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DIVISION OF GEOLOGICAL SURVEY
Horace R. Collins, Chief

Information Circular No. 41

HYDROGEOLOGIC AND OTHER CONSIDERATIONS RELATED TO THE SELECTION OF SANITARY-LANDFILL SITES IN OHIO

by

Gerald H. Groenewold

Columbus
1974

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GEOLOGY SERVES OHIO

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HYDROGEOLOGIC AND OTHER CONSIDERATIONS RELATED TO THE SELECTION OF SANITARY-LANDFILL SITES IN OHIO

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ABSTRACT

The landfilling method of disposing of solid wastes is widely practiced in Ohio. Proper selection of landfill sites is of major concern. Infiltration of precipitation through the landfill cover resulting in the production of highly toxic leachate is inevitable in the humid Ohio climate. The production of various gases is common also.

Leachate can, under certain conditions, enter ground-water aquifers near the base of the landfill. If the site is properly chosen, natural processes of filtration and purification will minimize the threat to ground-water quality. Major considerations include the topography and hydrogeology of the proposed site as well as the availability of suitable cover materials.

Flat to gently sloping upland areas are generally better suited than lowlands and steep slopes. Dry fine-textured materials are the most effective natural filtering agents. Saturated coarse-textured materials and fractured rocks are very ineffective as filtering agents. However, depth to the water table is generally not as important as the texture of the materials. Extremely fine-textured materials may act as impermeable membranes and eliminate all downward movement of leachate; under such conditions surface seeps may form around the landfill. Proper selection of cover materials will decrease infiltration into the landfill as well as help to eliminate the lateral migration of gases from the site.

Utilization of existing geologic, soil, and ground- and surface-water information in conjunction with on-site investigation is of utmost importance in the proper selection of disposal areas. Sites having natural safeguards and not requiring excessive alteration are abundant in most areas of Ohio. In some localities leachate collection and treatment may be necessary to assure safe disposal.

INTRODUCTION

Open burning and dumping of refuse have been illegal in Ohio since July 1969. The most logical alternative for the disposal of large quantities of solid waste, at least at the present time, is the sanitary landfill. The sanitary-landfill method requires that the refuse be compacted and covered daily with a compacted layer of at least 6 inches of earth material, preferably of low permeability.

Two landfilling methods are used currently: the area method and the trench method. The area method involves spreading and compacting the waste on the original ground surface (fig. 1). Cover material is then spread and compacted over the refuse. This type of landfilling is used on flat to gently sloping surfaces as well as in natural and manmade depressions such as ravines and strip mines (Brunner and Keller, 1972, p. 29). Lack of sufficient amounts of suitable cover materials may limit the use of this type of landfill in some areas.

The trench method involves the excavation of a trench or series of trenches into which the waste is dumped, compacted, and covered (fig. 2). Trench-type landfills are generally restricted to flat or gently rolling areas. Cover material is readily available as a result of the excavation.

Whichever method is used, it is essential that easily excavated materials be available. Unconsolidated materials are the most easily worked; most bedrock, with the possible exception of shaly material, is therefore undesirable. The two methods of landfilling are not mutually exclusive and in many places are used in combination. This is especially true at sites where there is variability in the thickness of suitable cover materials.

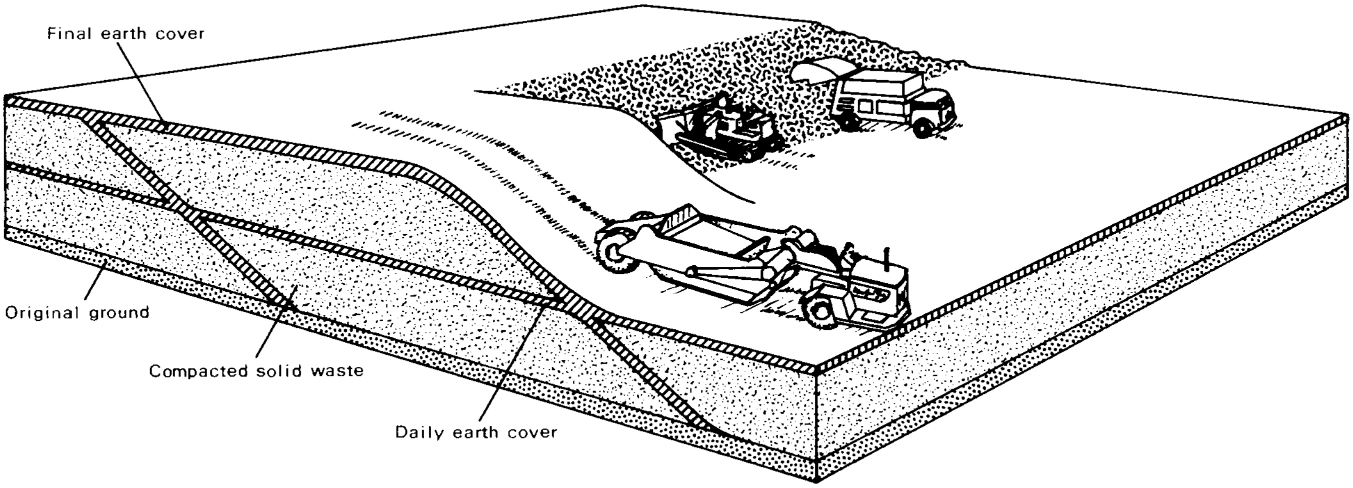


FIGURE 1.—Area method of landfilling (from Lewicke, 1972).

A properly run sanitary landfill eliminates most of the problems commonly associated with open dumps. Such problems include the breeding of insects and rodents, burning, and the scattering of refuse by the wind. However, great caution must be exercised in the selection of a landfill site.

The purpose of this report is to discuss the hydrogeologic and topographic considerations that relate to the selection of sanitary-landfill sites in Ohio. The possibility of contamination of surface and ground water by the landfill is the most important consideration in the site-selection process. If the buried refuse comes in contact with water, even intermittently, the resulting leachate has a high concentration of dissolved solids and acts as a transporting medium for bacterial pollutants. The leachate can, in turn, degrade the quality of the surrounding ground and surface waters. Regulation HE-24-04 (A) of the Ohio Sanitary Code (Ohio Department of Health, 1969) states: "Solid waste disposal sites and facilities shall not be located in areas where they constitute a hazard to the quality of the ground water or surface water resources or create a health hazard." In addition, HE-24-04 (B) states: "No person shall place or dispose of solid wastes in any ditch, stream, river, lake, pond, or other watercourse, except those waters which do not combine or effect a junction with natural surface or underground waters, or upon the banks thereof where the same is liable to be washed into the water by ordinary flow or annual floods. This division does not apply to the placing of any substance under authority of a permit issued by the water pollution control board."

In a humid climate such as we have in Ohio essentially any landfill, no matter where it is located, will produce leachate either from infiltration of precipitation

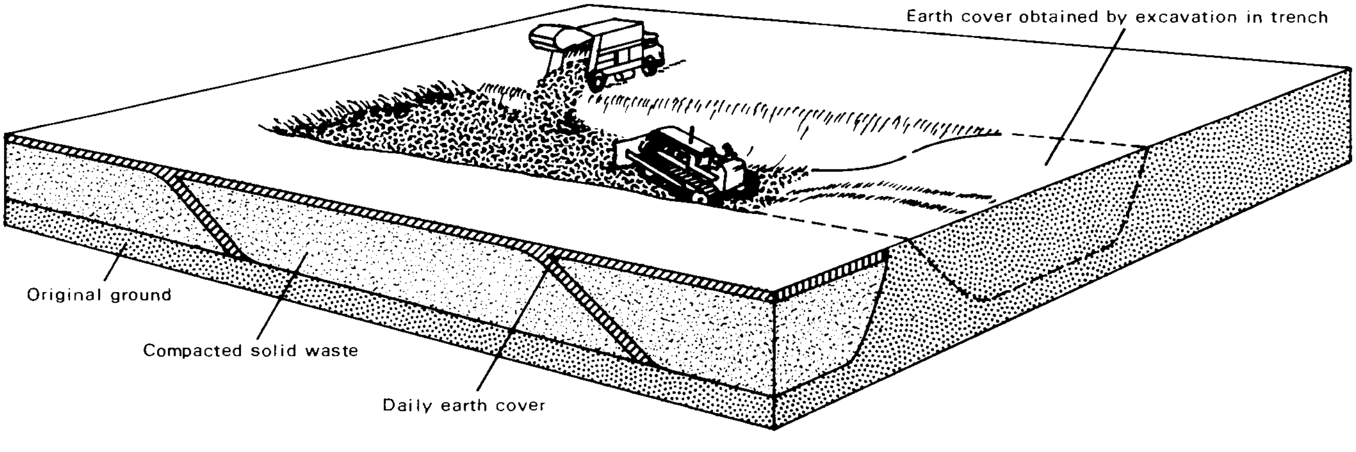


FIGURE 2.—Trench method of landfilling (from Lewicke, 1972).

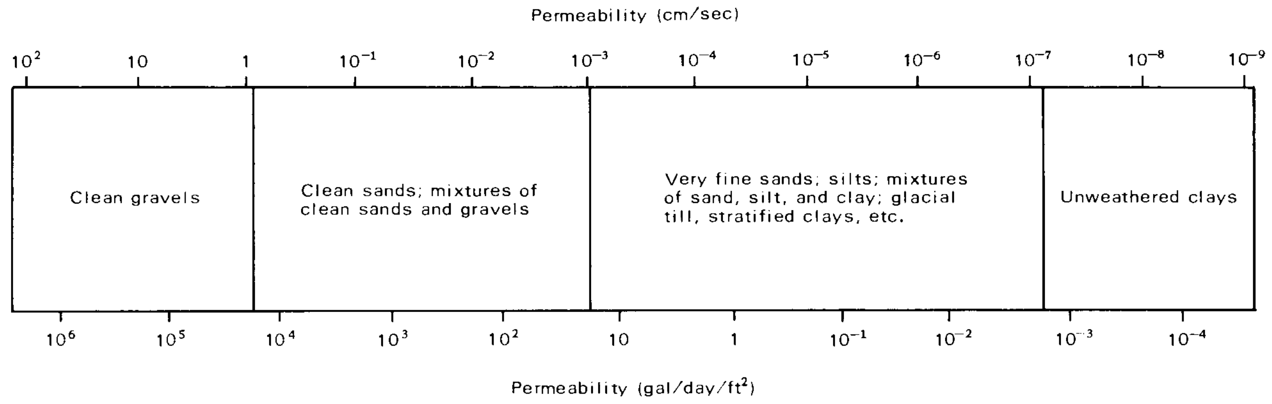


FIGURE 3.—Ranges in permeability of various unconsolidated sediments (modified from Todd, 1959, p. 53).

through the cover or from contact with ground water (Apgar and Langmuir, 1971, p. 78; Emrich and Landon, 1969, p. 10). Ideally, the objective is to locate the landfill in such a way within the hydrogeologic system that the amount of leachate produced is minimized and its migration through the system is retarded, thus allowing more time for natural purification of the leachate.

CONSIDERATIONS FOR SITE EVALUATION

Hydrogeology

Essentially all earth materials have pores or void spaces. When these voids are completely filled with water the material is said to be saturated. The uppermost extent of this zone of saturation is the water table. The earth materials above the water table constitute the zone of aeration and are characterized by only partial filling of void spaces by water. Under natural conditions the depth to the water table at any particular place depends upon seasonal fluctuations in the amount of precipitation moving down through the zone of aeration.

If the pores in the zone of saturation are interconnected the water can move from one point to another. The greater the size and interconnection of pore spaces, the greater the permeability of the materials. Earth materials can generally be divided into two groups—unconsolidated and consolidated or bedrock. Examples of unconsolidated earth materials having high permeabilities are coarse sands and gravels. Silts and clays, because of their small pores and interconnecting openings, typically have low permeabilities. Figure 3 shows ranges in permeability for various unconsolidated sediments.

Dense rigid consolidated rocks such as most limestone, shale, and granite are essentially impermeable unless they are transected by fractures and joints. Under fractured conditions large amounts of water can be transmitted through these materials. This is especially true of limestones, in which large cavities may form owing to solution of the rock by water moving along fracture surfaces. Sandstones, on the contrary, are typically highly permeable even when unfractured and are a major source of water in many areas.

Figure 4 demonstrates, in a simplified fashion, the way in which water moves down to the zone of saturation (recharge) and subsequently to areas of discharge. The ground water may either be discharged locally, as in a swamp or small stream, or may continue to percolate downward and be incorporated into the regional flow system, thus moving toward major discharge areas such as large streams or lakes. Leachate from a landfill is incorporated as an integral part of the hydrologic system, moving with the ground water. If we are to control the leachate we must be able to predict its path of movement.

The movement of ground water through porous materials is fairly predictable. However, fractured rocks do not lend themselves to easily predicted flow paths, and only very limited speculation can be made regarding ground-water movement in such materials. Areas that are underlain by fractured and jointed rocks are therefore very problematic with regard to the selection of landfill sites and should be avoided if possible.

The three most important hydrogeologic factors which affect landfill sites are the texture and composition of the surrounding materials, the position of the refuse relative to the water table, and the position of the landfill within the ground-water flow system (Hughes, 1972, p. 2). An intelligent selection of sites is impossible without an understanding of these factors.

Texture and composition of the materials.—A landfill site should be located in such a way that natural purification of the leachate can be maximized. Natural attenuation of contaminants is effected by the processes of filtration, adsorption, biodegradation, and ion exchange. The texture and composition of the surrounding materials largely control these processes,

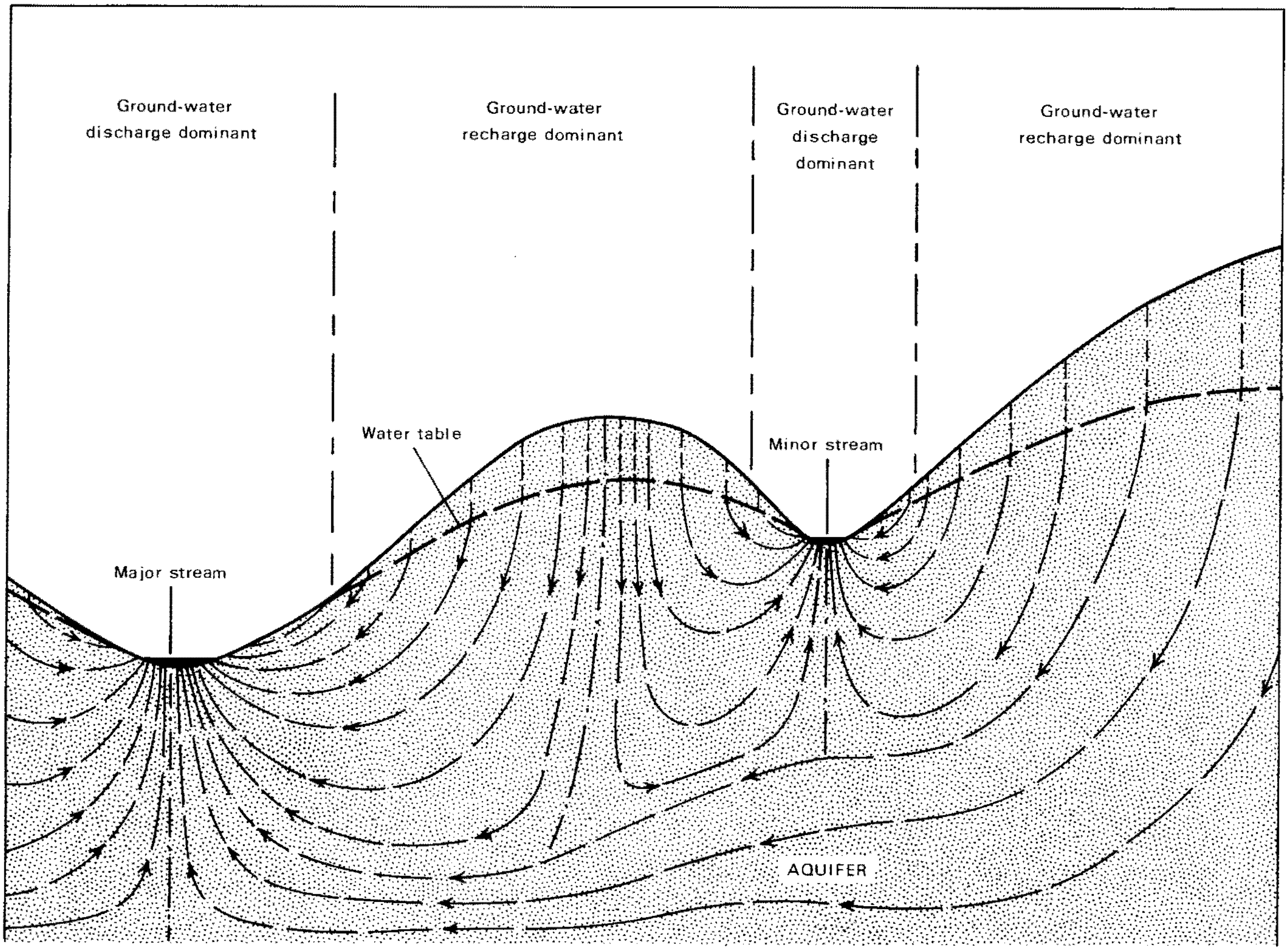


FIGURE 4.—Idealized cross section showing ground-water flow lines in a homogeneous material (modified from Otton, 1972, p. 14).

which have been found to be much more efficient in the zone of aeration than below the water table (Apgar and Langmuir, 1971, p. 93). Hughes and others (1971, p. 24) have found that dissolved solids in leachate are reduced by approximately equal amounts after traveling through either 5 feet of sandy clay till (permeability approximately 10^{-7} cm/sec) or 600 feet of sand and silt (permeability approximately 10^{-3} cm/sec). Inorganic and refractive organic ions can travel much greater distances than organic ions and therefore are the most difficult to dissipate. This is especially true of chloride, which is used commonly as an indicator of leachate movement away from a landfill (Emrich and Landon, 1969, p. 10).

Most studies of natural purification of leachate have involved only the zone of saturation. According to Brunner and Keller (1972, p. 5) the distance that contaminants travel within the saturated zone "depends on the composition of the soil, its permeability, and the type of contaminant." Fine-textured materials such as clay, silt, sandy shale, siltstone, and boulder clay (glacial till) are the most effective in removing dissolved solids. The rate of movement through such materials is low because of low permeabilities, thus allowing for maximum leachate filtration. Also, clay content is usually higher in fine-grained materials; therefore ion-exchange capacity is greater. Higher rates of movement in sand, gravel, and sandstone result in much less effective retention of dissolved solids. Even less effective are fractured rocks where high rates of ground-water movement are possible. However, this should not be misconstrued to mean that the finer the texture of the materials, the greater the filtration capacity. Certain shales, for example, have extremely low permeabilities and will act as essentially impermeable membranes, eliminating all downward movement of the leachate. The leachate will move along the upper surface of the impermeable unit, resulting in surface seeps around the landfill. These problems will occur in any locality where impermeable materials are present. In such locations, tile drainage fields should be installed in order that leachate can be collected and treated (Lessing and Reppert, 1971, p. 6).

Position of the refuse relative to the water table.—The position of the bottom of the refuse relative to the water table is important. If the refuse is placed below the water table, large amounts of leachate will be produced and major ground-water contamination may result. If the refuse is placed above the water table, ground water cannot contribute to the production of leachate. However, infiltration through the cover will result in the production of at least some leachate. It is therefore generally advisable to place the refuse as far above the water table as is feasible, thereby allowing for as much natural filtering as possible. As previously mentioned, natural purification is much greater in the zone of aeration than below the water table. This is due to the fact that aerobic degradation of leachate is much faster and more complete than anaerobic processes. The minimum amount of relatively impermeable material between the refuse and the water table as suggested by various researchers varies greatly: estimates range from 5 to 30 feet. Because of the climate, at least 25 feet of separation is advisable in Ohio. In addition a landfill should not be within 500 feet of any dug water well that is in use (Cartwright and Sherman, 1969, p. 12).

It should not be concluded, however, that burial above the water table is always best. Apgar and Langmuir (1971, p. 73) state that under humid conditions "location of landfills above the water table in permeable soils and rock may result in more serious ground water pollution than deposition of the same wastes in an impervious zone below the water table." What this means is that the permeability of the surrounding earth materials may be a more important consideration in the evaluation of a landfill site than the position of the water table. Although large amounts of leachate would be produced by burial below the water table, the contaminants would be contained by the impervious materials and would not do nearly the damage to the regional ground-water quality that might occur if leachate were allowed to migrate down from the refuse to the water table through highly permeable materials.

Detailed hydrogeologic studies of four landfills in northern Illinois are discussed by Hughes and others (1971). The four sites are located in glacial material, mostly silty clay, having low permeabilities (10^{-3} to 10^{-7} cm/sec), and of a character similar to that of the till materials which are found in much of the glaciated portion of Ohio. The climate in Illinois is very similar to that of Ohio, and the conclusions of these authors are therefore very applicable to this state. At three of the Illinois sites the water table was intersected by the refuse. The study indicated, however, that no appreciable ground-water contamination had resulted at any of the four sites except in the immediate vicinity of the landfills; contamination dissipated rapidly away from the landfill. Hughes and his coworkers concluded: "Sanitary landfill designs in most of northeastern Illinois need not include protective measures to prevent ground water pollution, because the hydrogeologic environment is naturally protective." The same should apply in this state. The optimum site would of course fulfill both conditions—materials having low permeabilities (less than 10^{-3} cm/sec) and a relatively deep water table (greater than 25 feet). In many areas of Ohio such favorable sites are available. If not, the permeability of the materials should be of primary concern.

A common problem of landfills in humid areas is the formation of ground-water mounds below the landfill. These are discussed in some detail by Hughes and others (1971, p. 41). Such mounds are common if the refuse intersects the water table, particularly if the surrounding materials have low permeabilities (less than 10^{-3} cm/sec). The mound forms because more water is infiltrating through the landfill cover than can move out from the sides and base of the landfill. The effect of such mounding is to cause the ground-water gradient to be away from the landfill. Thus, even if the water is intersected, only that water which is infiltrating through the landfill cover can contribute to the production of leachate. Springs and seeps are likely to form around the landfill, especially if the refuse is mounded above the surrounding land surface. The leachate from these springs and seeps may constitute a very serious hazard to the quality of surface waters in the immediate vicinity of the landfill.

The logical way to eliminate mounding is to decrease, as much as possible, the amount of precipitation and surface flow which infiltrates the landfill cover and to keep the refuse above the water table. If this is impossible, then draining and collecting the leachate by emplacement of tiles and well points in the refuse may be the only solution.

Most of the previous discussion has been concerned with the relationship of the refuse to ground water. The interaction between the refuse and surface water is equally important. Since the major objective is to keep the refuse as dry as possible, surface flow must be kept from entering the landfill. A landfill should not be located in an area which is subject to flooding. Not only would the landfill be saturated during floods but actual uncovering and scattering of the refuse is highly probable. For similar reasons the lower reaches of gullies and ravines are also very poor sites. In addition, if the landfill is to be located on a slope, as much surface drainage as possible should be diverted from the site. Water bodies such as lakes, ponds, and water-filled quarries and mines should be avoided as landfill sites.

Position of the landfill within the ground-water flow system.—An understanding of the flow system in the vicinity of the site is essential. If, for example, the refuse is placed within an area of ground-water recharge, leachate will move downward with the ground-water gradient, and dissolved solids could be incorporated into underlying aquifers. Under such conditions recovery of the pollutants would be nearly impossible. Therefore, if the site is in a recharge area, materials having permeabilities less than 10^{-3} cm/sec and a water table greater than 25 feet deep are essential if the ground-water quality is to be maintained.

If the landfill is located within a ground-water discharge area a much different situation will result. In discharge areas the ground-water gradient is upward, and contaminants are unlikely to reach underlying aquifers, even if the materials are highly permeable. However, because discharge areas are commonly associated with a surface body of water such as a lake, stream, or swamp, there is a pollution threat to these waters. The fact that the contaminants remain at the surface, however, makes for much easier monitoring and control than in recharge areas. Such a situation could be used to great advantage if leachate collection and treatment is considered: the natural flow system could move the leachate to a collection point, thus facilitating treatment. Also, mixing and dilution are more rapid in surface waters than in ground water because surface water is typified by turbid flow as opposed to nonturbid flow in ground water. The refuse should be placed in a situation such that maximum purification can occur before the leachate is incorporated into the flow system.

Cover materials

Information regarding the proper selection of cover materials is very limited. Coarse materials such as sand and gravel are obviously very poor because of their high permeabilities. Extremely fine-textured materials such as certain shales may be subject to cracking upon drying, thereby allowing for rapid movement of water into the refuse (Emrich and Landon, 1969, p. 3). Mixtures of sand, silt, and clay are therefore generally the most suitable. In glaciated areas most tills are acceptable as cover materials. In unglaciated areas suitable materials are generally much less abundant: soils derived from fine-textured materials are the most likely source for these purposes. However, the soils are often of insufficient thickness to supply the amount of cover needed. Soil, as used here, refers only to that material which differs from the underlying rock material as a result of interactions between climate, living organisms, parent materials, and relief. The lower limit of a soil therefore is the lower limit of rooting of the common perennial plants. Soil surveys of the various counties are helpful in determining the characteristics and distribution of these materials and should be used in conjunction with other information when locating landfill sites in the unglaciated portion of the state.

Topography

Topography is a major factor in the selection of landfill sites. Included are considerations such as slope stability, accessibility, and drainage. In Ohio the unglaciated portion, which is largely in slope, is the most problematic from the standpoint of topography. Most flat-lying areas are stream bottoms, which are often subject to flooding and are therefore unsuitable.

Steep slopes, which are unstable in many cases and which lack suitable cover material for the landfill, should generally be avoided. A moderate slope, on the contrary, may be a very fine site, assuming that it is easily accessible and that sufficient cover material is available. Infiltration is generally less on a slope than on a flat valley bottom. Landfills located on valley bottoms are likely to produce anaerobic leachate which, as previously mentioned, is highly contaminated as opposed to leachate produced by aerobic conditions, which are more likely to be present in a landfill located on a hillslope (Apgar and Langmuir, 1971, p. 92-93).

Natural closed depressions should be avoided; these are generally catch basins for precipitation and often contain standing water during wet seasons, if not the year around. Manmade depressions such as clay pits, strip mines, and sand and gravel quarries are tempting locations for the disposal of wastes. Strip mines and clay pits, if dry, are generally suitable as landfill sites. After filling, such sites can in many cases be reclaimed for useful purposes such as parks or golf courses.

In sharp contrast are sand and gravel quarries which, even if they are dry, are generally not good locations. The permeability of the surrounding materials is commonly very high and contamination of ground water is very likely. Exceptions do exist, however. If the sand and gravel deposit is an isolated body within low-permeability materials such as boulder clay (glacial till), such a site may be suitable.

Landfill gases

A problem associated with the decomposition of buried organic refuse is the production of various gases. Methane and carbon dioxide are the predominant gases (U.S. Department of Health, Education, and Welfare, 1969, p. IX-4). Hydrogen sulfide is generally present in lesser amounts. Methane is a hazard in that it is highly explosive. Carbon dioxide is a problem because mineralization of the ground water can result if the carbon dioxide dissolves and forms carbonic acid.

The movement of gases from a landfill is regulated by the permeability characteristics of the earth materials around the landfill. Thus fine-grained cover materials will greatly hinder the escape of gases and may result in horizontal movement from the landfill. Such migration is likely if permeable unsaturated materials are present around the landfill. Buildings near the landfill might act as traps for the gas and thus a very dangerous situation can result. Studies in California (U.S. Department Health, Education, and Welfare, 1969, p. IX-5) suggest that the best solution to the problem of horizontal gas movement is venting under and in buildings which are located on or near the landfill site. Hughes and others (1971, p. 61) suggest venting and burning of the gas as another possible method of eliminating potentially explosive accumulations. This would be unnecessary, however, if the landfill cover is sufficiently permeable to allow for escape of the gases, thereby decreasing the probability of horizontal movement away from the landfill. Obviously, a conflict is involved here: increased permeability of the cover permits increased infiltration and production of leachate. The best solution is to keep the site as far from buildings as possible.

This discussion is possibly a bit confusing, but for good reason. It should help to demonstrate that the selection of a good sanitary-landfill site is not an easy process. Detailed examination of every proposed site is essential. It should be painfully clear that generalizations with regard to site selection have no place in this process.

The previous discussion has been directed toward the construction of landfills such that natural safeguards will be the major factors involved in protecting the quality of the environment around the site. Any procedure which might help to increase the purification of leachate should be considered. Apgar and Langmuir (1971, p. 93) suggest leaving undisturbed strips of land between landfill cells, thereby allowing for increased fresh recharge into the subsurface and increased dilution and oxidation of leachate. They suggest also that concrete demolition wastes be placed in the bottom of landfill trenches. The wastes would help to raise the pH of the leachate, with a corresponding increase in base-exchange capacity of the materials and therefore an increase in adsorption of various cations in the leachate. These are fairly simple procedures which involve little expense. Actually, if the expense of placing impervious liners under the refuse and recovering the leachate for treatment can be rationalized, a sanitary landfill can be constructed almost anywhere. Hughes (1972, p. 10-17) gives a good discussion of some of the engineering techniques involved. It must be remembered, however, that when a sanitary-landfill site has been totally filled and a new site is chosen it is not possible merely to "turn off the valve" and stop the discharge of leachate at the old site. The length of time required for stabilization of the refuse varies greatly and depends upon various factors, including type of refuse, available moisture, and method of burial. Stabilization may take place in a few years, but some sites are not yet stabilized after 30 years (Hughes and others, 1971, p. 4). Therefore if leachate recovery and treatment is necessary at a given site it must be considered as a long-range project. Location of such a site near a permanent sewage disposal plant might be a logical solution. However, the expense of collection and treatment of leachate should seldom be necessary in Ohio: sites which do not require excessive alteration are fairly abundant in the state.

All the previously discussed criteria are summarized in table 1.

Sources of information

Information pertinent to the siting of landfills can be obtained from various state and federal agencies. Geologic maps of various portions of Ohio are available from the Ohio Division of Geological Survey. Geologic information for certain areas is available also from the U.S. Geological Survey. Data on ground and surface water are available from the Ohio Division of Geological Survey and the U.S. Geological Survey. Data on the levels and frequency of floods are available through the U.S. Geological Survey, U.S. Army Corps of Engineers, and the Ohio Division of Geological Survey. This information should be utilized in evaluating sites on or near floodplains. Topographic maps at a scale of 1:24,000 are available for the entire state of Ohio and may be obtained from the Ohio Division of Geological Survey. Soils data are available from the Ohio Division of Lands and Soil and the U.S. Soil Conservation Service. Unfortunately, either through lack of awareness or through lack of concern, this valuable information has been ignored in many cases and poor planning has resulted.

STARK COUNTY AS AN EXAMPLE

Location

The location of Stark County and its position relative to the glacial boundary are shown in figure 5. Several reports exist regarding the geology and water resources of the county. Harker and Bernhagen (1943), Schaefer and others (1946), and DeLong and White (1963) are among the more recent. In addition, a sanitary-landfill location study (Stark County Regional Planning Commission, 1969) analyzes the suitability of various strip mines within the county as possible landfill sites. A detailed soil survey of Stark County is available also (Christman and others, 1971); this report indicates the suitability of the various soil types for sanitary-landfill purposes.

Climate

The climate in Stark County is fairly representative of the entire state of Ohio. At the Akron-Canton

TABLE 1.—*Summary of criteria for evaluating landfill sites*

Criterion	Description	Evaluation
Unconsolidated materials	Silty clay, silt, boulder clay (till)	Favorable
	Sand, gravel	Unfavorable
Consolidated materials	Sandy shale, siltstone	Favorable
	Shale, unfissured limestone	Questionable
	Sandstone, fissured limestone	Unfavorable
Thickness of relatively impermeable materials between water table and bottom of refuse	25 feet or more	Favorable
	Less than 25 feet	Questionable
Topography	Flat upland areas, moderate slopes, heads of gullies and ravines, dry strip mines	Favorable
	Closed depressions where water accumulates, steep slopes, floodplains, lower reaches of gullies and ravines	Unfavorable
Water sources	Deep bedrock wells, sand and gravel wells where aquifer is overlain by impermeable cover, dug wells if at least 500 feet from the landfill	Favorable
	Shallow bedrock wells (fissured limestone particularly unfavorable), sand and gravel wells where aquifer has little or no impermeable cover, any dug well within 500 feet of the site	Unfavorable

airport, just northwest of Canton, the average annual precipitation for the 30-year period ending in 1960 was 36.43 inches; the state range for the same period was from a minimum of 30.50 inches at Toledo to a maximum of 44.35 inches at Wilmington (U.S. Department Commerce, 1962).

Geology

Pre-Quaternary systems represented in Ohio are shown in figure 6. A classification of Quaternary deposits is shown in table 2, along with a brief description of each. Those materials found at or near the surface in Stark County and which are therefore pertinent to this report include various units of Pennsylvanian and Quaternary ages. At the back of this report is a map (pl. 1A) of the Pennsylvanian materials of the county and a map (pl. 1B) of the Quaternary materials. These two maps will be referred to often during the following discussion.

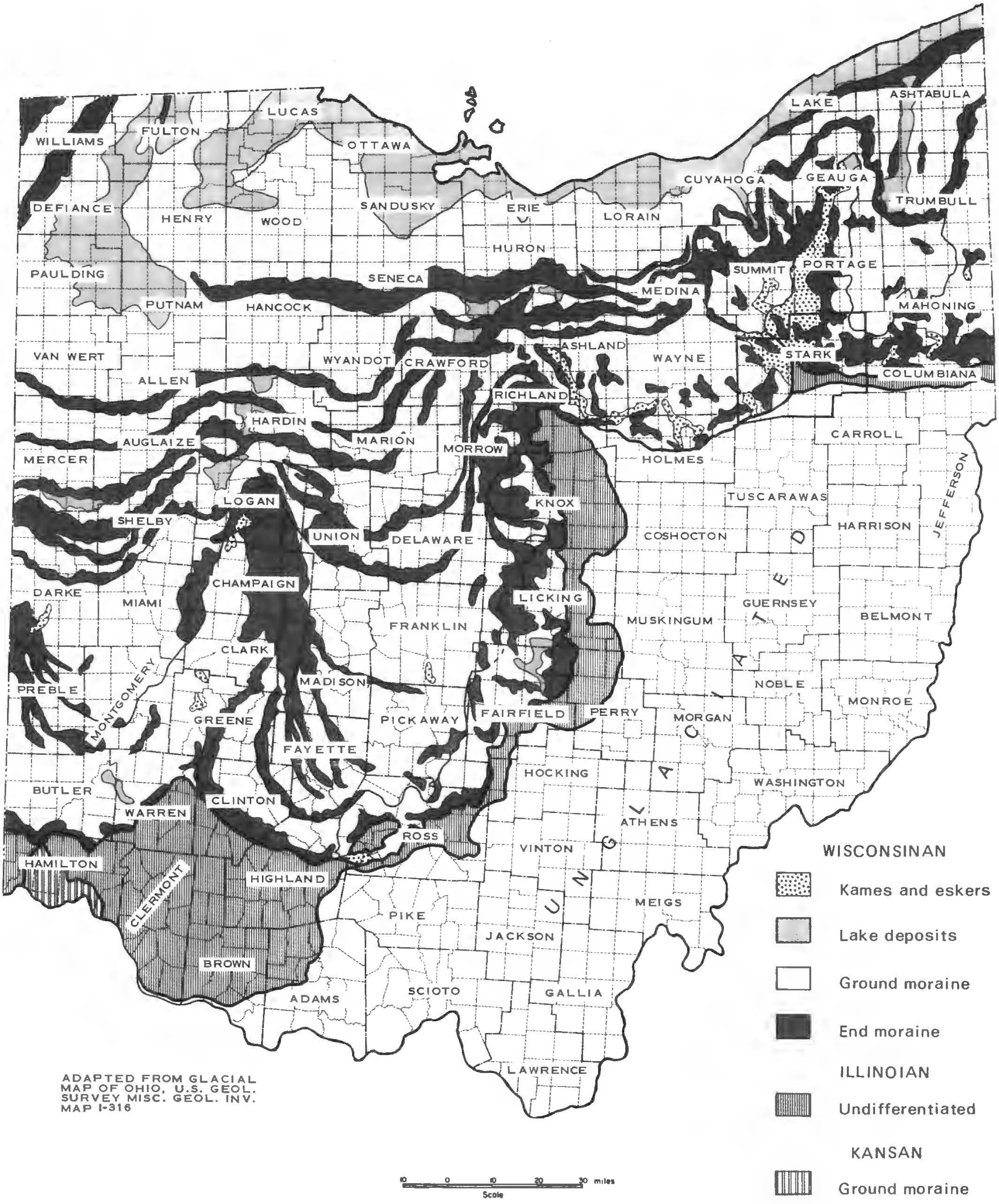
Unglaciated areas

General statement.—The unglaciated southeastern corner of Stark County is approximately one-eighth of the county area and is representative of most of the unglaciated areas of Ohio. The topography is especially characteristic.

The vast majority of the geologic units exposed in the unglaciated area of Ohio are alternating and gradational sandstones and shales with a few coal, clay, and thin limestone beds. Included within this broad category are units of Devonian, Mississippian, Pennsylvanian, and Permian ages (fig. 6). The only important exception is the southern portions of Adams and Brown Counties (fig. 6), where limestone and interbedded limestone and shale of Ordovician and Silurian ages are exposed. In this particular area extreme caution is necessary if proper landfill sites are to be chosen; the limestones are characteristically jointed and fractured, and it may be nearly impossible to find a site which will not require some type of alteration in order for the ground-water supply to be protected properly. Similar conditions do not exist anywhere in Stark County or in any other part of the unglaciated portion of the state.

Hydrogeology.—The geologic units exposed in the unglaciated portion of Stark County are included within the Pottsville, Allegheny, and Conemaugh Groups of Pennsylvanian age (pl. 1A). The most important aquifers are the Sharon conglomerate and the Massillon sandstone, both of the Pottsville Group. These aquifers supply water for various municipal and industrial purposes (Harker and Bernhagen, 1943, p. 18). The Pottsville Group is covered by drift throughout most of the area. It is exposed only in portions of Sugar Creek, Bethlehem, Pike, Sandy, Canton, and Osnaburg Townships (pl. 1A). The Massillon sandstone, uppermost of the two aquifers, is 200 to 300 feet below the surface throughout most of the unglaciated area; the Sharon is 300 to 400 feet below the surface.

Most of the rocks exposed in the unglaciated area



ADAPTED FROM GLACIAL MAP OF OHIO, U.S. GEOL. SURVEY MISC. GEOL. INV. MAP I-316

FIGURE 5.--Location of Stark County and distribution of glacial deposits in Ohio.

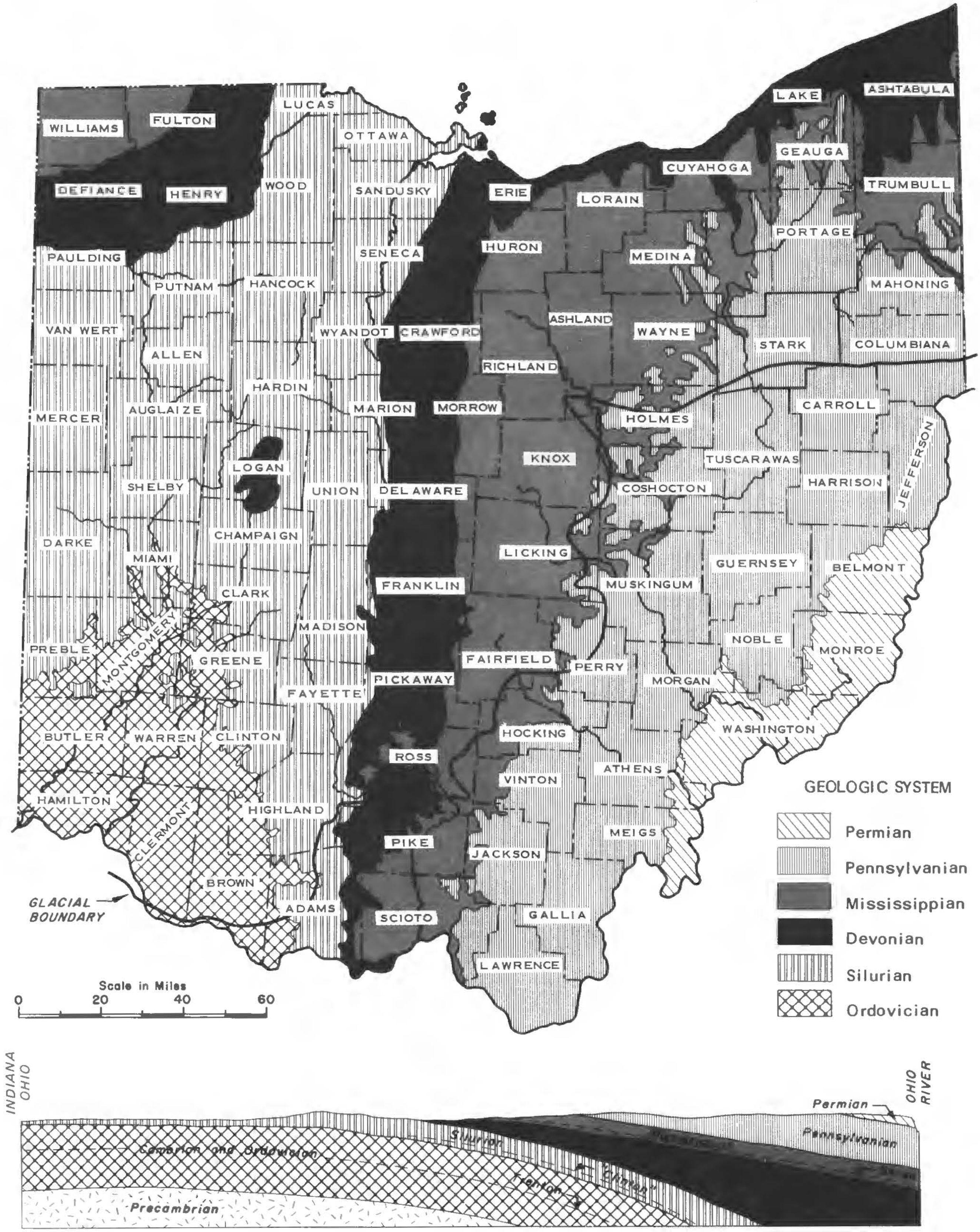


FIGURE 6.—Geologic map and cross section of Ohio.

TABLE 2.—*Classification of Quaternary deposits in Ohio*

Time-stratigraphic units		Lithologic character and origin
System	Series	
Quaternary	Holocene	Silt, sand, and clay with minor peat and muck (fluvial sediment)
	Pleistocene	Interbedded, slightly pebbly mixtures of sand, silt, and clay (glacial sediment); sand and gravel (fluvial sediment); silt and clay (fluvial and lacustrine sediment)

belong to the Allegheny Group; rocks belonging to the Conemaugh Group are found on hilltops. Sandstone stringers and lenses within the Allegheny Group serve as water sources for numerous farm and domestic users, but yields are small. Few other water sources are available except for a few occurrences of fissured shaly materials. Most of the exposed rocks are shaly sandstones and sandy shales, and these are essentially impervious (Harker and Bernhagen, 1943, p. 21). The formations underlying the Pennsylvanian strata yield only brackish or salt water (Harker and Bernhagen, 1943, p. 18).

Sand and gravel deposited by glacial meltwater are common along various streams (pl. 1B). These deposits serve as important water sources for municipal and domestic purposes. Fine-textured valley-fill materials of Holocene age are common along all the major streams. Water yields from these materials are very limited.

The depth to the zone of saturation (water table) throughout the unglaciated area is highly variable. On upland areas it can generally be expected to be within 30 feet of the land surface. On lowland areas such as floodplains the water table is generally within a few feet of the surface.

Evaluation of unglaciated areas.—From a strict hydrogeologic standpoint, most of the unglaciated portion of Stark County is adaptable to the construction of sanitary-landfill sites without extensive modification. Topography, however, is definitely a problem in some areas. Very steep slopes are generally unsuitable for simple reasons of inaccessibility. This is largely a problem of economics and must be dealt with accordingly. If landsliding is also a problem, then the site is unsuitable regardless of other considerations.

Massillon sandstone and Sharon conglomerate are restricted to the subsurface and are overlain by thick relatively impermeable materials. Sanitary landfills cannot be considered a threat to the quality of water in these aquifers.

A much different situation exists with regard to the surficial sand and gravel deposits. These materials are highly permeable and very inefficient as filtering agents. In addition they are in many instances found in areas characterized by shallow water tables. A landfill placed in these materials would almost certainly contaminate the ground water. The expense involved in altering such a site so that it would be suitable would probably not be justified where abundant sites having natural safeguards are available at much less expense. These areas of sand and gravel should therefore be avoided.

Adequate consideration must be given also to the small water-bearing lenses in the Allegheny Group. Because of their discontinuous nature, locations are not readily predictable; a detailed study of each proposed site is necessary.

A landfill constructed in the low-permeability shaly sandstones and sandy shales of the Allegheny Group, even if the water table is intersected, should not be a threat to the quality of ground-water supplies except in the immediate vicinity of the site. The same is true for the Conemaugh Group.

Areas underlain by impervious shale and clay, as previously discussed, will probably require the collection of leachate in order to avoid surface seeps. Most coal strip mines fall into this category. The pit is a natural catch basin for water which falls as precipitation and which comes from seeps and springs on the highwall. The presence of underclay below the coal will retard the downward movement of leachate from the refuse deposited in the strip mine. Excessive saturation will result unless adequate drainage is provided. Otton (1972, p. 29) and Emrich and Landon (1969, p. 12) suggest the emplacement of a tile field to collect the leachate for treatment. If drains are not installed the leachate may move through the length of the pit and drain from the lowest outlet of the stripped area. A ditch or small stream is the most likely destination for the leachate in such a case (Otton, 1972, p. 31). Diversion of surface water from the strip mine is advisable also.

The few limestones scattered throughout the section are generally inconsequential; they are very thin and generally do not constitute a water source. In very rare cases they might supply water to a small well.

Silt and clay deposits on the floodplains of various streams are characterized by low permeabilities and shallow water tables. The deleterious effects of a shallow water table may not be critical if the fine-textured materials are thick. In most cases, however, these deposits are quite thin and unless underlain by other fine-textured materials will not purify leachate sufficiently to allow the construction of sanitary landfills. Also, by their very nature most of the floodplains are subject to flooding which, regardless of other considerations, make them unsuitable for sanitary landfills.

The previous discussion indicates some of the considerations involved in the selection of landfill sites in the unglaciated portion of Stark County and of Ohio in general. The following conclusions can be drawn regarding the selection of sanitary-landfill sites in the unglaciated portion of Ohio:

1.—Upland areas of predominantly thick sandy shales and shaly sandstones are hydrogeologically well suited for sanitary-landfill sites without modification. Steep topography and related accessibility and landsliding problems are the major limiting factors in such areas. Caution must be exercised that small discontinuous water-bearing lenses are not contaminated. Suitable cover materials are generally available. Representative areas in Stark County include localities where rocks of the Conemaugh Group are exposed, as in sec. 30 of Osnaburg Township and sec. 17 of Sandy Township.

2.—Upland areas underlain by impervious materials such as shale or clay may require the collection of leachate to prevent seepage around the margins of the refuse. Most strip mines are included in this category. Suitable cover materials are generally available. Representative areas in Stark County include localities where the Lower Allegheny Clarion shale is exposed; such localities should be expected wherever the contact between the Allegheny and Pottsville Groups is shown, as in secs. 15, 22, and 27 of Pike Township.

3.—Locations where thick sandstone aquifers are at or near the land surface are generally unsuitable as landfill sites. This includes strip mines where thick sandstones are exposed on the highwall. A possible exception might be an area of regional discharge in which leachate could not migrate downward into the aquifer. Suitable cover materials are generally not available. Sites of this type are not a problem in Stark County because major sandstone aquifers are restricted to the subsurface.

4.—Areas underlain by sand and gravel require considerable modification and should be avoided if possible. Suitable cover materials are generally not available. Representative areas in Stark County include areas along Little Sandy Creek in portions of secs. 3, 10, and 15 of Sandy Township.

5.—Lowland areas of fine-textured materials (silt and clay) should be considered only if the materials are more than 25 feet thick or if they overlie other fine-textured deposits. The water table will very likely be intersected by the refuse. Monitoring of such a site may be advisable in order to assure the quality of water in the vicinity of the site. Suitable cover materials are available. Representative areas in Stark County include all floodplains which are protected by flood-control structures.

6.—Areas subject to flooding, regardless of other considerations, should be avoided. Representative areas in Stark County are most stream floodplains.

7.—Areas underlain by thick limestones, especially if the rock is known to be fractured, should be avoided. Such areas do not exist in Stark County.

Glaciated areas

General statement.—The glacial map of Stark County (pl. 1B) delineates glacial materials of two distinct ages: Illinoian and Wisconsinan. The Wisconsinan deposits range in thickness from 50 to more than 100 feet and are characterized by moderate relief and gentle slopes. The deposits mapped as Illinoian are lithologically similar to those of Wisconsinan age, but are typically very thin and discontinuous and in many places are represented by little more than a few scattered cobbles. The area covered by Illinoian materials is characterized by strong relief and steep slopes reminiscent of the unglaciated portion of the county. Therefore, for our purposes, the Illinoian area can be considered essentially as part of the unglaciated portion of the county and evaluated accordingly. Much of the Illinoian throughout Ohio has characteristics similar to those of the Illinoian in Stark County and in most cases can be given similar consideration. Glacial materials designated as Kansan in age have been mapped in Hamilton County in extreme southwestern Ohio (fig. 5). The Kansan materials are quite thin and discontinuous also and should be evaluated accordingly.

Before discussing the glaciated portion of Stark County, an explanation of mapping philosophy seems necessary and appropriate. A communication barrier commonly exists between the geologist who maps glaciated areas and the person who is using the maps. Almost invariably, the map is presented on a combined descriptive and genetic basis. This lack of consistency often leads to misunderstanding and confusion. Unfortunately it is very difficult, if not impossible, to avoid such inconsistency if both the geologic history and the distribution of materials are to be shown on one map.

For applied purposes, such as the selection of landfill sites, the material is of primary interest. The texture and other physical characteristics must be known if intelligent decisions are to be made. For our purposes genetic considerations are secondary and largely of academic interest and therefore need not be discussed. Terms such as "till," "kame," and "outwash" are genetic and imply, but do not necessarily restrict, the lithology of the mapped unit. For the sake of clarity and consistency these terms will be deemphasized in the following discussion. Kames are a particular problem in that they are commonly shown on a supposedly surficial map when in fact they may be veneered by as much as 50 feet of sand, silt, and clay (till). This is generally done to facilitate a genetic interpretation of the area. Unfortunately, it is misleading and necessitates a field check to ascertain whether the kame is truly a surficial feature or is buried.

All map units on plate 1B have been classified on a strictly descriptive (lithologic) basis and will be considered accordingly in the following discussion.

This should help to eliminate some of the confusion which is inherent in the use of such maps.

Hydrogeology.—The Quaternary deposits mapped on plate 1B include several till units, kames, and valley-fill materials. The till units can be grouped into three distinct lithologies: (1) slightly sandy clayey silt with a few cobbles and boulders—Hiram Till, (2) sandy clayey silt with a few cobbles and boulders—Lavery and Hayesville Tills, and (3) moderately pebbly slightly clayey silty sand with a few cobbles and boulders—Kent and Navarre Tills. Sand and gravel masses are commonly included in all the tills. The combined thickness of the tills in various parts of Stark County ranges from about 10 to 75 feet. All the till units are characterized by low permeabilities (10^{-3} to 10^{-7} cm/sec). This is especially true of the Hiram, Hayesville, and Lavery Tills; because of their finer texture these tills would be expected to be less permeable than the more sandy Navarre and Kent Tills. Ground-water supplies in these materials are limited to small domestic and farm wells which have been developed in some of the isolated sand and gravel lenses within the tills (Schaefer and others, 1946, p. 10).

The various kame units can be grouped into one lithologic category and described collectively as sand and gravel with a few included masses of sand, silt, and clay. Sand and gravel deposits of this type cover much of Stark County, especially in the areas to the north and west of Canton (pl. 1B). These deposits are highly permeable and are sources of large amounts of ground water for municipal and industrial purposes.

The valley-fill materials are of two distinct lithologies. The Pleistocene deposits are typically silt, sand, and gravel. The Holocene valley-fill materials are predominantly silt and clay, but include small areas of peat and muck. Some Pleistocene valley-fill materials are highly permeable and constitute an important ground-water supply for the area. The Holocene valley-fill materials, on the contrary, are generally poor sources of water.

Silt and clay of lacustrine origin are not found in Stark County, but are widespread along Lake Erie and in portions of northwestern Ohio (fig. 5). These materials are similar to Holocene floodplain silt and clay and should be treated similarly.

By far the largest source of ground water in the glaciated portion of Stark County is the sand and gravel deposits of a large buried valley system (DeLong and White, 1963). The combined thickness of the buried valley fill and the overlying younger materials is well over 200 feet in many places. The buried sand and gravel serve as the water source for the majority of municipalities in Stark County and therefore must be protected from contamination. The depth to the water table ranges from 10 to 50 feet in the upland areas. In lowlands and on the modern floodplains the water table is generally within a few feet of the surface. Many of the lowland areas are subject to flooding.

Evaluation of glaciated areas.—Considering the previous discussion, it becomes apparent that certain areas in the glaciated portion of Stark County are very problematic from the standpoint of locating landfill sites. Of special concern are areas of widespread sand and gravel deposits, both kame and valley-fill materials, as well as areas where buried valley materials are overlain either by highly permeable materials or by low-permeability deposits which are too thin to protect underlying aquifers. In general, upland areas make better landfill sites because the water table is typically deeper than in lowland areas, and floods are generally not a problem.

The lithologic classification of the glacial deposits in Stark County is similar to that of glacial deposits throughout Ohio. The same is true of the hydrologic and topographic conditions. Extrapolation of the following conclusions throughout the glaciated area of Ohio is therefore warranted. Obviously, variations do exist and in some cases may be extreme. This merely emphasizes the need for detailed reconnaissance of every proposed solid-waste disposal site.

Considering all the aspects of the situation the following conclusions can be drawn regarding the selection of landfill sites in glaciated areas of Ohio:

1.—Upland areas with more than 25 feet of till cover, especially if the till is clay rich, are well suited for sanitary-landfill sites. Most such areas should be safe for solid-waste disposal without engineering alteration and modification. This should hold true even if the water table is intersected by the refuse; the low permeability (less than 10^{-3} cm/sec) of the materials will restrict the movement of leachate. Caution must be exercised, however, with regard to isolated sand and gravel lenses which might serve as water sources for small domestic wells. Suitable cover materials are plentiful in these upland areas. Representative areas in Stark County include secs. 3 and 4 in Tuscarawas Township, secs. 1 and 2 in Washington Township, and sec. 36 in Nimishillen Township.

2.—Upland areas with less than 25 feet of till overlying bedrock (interbedded shale and sandstone in Stark County) should require only minor modification unless a major sandstone aquifer is involved. Adequate cover materials are available in such areas. Representative areas in Stark County include most of the areas covered by Illinoian drift, as well as the northern halves of secs. 17 and 18 in Lawrence Township, sec. 5 in Osnaburg Township, and sec. 32 and the eastern half of sec. 27 in Tuscarawas Township.

3.—Upland areas with less than 25 feet of till over sand and gravel deposits of various origins should be treated with great caution. Liners and leachate collection facilities will generally be necessary at such sites; natural purification of the leachate will be inadequate to protect the aquifers. Suitable cover materials are available at such sites. Representative areas in Stark County include the southern half of sec. 8 in Sugar Creek Township and the northern half of sec. 24 in Lawrence Township.

4.–All areas of widespread sand and gravel deposits are generally unsuited for waste disposal. This includes all kame deposits, glacial outwash materials, and abandoned sand and gravel quarries. Only with extreme modification and expense could such sites be safe for solid-waste disposal. A further deterrent is the fact that suitable cover materials are generally not available at such sites. Representative areas in Stark County include outwash along the Tuscarawas River in portions of secs. 19, 20, 29, and 32 in Perry Township, along Nimishillen Creek in the Canton area, and in large kame areas to the north and northwest of Canton.

5.–Lowland areas of silt and clay, such as are representative of some Holocene floodplain deposits, could be suitable for solid-waste disposal, given that flooding does not occur. Such materials are relatively impermeable and generally yield only very small amounts of water. Although the water table is in most cases very close to the land surface, leachate migration would be very slow and should not constitute a threat to underlying aquifers because such areas are usually in a ground-water discharge zone. This is especially true if the fine-textured materials are thicker than 25 feet or if they overlie other materials of low permeability, as is the case along Pigeon Run in Tuscarawas Township. In areas where the silt and clay are less than 25 feet thick and overlie sand and gravel, contamination would be probable and considerable alteration, such as installation of liners and collection of leachate, would be necessary. Suitable cover materials are generally available at such sites. Floodplains along West Branch Nimishillen Creek in Paine Township exemplify such a situation.

6.–Lowland areas which are subject to flooding are totally unsuitable for sanitary landfills and should not be considered for such use. This is true regardless of the materials or the hydrology of the site. The floodplain of any stream not regulated by dams is included in this category.

SUMMARY AND RECOMMENDATIONS

Solid waste in huge quantities is one of the unfortunate byproducts of our civilization. Until we reach a level of sophistication where such material can be recycled we must find a method of disposing of it. Burial in a sanitary landfill is, at present, the most feasible method. However, if a landfill is to be truly sanitary, the selection of a site is of utmost importance. Leachate produced by the contact of the refuse with water is extremely toxic and is capable of contaminating both surface and ground water. The production of leachate by a landfill is inevitable in a humid climate such as we have in Ohio. Minimization and purification of the leachate by appropriate site selection and by optimum utilization of natural processes is the ultimate goal of the site-selection process.

Fine-textured materials are much more effective as filtering agents than are coarse materials. Areas underlain by sand and gravel or by fractured limestone make very poor landfill sites. Areas characterized by a shallow water table generally make poor sites; however, if materials are fine textured and relatively thick the depth to the water table may not be critical. The use of coal strip mines will generally require leachate collection and treatment in order to prevent pollution of adjacent surface waters. Relatively flat upland areas of thick fine-textured materials are good potential sites. Areas subject to flooding should not be considered. Steep slopes are generally poor sites, especially if subject to slumping. In areas where sites having natural safeguards are at a premium various engineering techniques can be applied to assure the quality of ground and surface water.

Both field and laboratory investigations are essential to the site-selection process. Borings are invaluable for obtaining detailed information regarding the lithology and thickness of the geologic units and the depth to the water table and should be made at every proposed site. The number of borings necessary depends on the complexity and size of the proposed site. Under the simplest conditions, 1 boring may suffice. In many cases, however, 10 or more may be required. These should be a minimum of 25 feet deep.

A second major concern is the hydrology of the proposed site. The ground-water flow pattern can be determined by the use of piezometers. A minimum of 5 piezometers is generally necessary under simple hydrologic conditions. Many more may be required as the complexity and size of the site increases.

Certain types of laboratory analyses are helpful in determining the suitability of the proposed site. Particle-size analysis of the various materials at the site is essential. Sieve and pipette techniques should be utilized for such determinations. Once the textures of the various materials are determined, a good estimate of permeability can be made from a diagram such as figure 3. A determination of the types of clay minerals present is also important, especially with regard to cover materials. The presence of clay minerals, which are subject to extreme shrinking and swelling, can lead to cracking in the cover of a landfill and therefore to unimpaired movement of surface water into the refuse.

All proposed landfill sites should be investigated in detail. If each landfill site is selected carefully, a minimum of problems will result, and ground and surface water will not be endangered.

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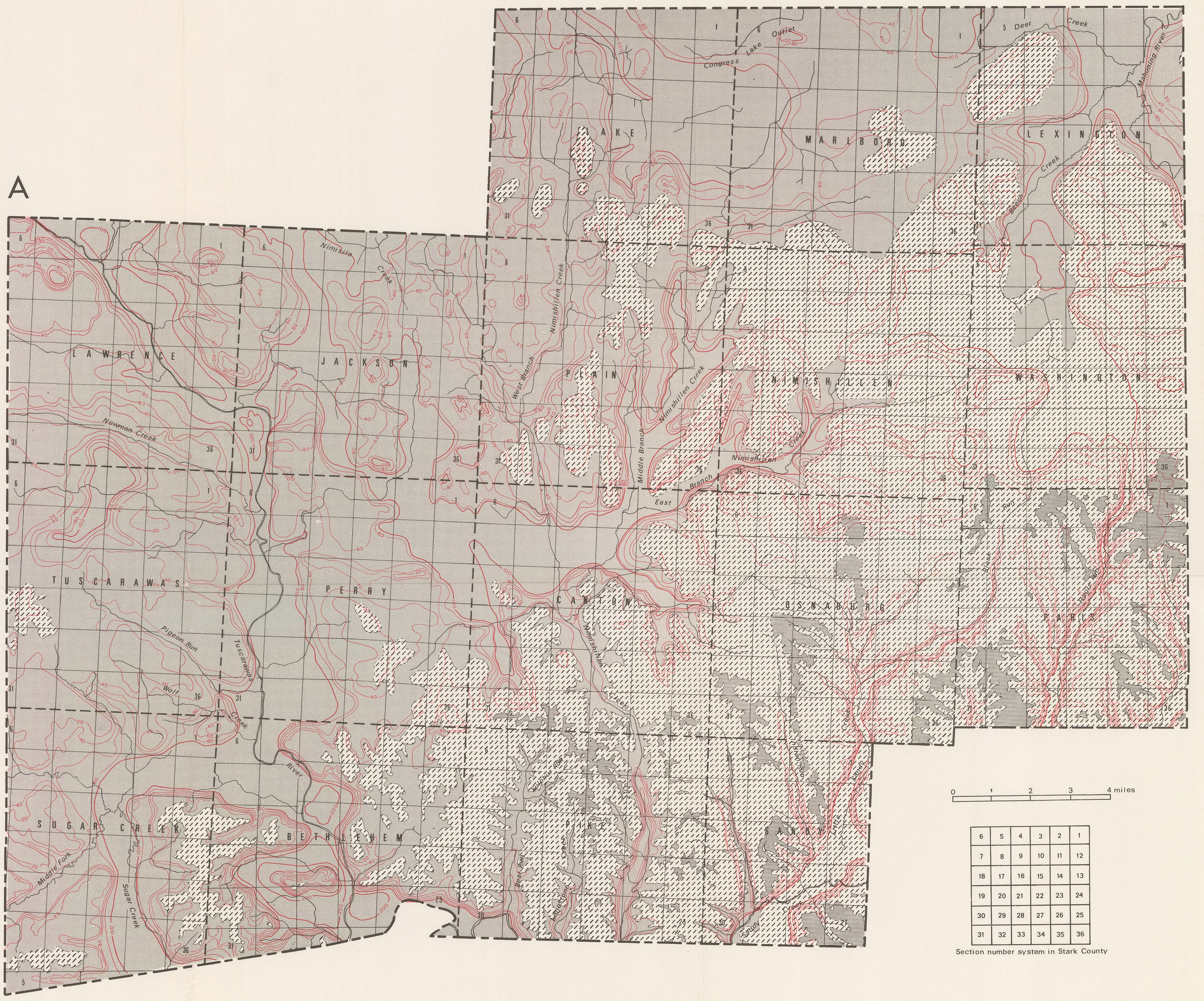
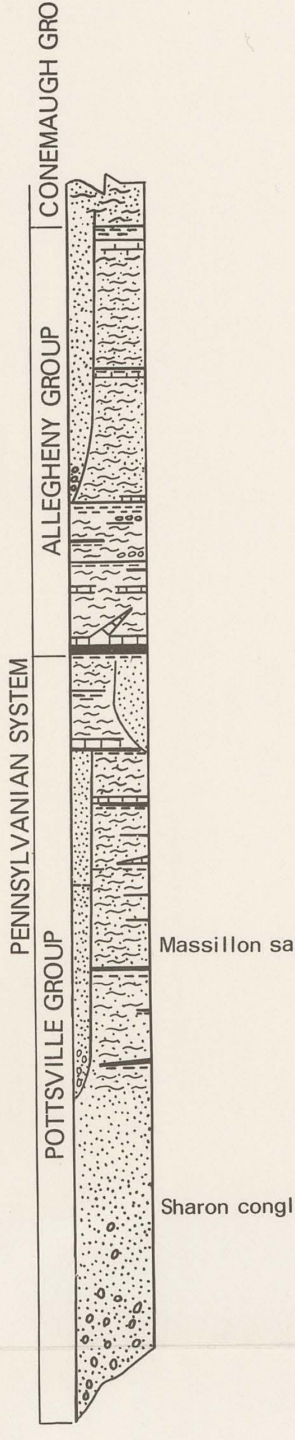
INFORMATION CIRCULAR NO. 41
PLATE 1





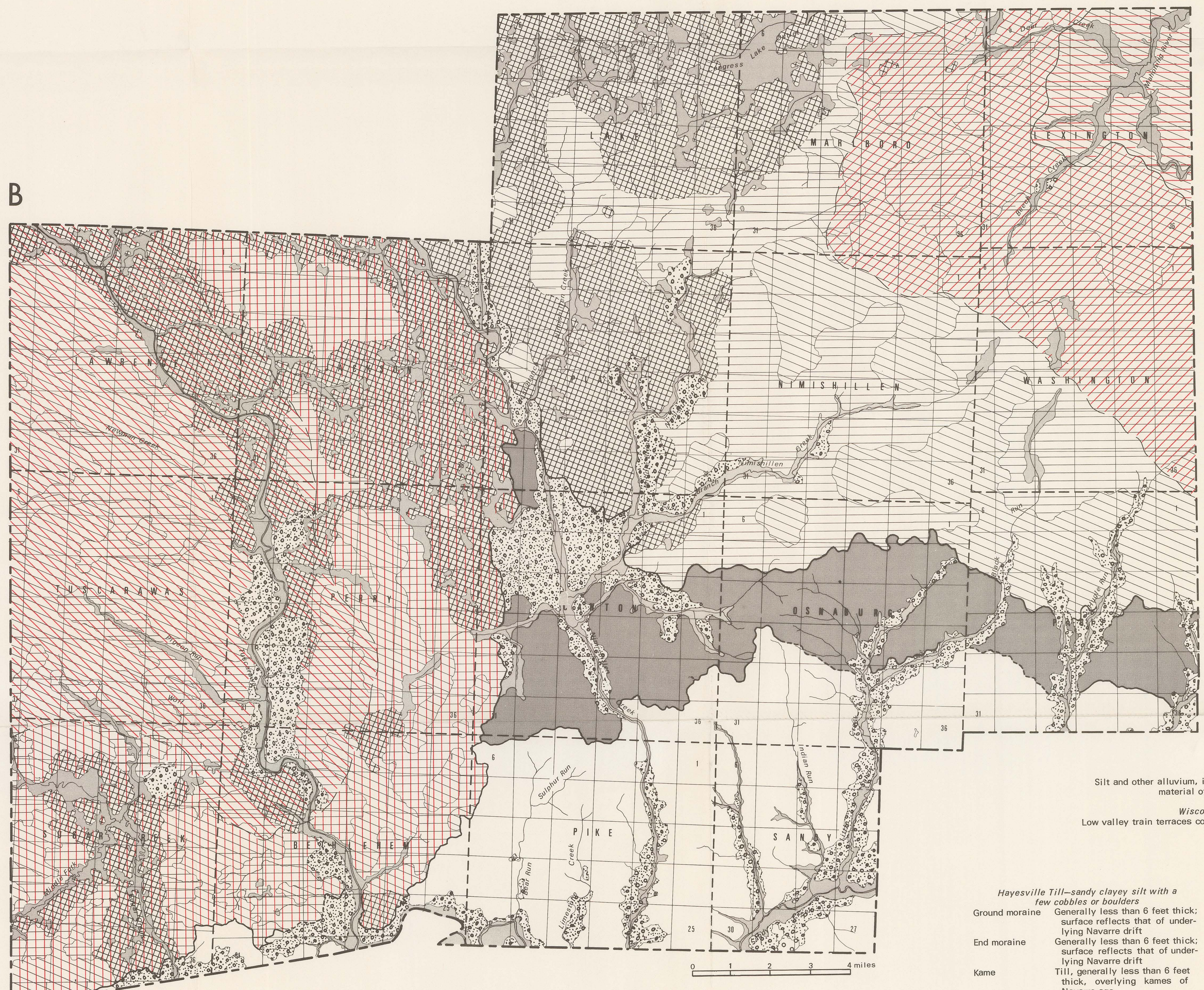
▤ Conemaugh Group

▨ Allegheny Group

▩ Pottsville Group

—100—
Drift thickness, *isopach interval 20 feet between 0 and 100 feet, 100 feet above that range*

MAPS FROM DELONG AND WHITE, 1963



EXPLANATION

QUATERNARY

Holocene

▩ Alluvium

▨ Outwash

Pleistocene (Wisconsinan)

KILLBUCK LOBE			GRAND RIVER LOBE		
			Hiram Till		
			▨ Ground moraine		
Hayesville Till			Lavery Till		
▨ Ground moraine	▨ End moraine	▦ Kame	▨ Ground moraine	▨ End moraine	▦ Kame
Navarre Till			Kent Till		
▦ Ground moraine	▦ End moraine	▦ Kame	▨ Ground moraine	▤ End moraine	▦ Kame

Pleistocene (Illinoian)

▨ Outwash

▩ Ground moraine

☐ unglaciated

Alluvium
Silt and other alluvium, in many places thin and lying upon material of different character

Wisconsinan outwash
Low valley train terraces containing well-washed gravel and sand

Hiram Till—slightly sandy clayey silt with a few cobbles and boulders

Ground moraine	Generally 5 to 15 feet thick; includes some lacustrine silt

Hayesville Till—sandy clayey silt with a few cobbles or boulders

Ground moraine	Generally less than 6 feet thick; surface reflects that of underlying Navarre drift
End moraine	Generally less than 6 feet thick; surface reflects that of underlying Navarre drift
Kame	Till, generally less than 6 feet thick, overlying kames of Navarre age

Lavery Till—sandy clayey silt with a few cobbles or boulders

Ground moraine	Generally less than 10 feet thick; surface reflects that of underlying Kent drift
End moraine	Generally less than 10 feet thick; surface reflects that of underlying Kent drift
Kame	Gravel and sand in low knolls

Navarre Till—moderately pebbly slightly clayey silty sand with a few cobbles and boulders

Ground moraine	Five to more than 30 feet thick
End moraine	May contain gravel masses
Kame	Gravel and sand in knolls; includes many till masses

Kent Till—moderately pebbly slightly clayey silty sand with a few cobbles and boulders

Ground moraine	Five to more than 30 feet thick
End moraine	May contain gravel masses; thickness generally greater than ground moraine
Kame	Gravel and sand in knolls; includes many till masses

Illinoian outwash
Gravel in small isolated valley train remnants

Illinoian ground moraine
Generally thin and discontinuous

PLATE 1. - A, Bedrock geology and B, glacial geology of Stark County, Ohio