areas in the western part are nearly 1,100 feet high. Most of the highlands in the eastern part are below 1,000 feet. The greatest relief within a small area is at Munising; the highest points on the hills southeast of the city, less than a mile from Lake Superior, are more than 400 feet higher than Lake Superior, which has a mean altitude of 602 feet above msl.

Drainage

About half the county is drained by streams tributary to Lake Michigan. The other half is drained by streams flowing to Lake Superior. Many of the streams tributary to Lake Superior flow across one or more bedrock escarpments and thus include falls, cascades, or rapids.

The county is poorly drained, as is indicated by the many swamps, lakes, and ponds. There is very little surface runoff from the Wetmore and Kingston outwash plains and the Munising and Newberry moraines, which have soils and subsoils that are sandy and permeable. Precipitation falling in these areas in returned directly to the atmosphere by evapotranspiration or moves to streams by ground-water underflow.

Climate

The climate is somewhat tempered by Lake Superior, which has a warming effect in the winter and a cooling effect in the summer. During the winter, however, the county experiences some rigorous weather, including considerable snowfall. Average annual precipitation at Munising is about 34 inches and mean annual temperature is about 42°F. The average growing season extends from June 2 to September 20.

GEOLOGY

Alger County is underlain by deposits of unconsolidated sand, gravel, and clay which mantle a thick sequence of sandstone, limestone, dolomite, and shale of Paleozoic age. The Paleozoic formations rest on a complex series of Precambrian rocks.

The geologic history of the area, including a discussion of the lithology of the various rock units, is described below. The water-bearing characteristics of the rocks are described in the section on ground-water and are summarized in table 1.

Geologic History

The geologic history begins in early geologic time with the formation of masses of granite, schist, and other Precambrian crystalline rocks and concludes with the deposition only a few thousand years ago of unconsolidated surficial sediments of glacial origin.

Precambrian Rocks

The Precambrian basement rocks of Alger County are mantled by hundreds of feet of Paleozoic and glacial sediments. The Precambrian rocks probably are similar to the complex series of highly folded and faulted Precambrian igneous, metamorphic; and sedimentary rocks that crop out in Marquette County to the west. Thus, the basement rocks probably include masses of granite, schist, and gneiss, and layers of highly folded and faulted quartzites, slate, iron formation, marble, and dolomite.

Paleozoic Sedimentary Rocks

The consolidated sedimentary bedrocks underlying the county were deposited in inland seas or basins which at one time covered a large part of Michigan. Early and Middle Cambrian sediments were deposited in a basin similar to but larger than the present Lake Superior Basin (Hamblin, 1961, p. 8). During Late Cambrian time the Michigan area included two separate basins of deposition; one was centered in the central part of the Lower Peninsula, the other was centered in about the center of Lake Superior. The two basins were separated by the Northern Michigan Highland (Hamblin, 1953, p. 57, 94) which extended in an east-west direction through the eastern part of the Upper Peninsula. This highland remained above sea level until the closing stages of Cambrian time when the downwarping that produced the Michigan Basin extended into the Lake Superior Basin and the two basins were joined together.

The Cambrian sediments of Alger County were deposited in the Lake Superior Basin, and are thinnest along the southern boundary and thickest along the shore of Lake Superior. The Ordovician sediments become thicker to the south, toward the central part of the Michigan Basin. Sediments deposited in the first Cambrian seas consisted principally of sand. The sediments deposited in the Ordovician seas consist largely of limestone and dolomite.

JACOBSVILLE SANDSTONE. According to Kamblin (1958) the Jacobsville Sandstone is of Cambrian age.* The Jacobsville is principally a medium-grained crossbedded sandstone, but includes beds of shale, siltstone, and coarse grained to conglomeratic sandstone. It is predominantly red or reddish brown, but is mottled with white spots, streaks, and blotches and thus can be readily recognized. The sandstone is hard and resistant to erosion. It is extensively broken and jointed in the outcrop areas, however, where it has-been exposed to weathering.

The Jacobsville was deposited in the Lake Superior Basin and, according to Hamblin (1958, p. 51), the source area for much of the sediments was the east-west trending Northern Michigan Highland described above. The formation becomes thicker toward the central part of the Lake Superior Basin and thins rapidly where it laps on the highland. Hamblin (1958, fig. 2) indicates that the formation thins to a featheredge in the southernmost part of the county, but is over 1,000 feet thick along the shore of Lake Superior.

In the northeastern and northwestern parts of the county and on the islands of Lake Superior, the Jacobsville crops out at the surface or beneath the glacial drift (fig. 5). In the remainder of the county the Jacobsville is overlain by other consolidated sedimentary rocks. The upper surface of the formation is rough and irregular as a result of erosion prior to deposition of the Munising Sandstone.

*According to the U. S, Geological Survey the Jacobsville Sandstone is of Precambrian or Cambrian age.

MUNISING SANDSTONE. The Munising Sandstone of Alger County was formed from the large quantities of quartz sand deposited over the Jacobsville Sandstone. The Munising is principally a white to gray, fine to medium-grained sandstone (fig. 6), but includes beds of coarse-grained to conglomeratic sandstone. The cross-grained bedding of the formation indicates deposition in shallow water. Throughout most of Alger County a bed of coarse conglomerate is present at the base of the formation.

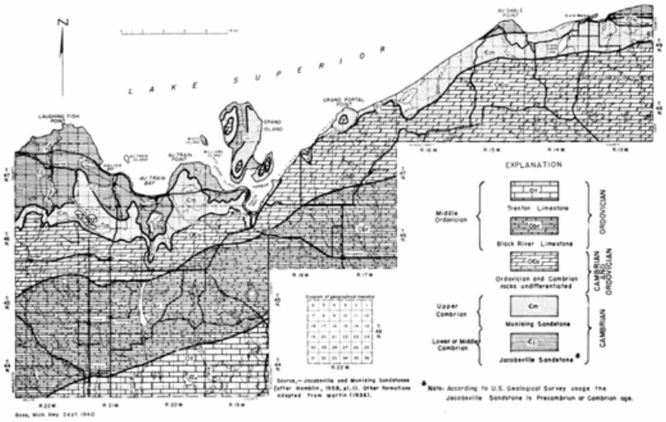
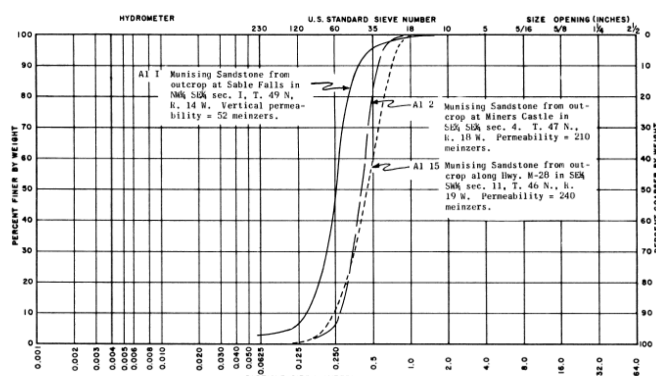


Figure 5. Bedrock Geology of Alger County

The Munising Sandstone of Alger County rests unconformably on the eroded surface of the Jacobsville Sandstone and dips to the south and southeast at about 30 feet to the mile. The formation is about 200 feet thick along its northern extent and less than 50 feet thick along the boundary common to Alger and Delta Counties (fig. 7).

In general the beds of the Munising Sandstone are indurated, competent, and relatively resistant to erosion. However, some beds weather readily and are easily eroded by wind or running water. The formation forms the steep and overhanging cliffs of the Pictured Rocks at Munising. The cliffs result from erosion, by wave action, of the beds of sandstone at the water line.



PERCENT OF SIZE

NO.	CLAY SIZES less than 0.004	SILT SIZES 0.004-0.0625	SAND SIZES V. fine .0625-.125	Fine .125-.25	Medium .25-.5	Coarse .5-1	V. coarse 1-2	GRAVEL SIZES V. fine 2-4	Fine 4-8	Medium 8-16	Coarse 16-32	V. coarse 32-64
Al 1	2.9		3.6	39.8	49.4	4.2	0.1					
Al 2	.6		0.6	6.0	74.1	18.7						
Al 15	.3		0.6	11.0	47.4	40.4	0.3					

Figure 6. Curves showing particle-size distribution of samples of Munising Sandstone.

CAMBRIAN AND ORDOVICIAN SANDSTONE, SANDY DOLOMITE, AND DOLOMITE. The Munising Sandstone is overlain by a thick sequence of sandstone, sandy dolomite, and dolomite. As the rocks of this sequence are exposed only at widely separated localities and contain relatively few fossil remains, it is difficult to separate them into distinct formations or correlate them with known formations of the same age in other parts of Michigan or adjacent States. The sequence can be differentiated as a single unit, however, as it immediately overlies the distinctive Munising Sandstone and underlies the distinctive dolomitic beds of the Black River Limestone.

The change in deposition from the "clean" Sandstone of the Munising to the dolomitic sandstone and sandy dolomite indicates a change in the source of sediments and in the character of the sea in which the sediments were deposited. Much of the sand deposited in these seas probably was derived from exposed areas of the Jacobsville and Munising Sandstones.

The lower part of this sequence consists largely of dolomitic sandstone and sandy dolomite, while the upper part is largely "pure" dolomite. Some of the sandstone and dolomite in the lower part of this sequence contains a significant amount of glauconite, a mineral commonly referred to as "green sand". Hamblin (1958, p. 119) noted that the glauconite content in some beds exceeded 35 percent.

In Delta County, Michigan, and in Wisconsin, the zone of transition from Lower Ordovician rocks to Middle Ordovician rocks is marked by beds of sandstone, conglomeratic limestone and dolomite, and shale. Where they are exposed or penetrated by wells in Wisconsin and are penetrated in oil wells in the Lower Peninsula, these rocks are locally called the St. Peter Glenwood interval. Although the presence of the so-called St. Peter Glenwood interval cannot be definitely established in Alger County at this time, beds of conglomeratic dolomite and beds of sandstone containing Middle(?) Ordovician fossils locally are found below the dolomitic beds of the Black River Limestone.

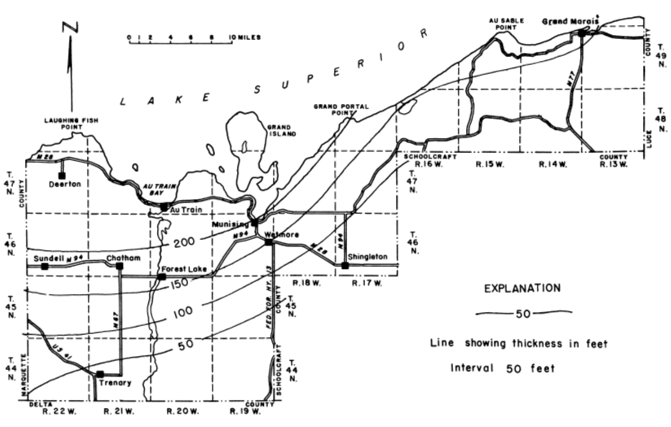


Figure 7. Map showing thickness of the Munising Sandstone (after Hamblin, 1958, fig. 30).

BLACK RIVER AND TRENTON LIMESTONES OF MIDDLE ORDOVICIAN AGE. During Middle Ordovician time the Michigan Basin sea received large amounts of soluble minerals from adjacent oceans and land areas. Calcium and magnesium carbonate were precipitated and were deposited on the bottom of the sea. The sediments compacted and lithified to form the limestone and dolomite of the Black River and Trenton Limestones.

Some beds in the formations are highly fossiliferous, and some include considerable amounts of shale.

In adjacent counties, where the entire formations are present, they have an aggregate thickness of about 275 feet. In Alger County, the formations were exposed to erosion and were worn down by wind, water, and glacial scour. They probably have a maximum thickness of about 250 feet, in the southeast corner of T. 44 N., R. 19 W. of Alger County. They are thinner to the north and are only a few feet thick along their northernmost extent.

Post-Paleozoic Erosion

Thick beds of shale, dolomite, and limestone of Late Ordovician and Silurian age that overlie the Black River and Trenton Limestones in Schoolcraft and Delta Counties at one time extended into Alger County. However, the Paleozoic Era was followed by a long period of erosion during which the exposed Paleozoic formations were worn down and washed or blown away. As a result of this erosion, Post-Trenton Paleozoic rocks are no longer present in Alger County.

The bedrock surface of the county is not a flat surface (fig. 11). Locally, it is quite rugged as a result of differential erosion that cut down into the softer rocks and left ridges where the harder formations crop out. The bedrock topography has been modified in more recent geologic time by glacial scour and wave erosion along Lake Superior.

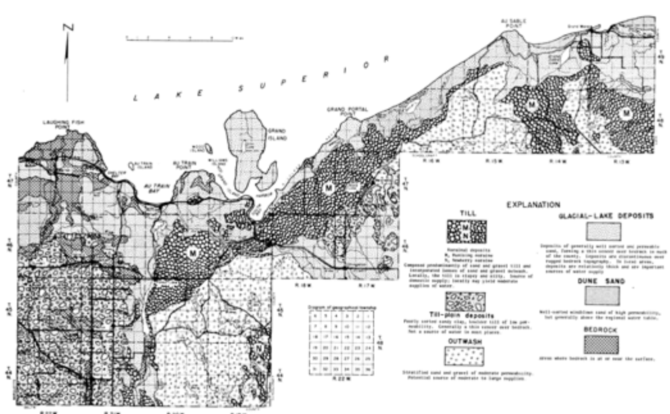


Figure 8. Surface geology of Alger County (adapted from Bergquist, 1936, fig. 14).

The Glacial Epoch

The most recent chapter in its geologic history is recorded in the physiographic features of the area and the deposits of unconsolidated sand, gravel, silt, and clay that underlie nearly all the county. The record shows that the county was covered by several continental glaciers. The surficial materials (fig. 8) were deposited when the last of these glaciers melted back toward Canada. The glacial deposits are formed from rock debris which was scraped, scoured, and plucked from the surface over which the glacier moved. As the glacier moved from the north it carried along pieces of granite and other Precambrian rocks from the Canadian shield as well as sand and pieces of sandstone from the formations that now form the bottom of Lake Superior, and as it moved across Alger County it picked up material from the dolomite and limestone formations. When the glacier melted from the county this rock debris was left behind. The glacial deposits in the northern part of the county are composed largely of sand, gravel, and clay with boulders of sandstone and crystalline rock. The glacial deposits south of the area where dolomite and limestone crop out consist largely of fragments and boulders of limestone and dolomite in a matrix of sand and clay.

The glacial deposits vary not only with the source of material, but also with the mode of deposition and can be separated into three main depositional types. Materials deposited directly from the ice with little or no transportation by moving water are called "tills"; those deposited in and by moving streams of water are called "outwash"; and those deposited in glacial lakes are "lake deposits."

Moraines and till plains are underlain principally by tills a mixture of sand, silt, clay, and rock which generally is not very permeable. Permeable sand and gravel outwash underlie the outwash channels, plains, and deltas. Lake-deposited sand and clay underlie the lake plains.

Portions of two moraines in Alger County mark the position where the front of the glacier halted temporarily while melting back. Outwash deposits of the county generally are associated with the moraines.

During this epoch the county was inundated by a large glacial lake, which preceded present Lakes Superior and Michigan (fig. 3). The sand and clay that washed into these lakes form the large lake plains in the eastern part of the Upper Peninsula.

Bedrock Structure

Little is known of the configuration of the Precambrian rock surface of Alger County, Hamblin (1958, p. 46) concluded from a study of exposures along Lake Superior west of Alger County that "the Precambrian surface was highly irregular at the time the Jacobsville was deposited." The Post-Jacobsville Paleozoic sediments of the Michigan Basin were deposited in nearly horizontal layers over the Jacobsville surface. Gradual deformation, subsidence, and compaction of the beds, contemporaneous with deposition and greatest in the center of the basin, produced a bowl-shaped structure (fig. 9). The youngest beds are exposed at the surface in the central part of this structure in central Michigan, and the rock units crop out in roughly concentric bands. Alger County is at the north edge of the structure where the oldest sedimentary rock units are exposed. The regional dip of the Post-Jacobsville Paleozoic formations of Alger County is southward and southeastward at about 30 to 50 feet per mile.

The bedrocks form broad cuestas across Alger County. These cuestas generally have rather steep north and northwest-facing escarpments and gentle slopes dipping to the south and southeast. The rock escarpments are exposed at many of the water falls and at the Pictured Rocks near Munising.

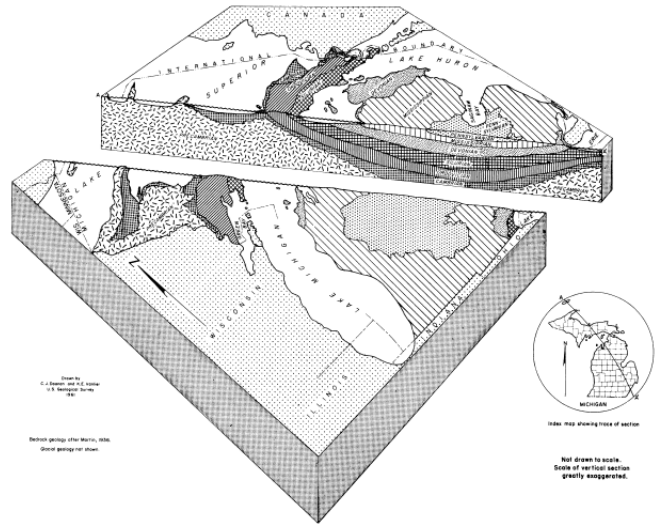


Figure 9. Schematic block diagram showing the basin structure of Michigan.

GROUND WATER

Principles of Occurrence and Availability

Rock strata that yield water to wells are called aquifers. Some aquifers yield large quantities of water; others yield only a few gallons per minute. The yield of an aquifer is governed by several factors, including permeability and porosity of the aquifer materials, availability of recharge, saturated thickness, and hydraulic gradient created by pumping.

Permeability is dependent upon the number, size, and shape of openings in the rock material. In rocks such as soft sandstone or sand and gravel the interstices or openings between the individual grains or rock particles form the conduits through which the water moves. In hard, competent rocks, such as quartzite, granite, limestone, and dolomite, water moves through openings along joints (fractures) and bedding planes. In limestone and dolomite, the openings along joints and bedding planes commonly are enlarged by solution.

Wells obtain water from interconnected water-filled openings in rock materials. Wells penetrating rocks containing only a few small openings yield only small amounts of water. When many large openings are penetrated, wells yield large supplies of water.

The water level in a well depends on several factors, including altitude of points of natural discharge of ground water, altitude of recharge areas, permeability of the aquifer materials, and amount of withdrawal from wells in the area.

Table 2 lists representative wells in the various areas of the county from which the conclusions regarding source and availability of ground water were made.

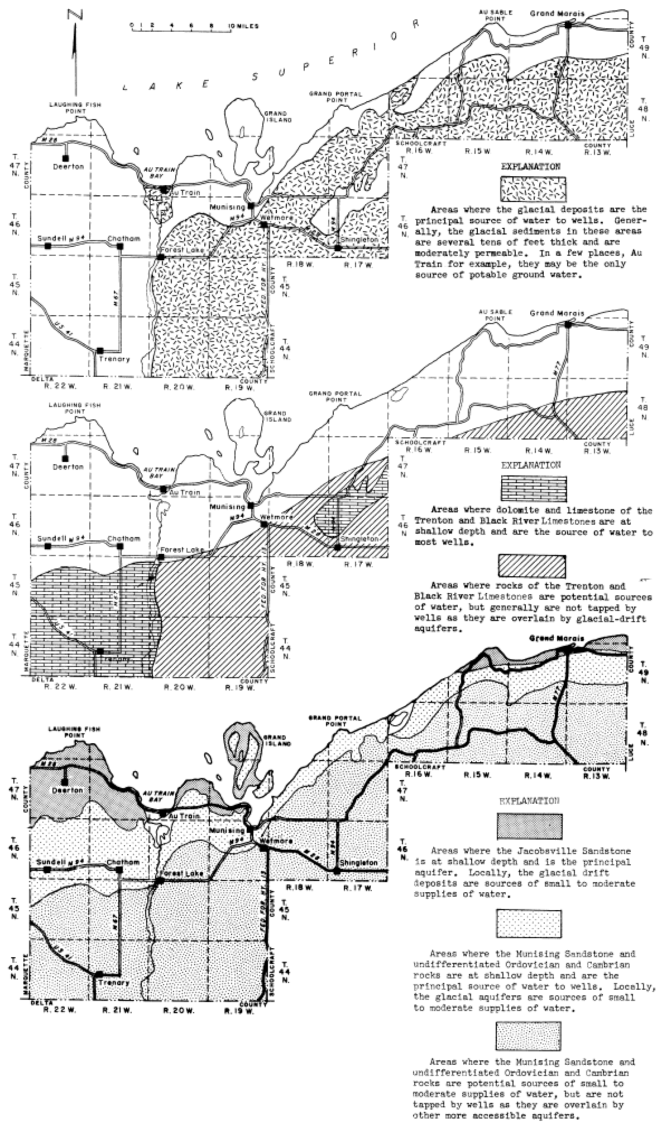


Figure 10. Source and availability of ground water in Alger County.

Water-Bearing Formations

Several of the rock units underlying the county are sources of water to wells (table 1). The various units provide at least one source of potable ground-water supply to nearly every part of the county (fig. 10), and most areas are underlain by several aquifers. Generally, wells draw from the uppermost aquifers because of the higher cost of drilling deeper wells. Locally, in the northern part of the county only one aquifer is present, and in places this aquifer is relatively unproductive or yields water of poor quality. Fortunately, only a few small areas have such problems.

The quality of the water yielded by the aquifers of the county varies considerably (fig. 11, table 4). Most aquifers yield water of good chemical quality, although some yield water containing objectionable quantities of iron, and locally the Jacobsville Sandstone yields salty water.

The water-bearing characteristics of the important aquifers in the county are described below. The aquifers are considered in sequence from top to bottom, or in the order that they would be encountered in drilling a well.

Glacial Drift Aquifers

The most accessible sources of ground water over a large part of the county are the deposits of glacial drift (fig. 10). These range from clayey till and lake deposits of low permeability to highly permeable sand and gravel outwash. The drift aquifers are tapped by relatively few wells, principally because the best drift aquifers are in the sparsely populated areas of the county. Locally, they provide small supplies of water for domestic use or for motels and cottage resorts. The drift aquifers have considerable potential for additional development.

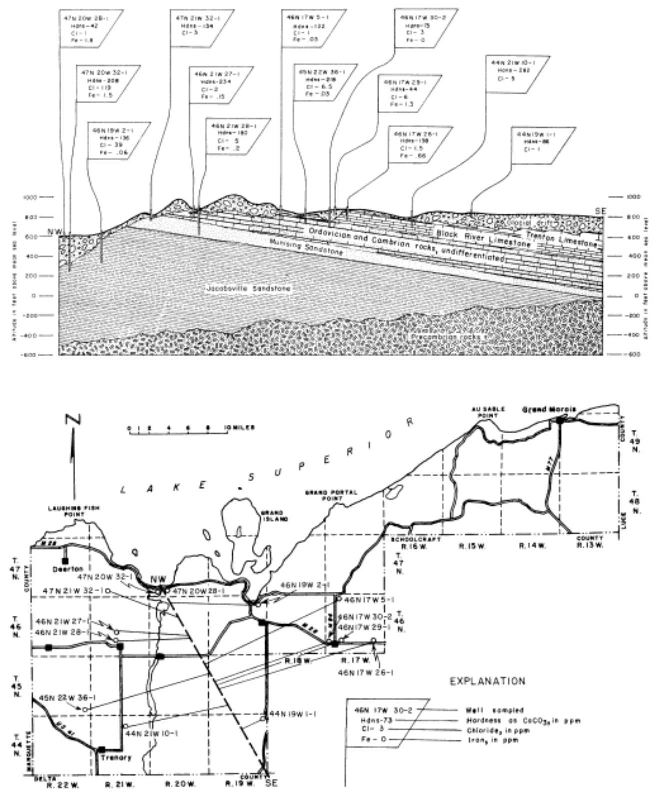


Figure 11. Generalized geologic section showing hardness, iron, and chloride content of water samples from selected aquifers.

OUTWASH. The outwash deposits are composed largely of sand, but include some gravel (fig. 12). Water moves through openings between the sand grains„ gravel, and boulders composing the outwash. Well-sorted coarse sand and gravel contains larger openings and is more permeable than sandy outwash.

The most extensive deposits of outwash underlie the Wetmore and Kingston outwash plains (fig. 4). The thickness of the outwash underlying the Wetmore plain is not accurately known, but it probably averages more than 100 feet. Well 45N 19W 5-1 in the northern part of the plain reportedly penetrated 160 feet of sand and gravel outwash. No data are available concerning the thickness of the outwash deposits of the Kingston plain but it probably exceeds 100 feet.

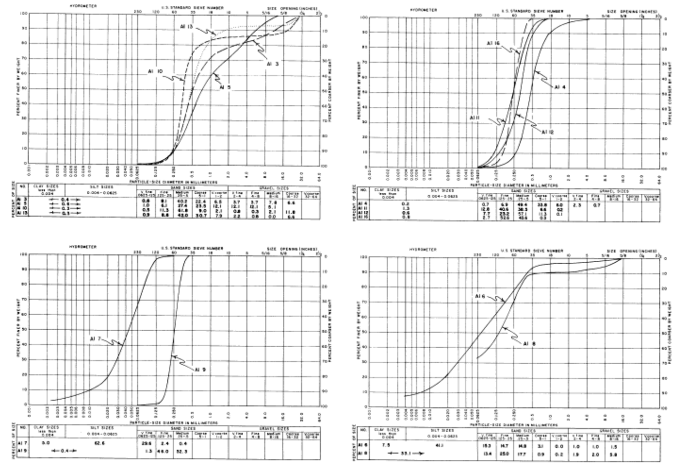
Most of the wells in the Wetmore plain are shallow driven wells equipped with sand points. Some drilled wells are equipped with screens; others are completed with the open end of the casing in coarse gravel. The wells furnish small supplies of water for domestic use, parks and recreation areas, and resort needs. Because of the small area of screen openings the maximum yield of these wells probably is in the range of 20 gpm (gallons per minute). Although there are no large producing wells tapping outwash in the county, wells yielding several hundred gpm probably could be constructed locally in these deposits.

The water yielded by outwash deposits generally is of good chemical quality, and is soft or only moderately hard. Locally, it contains objectionable amounts of iron. Iron in excess of 0.3 ppm will cause staining of plumbing fixtures and laundry.

The outwash aquifer is recharged directly from rain and melting snow. Direct runoff from the outwash plains is small, as the permeable sandy soils and subsoils permit rapid infiltration of precipitation. About 16 inches of the total annual precipitation average of 34 inches falling on the Kingston and Wetmore plains probably recharges the ground-water reservoirs; most of the remaining 18 inches is lost to evapotranspiration. The outwash aquifer is discharged principally by effluent flow to surface streams. In the southern part of the Wetmore plain the water table is close to the surface. In this area, some water is withdrawn from the ground-water reservoirs by evapotranspiration.

MORAINAL AREAS. Segments of two moraines extend into Alger County (fig. 4). The moraines can be identified by their rough, hilly topography. The Munising Moraine trends westward through the eastern part of the county to Munising, then southwestward to Forest Lake, and then south. Segments of the Newberry Moraine are in Twps. 45 and 44 N., R. 19 W.

The deposits underlying these moraines range from clayey tills of low permeability to beds of highly permeable sand and gravel. Most of the deposits, however, consist of moderately permeable sandy till. The thickness of the glacial materials in the morainal areas varies considerably. Where the higher hills of the moraine overlie bedrock valleys or depressions, the drift is over 300 feet thick. Where morainal hills overlie bedrock highs, the drift commonly is only a few tens of feet thick. Well 45N 20W 5-2 (table 3), near Forest Lake, penetrated 219 feet of drift without reaching bedrock. Well 46N 20W 36-1, near Stillman, penetrated 138 feet of drift. The glacial drift probably is about 100 to 150 feet thick throughout most of the morainal areas.



EXPLANATION

Al 3. Sand and gravel outwash from road cut in the SE¼ of SW¼ sec. 30, T. 48 N., R. 16 W. Permeability = 920 meinzers.

Al 4. Sandy outwash from pit in SE¼ of SW¼ sec. 19, T. 46 N., R. 17 W. Permeability = 1400 meinzers.

Al 5. Sand and gravel outwash from pit in SE¼ of SW¼ sec. 19, T. 46 N., R. 17 W. Permeability = 490 meinzers.

Al 6. Clay, silt till from pit in moraine in NE¼ of NW¼ sec. 10, T. 45 N., R. 20 W. Permeability = 0.4 meinzer.

Al 7. Lake deposited sandy silt from road cut in NE¼ of NE¼ sec. 19, T. 46 N., R. 20 W. Permeability = 6 meinzers.

Al 8. Silty clay till from road cut in SW¼ of NE¼ sec. 10, T. 47 N., R. 22 W. Permeability = 0.5 meinzer.

Al 9. Sand from dune in SW¼ of SW¼ sec. 11, T. 49 N., R. 14 W. Permeability = 510 meinzers.

Al 10. Sand and gravel outwash from pit in SE¼ of SW¼ sec. 21, T. 48 N., R. 16 W. Permeability = 700 meinzers.

Al 11. Sandy outwash or wave-washed sandy moraine from road cut in SW¼ of NW¼ sec. 25, T. 44 N., R. 19 W. Permeability = 190 meinzers.

Al 12. Sandy outwash from pit in SE¼ of NW¼ of sec. 31, T. 46 N., R. 20 W. Permeability = 300 meinzers.

Al 13. Sand and gravel outwash from road cut in SE¼ of SW¼ of sec. 32, T. 46 N., R. 20 W. Permeability = 740 meinzers.

Al 16. Sandy outwash from road cut in NE¼ of SE¼ of sec. 14, T. 45 N., R. 19 W., Permeability = 380 meinzers.

Figure 12. Curves showing particle of glacial deposits size distribution of samples from Alger County.

Wells tapping the glacial drift in the moraine areas produce small supplies of water for domestic and other needs. Locally, where thick beds of sand and gravel underlie the moraine, wells yielding more than 100 gpm probably could be developed from properly constructed, large diameter, screened wells.

The aquifers underlying the moraines are recharged by local precipitation. Discharge from the aquifers is to streams draining the area and to adjacent aquifers through underground flow.

LAKE DEPOSITS. Beds of sand that were deposited in glacial lakes also are a source of water to wells. Glacial lake deposits underlie two main areas, a strip along the shore of Lake Superior and a smaller area around Shingleton (fig. 8). The lake deposits are composed principally of well-sorted fine and medium sand, but include also clayey and silty sands (fig. 12) and lenses of beach gravel. Locally, the lake deposits overlie other types of glacial drift.

The lake deposits vary considerably in thickness as they mantle an uneven bedrock surface. In the northwestern part of the county, for example, they commonly form only a thin veneer over the bedrock highs. Where valleys or depressions are present in the bedrock surface the deposits are much thicker. Well 47N 20W 32-1 penetrates nearly 300 feet of unconsolidated material, most of which probably is lake deposit. Well 48N 16W 17-1 reportedly penetrated 262 feet of lake-deposited fine red sand. Both wells were drilled over valleys or depressions in the bedrock surface. The lake deposits in the vicinity of Shingleton probably average more than 40 feet in thickness, and locally they are considerably thicker. Well 46N 18W 22-1 reportedly penetrated 225 feet of sand, most of which probably is lake deposit.

Lake-deposited beds of sand are sources of water for domestic and other needs. At the present time (1960), most of the wells tapping the lake deposits are shallow-driven wells, which commonly provide a satisfactory and inexpensive water supply. Undoubtedly, 10 to 20 gpm can be obtained from properly constructed wells tapping sandy lake deposits, and where outwash or beach-deposited sand and gravel are present wells should yield 100 gpm.

The lake deposits commonly yield water that is soft to moderately hard, though it contains objectionable amounts of iron. The iron content can be reduced to satisfactory levels by commonly used home water-treatment equipment.

The lake deposits are recharged by local precipitation. Discharge from the lakebeds is chiefly to streams and directly to Lake Superior. Where the water table is near the surface, discharge by evapotranspiration may be dominant. Natural discharge from these deposits exceeds by many magnitudes the amount of water discharged from wells. In areas along Lake Superior and near other bodies of surface water the lake deposits would be recharged by induced infiltration of surface water if the hydraulic gradient were reversed by heavy pumping.

DUNES. The dune deposits of Alger County are related to Lake Superior and ancient glacial lakes. The largest dune areas are near Grand Marias (fig. 8). Other small dune areas occur throughout and adjacent to the parts of the county inundated by the glacial lakes (fig. 3).

Dunes are composed of well-sorted, wind-blown sand (fig. 12). They generally occur above the water table and as they are not saturated, do not yield water to wells. Most of the dunes are underlain by other glacial deposits or bedrocks that are a source of water.

Dune sands are very permeable, and most of the precipitation falling on them infiltrates to recharge the underlying ground-water reservoirs.

Trenton and Black River Limestones

The Trenton and Black River Limestones are the principal source of water to wells in the southwestern part of the county and in a small area north of Shingleton (fig. 10). The formations are a potential source of water in other areas along the southern edge of the county, but are not tapped by wells because the overlying glacial deposits are a more accessible source of water.

Water moves through openings along joint fractures and bedding planes in the beds of limestone and dolomite comprising the Trenton and Black River Limestones. Some of the openings have been enlarged by solution. Apparently, some beds are much more permeable than others, and those of very low permeability act as confining layers. Where they are the principal source of ground water the formations are at or very near the surface. The drift in these areas is thin, generally of low permeability, and locally unsaturated. Many of the wells tapping the Trenton and Black River in these areas are less than 50 feet deep and most are less than 100 feet deep. The formations yield small supplies of water to wells for domestic and farm uses. Locally, more than 20 gpm can be developed from wells tapping these formations, especially where they are recharged from a nearby stream.

Water from these formations is hard to very hard and locally contains sufficient iron to cause staining. The principal quality problem, however, is one of bacterial rather than chemical quality. The filtering action that generally takes place as water moves through sand and gravel aquifers generally is not effective in limestone. The formations are at shallow depth, and organic pollutants such as barnyard wastes and septic-tank effluents infiltrate into the upper part of the formation. If the contaminated upper part of the formation is not properly sealed or closed off in deeper wells, the lower part of the formation also can become contaminated. Several wells in Trenary and Chatham have produced contaminated water.

The formations are recharged principally from local precipitation, through the overlying drift or, where the rocks are exposed at the surface, directly to the formations. Water is discharged principally by drainage to streams. The amount of water discharged naturally greatly exceeds that discharged by wells.

Ordovician and Cambrian dolomite and sandstone, undifferentiated

A thick sequence of dolomite and sandstone underlies the Black River Limestone and overlies the Munising Sandstone. The rocks of this sequence yield water to wells in the western part of the area where they crop out at the surface or beneath the glacial drift or are mantled by only a few tens of feet of the Black River Limestone (fig. 10). They are an untapped source of water in large areas along the southern boundaries of the county where they are overlain by glacial drift and the Trenton and Black River Limestones and are at considerable depth. In T. 44 N., R. 19 W., the uppermost rocks of this sequence are about 500 feet below the land surface (fig. 11).

Most of the wells that produce water from these rocks tap crevices and solution openings in the beds of dolomite. Well 46N 20W 36-1, for example, taps crevices at a depth of 240 to 245 feet. The crevices are large enough that the drill cuttings were washed into them and were not recovered. Most of the wells obtaining water from dolomite strata of this sequence are in the western part of the county. They yield small supplies of water for domestic and farm needs. The dolomite beds might yield as much as 50 gpm to wells in some areas.

Some wells in Alger County produce water from sandstone strata in this rock sequence, as do deep wells in Luce, Mackinac, Schoolcraft, and Delta Counties. The exact thickness and areal extent of these sandstone beds is not known. Wells 46N 17W 30-1 and 30-2 tap beds of sandstone and dolomite which apparently lie just below the base of the Black River Limestone.

Apparently, the sandstone beds in the upper part of the sequence become thinner or are not present in the western part of the county. Some wells producing water from these rocks also obtain water from the underlying Munising sandstone, and some wells obtain part of their water from the overlying Black River Formation.

Wells tapping the dolomite and sandstone of this sequence yield water of good chemical quality. Water from the dolomite tends to be harder than that from the sandstone. Both the dolomite and sandstone yield water softer than that from the Trenton and Black River Limestones and harder than that from the Munising Sandstone.

The aquifers in this sequence are recharged principally from precipitation falling on the area where the rocks outcrop or subcrop beneath the glacial drift. They are recharged also indirectly from the overlying glacial drift. Discharge is principally to local streams; however, some water moves southward out of the county by underflow and is discharged through interaquifer leakage or to wells in adjacent counties.

Munising Sandstone

The Munising Sandstone underlies nearly all of the county. It is a potential source of water throughout its area of occurrence (fig. 10), but it is tapped by wells only where it outcrops or subcrops beneath the glacial drift (fig. 5). The Munising dips to the south and southeast at about 30 feet to the mile (fig. 13). The top of the formation is about 700 feet below the surface in T. 44 N., R. 19 W. (fig. 11).

Water moves through openings between the sand grains of the Munising. The formation is of moderate permeability as it is made up of well-sorted sands (fig. 6) and is not well cemented.

Although the Munising Sandstone forms the most extensive aquifer, it is tapped by only a few wells. This apparent paradox is due to the fact that in most of the area, it is overlain by other aquifers that can be tapped at less cost, and the areas where it is at shallow depth are sparsely populated. The Munising will provide small to moderate supplies of water to wells in most of the county, but extensive development is not likely because it is overlain by other aquifers. The formation yields water of good chemical quality. The water is moderately hard, but can be softened by commonly used water-softening equipment.

The aquifer is recharged by precipitation in the area of outcrop or sub-crop. Although some recharge to the formation occurs directly on the outcrops, most of the recharge water moves through the overlying glacial drift.

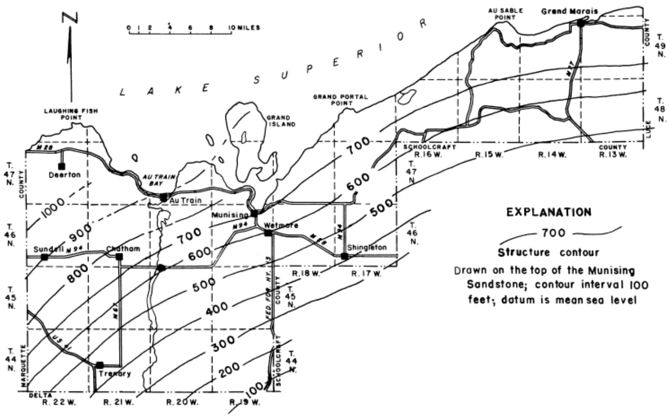


Figure 13. Generalized contours on the top of the Munising Sandstone (after Hamblin, 1958, fig. 75).

Jacobsville Sandstone

The Jacobsville Sandstone underlies all of Alger County, though in much of the county it has little potential as a source of water. In areas along Lake Superior, however, it is at or near the surface (fig. 10) and is important as the only source of water to wells. Most wells tapping the Jacobsville are less than 100 feet deep, a few are much deeper. Well 49N 13W 5-4 was drilled to a depth of 1200 feet, 1100 feet of which was in the Jacobsville Sandstone. It was not reported if permeable zones were encountered in the lower two-thirds of this well.

The Jacobsville is a well-cemented sandstone, and its primary permeability is therefore very low. The formation is somewhat permeable as a result of openings along joint fractures and bedding planes, and where it is exposed or is near the surface it is extensively fractured and permeable. At depth the openings are small because of the pressure of overlying rocks, and the permeability of the formation is decreased.

Water from the Jacobsville generally is moderately hard to hard, and locally it contains objectionable amounts of iron. The iron content can be reduced to satisfactory levels with commonly used water-treatment equipment. Wells at Deerton, Shelter Bay, and near Au Train produced salty water from the Jacobsville. The salt water occurs in an area that is an extension of a fault zone mapped by Thwaites (1935). A similar occurrence of salt water in Chippewa County is also believed to be related to deep faulting (Vanlier and Deutsch, 1958, p. 48). A fault zone would provide an avenue for salt water migrating from the Michigan Basin. Apparently, the salt (chloride) content increases with depth. For example, wells 47N 21W 16-1, 3, and 4 at Shelter Bay are 110 feet or less in depth and yield fresh water. Well 47N 21W 16-2 in the same area is 144 feet deep and it yielded salty water. Well 47N 20W 28-2 produced fresh water when drilled, but after several years produced water containing 1800 ppm of chloride (table 4). Wells drilled in the western part of the area where the Jacobsville is the principal source of water (fig. 10) should be completed at as shallow a depth as is practicable to prevent salty water from entering the well.

The Jacobsville Sandstone is recharged from precipitation and discharges by underflow to surface streams and to Lake Superior.

SUMMARY AND CONCLUSIONS

Alger County is rich in water resources. Lake Superior provides a nearly unlimited supply of water along its shoreline, several streams in the county provide a large potential supply, and the ground-water reservoirs in much of the county will yield several tens to several hundreds of gallons of water per minute. Thus, the water resources of the county are more than ample for any anticipated or foreseeable industrial or other economic growth.

Rain and snow are the initial source of the ground water. Precipitation infiltrates to the ground-water reservoirs, runs off to the streams, or returns to the atmosphere by evapotranspiration. There is little or no surface runoff from some large areas, as all the precipitation infiltrates or returns to the atmosphere.

Sandy outwash plain and moraine uplands are areas of greatest ground-water recharge. Water moves downgradient from the areas of recharge and is discharged, via springs and seeps, to surface streams and to lakes. Stream-flow records in the eastern part of the Upper Peninsula indicate that on the average more than 6 inches of precipitation is recharged annually to the ground-water reservoirs of the county.

The county is underlain by several aquifers that will yield 5 to 10 gpm to individual wells in nearly all the county, as much as 50 gpm in much of it, and more than 100 gpm in many small areas. Most of the ground water is of generally satisfactory chemical quality, although most wells produce hard or moderately hard water and some produce water containing objectionable concentrations of iron. The hardness and iron content generally can be reduced to satisfactory levels by commonly used water-treatment equipment.

Water containing undesirable amounts of chlorides (salty water) is produced from some of the wells tapping the Jacobsville Sandstone in the northwestern part of the county. High-chloride water cannot be treated economically. Fresh water can be obtained in these areas by completing wells at shallow depth, either in the upper part of the Jacobsville or in the overlying glacial-drift aquifers.

Water contaminated with septic tank-effluents and other pollutants is present in a few areas of the county. In most of these areas, water of good quality can be obtained from wells tapping deeper aquifers.

The development of water-supply systems that would produce more than 50 gpm from a well would probably call for detailed investigations at the sites. Test drilling and aquifer tests would be needed to determine the quantity of water obtainable.

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