GEOLOGIC CONSIDERATIONS IN URBAN PLANNING
FOR BLOOMINGTON, INDIANA

by

GARY R. GATES

Indiana Department of Conservation
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Table 1. Description, characteristic topography and drainage, and economic uses of the rock units in Bloomington, Ind., and vicinity - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - 6
The geology of Bloomington, Ind., and vicinity has a direct bearing on the community's future. Mineral resources, mostly from limestones, are plentiful around Bloomington and require careful study in relation to urban planning to ensure adequate supplies of raw materials. Water-supply problems are increasingly troublesome in areas not serviced by city water. Drainage and soil conditions in and around Bloomington require that special precautions be taken in sewage disposal, construction, and land development. Recommendations based on geologic factors should be formulated for use in urban development planning for Bloomington.

INTRODUCTION

Geology is applicable to many problems associated with urban development planning. Mineral resources, water supply, sewage disposal, flood control, and construction are related to the distribution and characteristics of rocks and soils, and thus geologic factors must be evaluated as a part of the development plan.

The geology and mineral resources of Monroe County, Ind., were studied in detail over a period of 3 years beginning in 1955. The information derived from this work and from basic research provided a basis for the present report on the application of geology to development planning. As a case history, this report should be useful in illustrating the application of scientific information to urban planning.

Bloomington, the county seat of Monroe County, is in the northern part of the famous Bedford-Bloomington dimension stone belt, an economically important mineral-producing area. In addition to dimension stone, other mineral resources are potential in this area, and thus the location, probable value, and uses of undeveloped mineral deposits must be considered in planning. Other geologic conditions influence the health, welfare, and recreational facilities of the community.

This report was prepared by the Indiana Geological Survey on behalf of the Bloomington City Plan Commission, which is currently preparing a comprehensive long-range development plan for an area covering approximately 38 square miles centered around Bloomington.
### Table 1. Description, Characteristic Topography and Drainage, and Economic Uses of the Rock Units in Bloomington, Ind., and Vicinity

<table>
<thead>
<tr>
<th>Rock-unit name</th>
<th>Rock type and thickness</th>
<th>Topography</th>
<th>Drainage</th>
<th>Economic uses</th>
</tr>
</thead>
<tbody>
<tr>
<td>Ste. Genevieve Limestone</td>
<td>Hard and dense white limestone; locally cherty; thin sandy or clayey limestones in middle and near top of formation; 80 to 90 ft thick.</td>
<td>Gentle slopes; low relief; large sinkholes common.</td>
<td>Much drainage is subterranean; surface streams generally drain into sinkholes.</td>
<td>Commonly used for aggregates, cement, high-calcium limestone, agricultural limestone, lime, and fluxstone; other minor uses.</td>
</tr>
<tr>
<td>St. Louis Limestone</td>
<td>Mostly impure, moderately soft limestone containing cherty and clayey limestone zones; thin bedded; 70 to 80 ft thick.</td>
<td>Moderately steep slopes; moderate relief; many small sinkholes.</td>
<td>Much drainage is subterranean; moderate relief allows considerable water to flow on surface to the various creeks in the area; small springs flow from many small openings.</td>
<td>Generally unsatisfactory for most economic uses.</td>
</tr>
<tr>
<td>Salem Limestone</td>
<td>Porous granular limestone; white or buff; massive; 70 to 80 ft thick.</td>
<td>Gentle to moderately steep slopes; generally characterized by nearly featureless, gently rolling slopes; small sinkholes moderately abundant.</td>
<td>Most runoff on surface in numerous small subdued &quot;draw&quot; (unconcentrated runoff) or in intermittent streams near the bases of hills.</td>
<td>Building or dimension stone, high-calcium limestone, agricultural limestone, lime, cement raw material, and fluxstone; other minor uses.</td>
</tr>
<tr>
<td>Harrodsburg Limestone</td>
<td>White well-cemented limestone; medium or thin bedded; 80 ft thick.</td>
<td>Similar to topography formed on Salem Limestone. (See above.)</td>
<td>Similar to drainage on Salem Limestone. (See above.)</td>
<td>Has been used for cement manufacture, aggregates, and other minor purposes but generally is of marginal quality.</td>
</tr>
<tr>
<td>Borden Group (only the upper part is exposed in the vicinity of Bloomington)</td>
<td>Siltstone and shale; blue gray or tan; 650 to 700 ft thick.</td>
<td>Very steep slopes, intricate system of high steep-sided ridges, and narrow to broad alluvium-filled valleys; no sinkholes or other undrained depressions.</td>
<td>All drainage from gullies and steep ravines descends rapidly until runoff reaches flat, broad valleys.</td>
<td>Upper part of Borden Group generally too sandy or silty for ceramic applications.</td>
</tr>
</tbody>
</table>
The assistance of Dr. William J. Wayne, of the Indiana Geological Survey, in preparing this report is gratefully acknowledged.

GENERAL GEOLOGY OF THE BLOOMINGTON METROPOLITAN AREA

Bloomington and the surrounding area are underlain dominantly by limestones that were formed during the Mississippian Period. The geologic map and cross section (pl. 1) show that the Mississippian rocks are assigned to one group and four formations (distinctive mappable units of rock). The geologic cross section illustrates the vertical succession of formations. The beds dip toward the west-southwest at about 30 feet per mile, but because of the low angle of dip (less than half a degree of inclination), the vertical dimension of the cross section has been exaggerated to 10 times the horizontal dimension. Table 1 summarizes the rock type, thickness, topography, drainage, and economic uses that characterize each of the rock units.

The four limestone formations (Harrodsburg, Salem, St. Louis, and Ste. Genevieve Limestones) (pl. 1) underlie most of the area of importance to the development plan for Bloomington. The particular type of weathering and drainage to which they are susceptible has resulted in the formation of the long, narrow karst plain (so-called) that extends from northwestern Monroe County to Kentucky. The karst plain and the limestone areas in Bloomington are characterized by red clayey soils that were derived from weathering of the limestone over a long period of time. Limestone areas also are typified by gently rolling topography and mixed underground and surface drainage; much rainwater is swallowed by sinkholes and is carried through underground passages.

The north-central, northeastern, and southeastern parts of the map area (pl. 1) are underlain by siltstones and shales of the Borden Group that presently appear to have little economic potential. As the topography of the Borden area is too rugged for extensive urban and industrial development, this area is not discussed in detail in this report.

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1 The term Mississippian refers to the geologic period of time extending from 350 to 310 million years ago.
Limestones suitable for producing dimension stone, cement, and aggregates and for manufacturing agricultural and chemical products are available in the vicinity of Bloomington (table 1). Currently, the most valuable resource in the map area is the dimension stone that is produced from the formation called the Salem Limestone (also called Bedford Limestone, Indiana limestone, Indiana Oolitic Limestone, etc.). This formation underlies a large part of Bloomington and the fringe areas, as is shown on plate 1.

**DIMENSION STONE**

**Economic importance of the dimension stone industry.**—Bloomington, as well as other areas in the Bedford-Bloomington dimension stone belt, owes much of its prosperity to the utilization of the Salem Limestone for dimension stone. (See Smith, 1956, for a map of the entire dimension stone belt.) Perhaps more than other mineral commodities, dimension stone provides a livelihood for many persons in varied occupations. This condition results from the high "value added" from the time that the stone is quarried until it is used for a wall, terrace, or other construction project. Before development the stone is worth only a fraction of a cent per ton in the ground, but in finished products the stone is worth $25 to more than $50 per ton exclusive of construction costs.

The value of undeveloped stone must be measured in terms of what each ton of stone represents potentially to the skilled labor supply required to quarry, mill, transport, and emplace the finished product; in income from investment in the quarrying, milling, transportation, and construction industries; as the government's share of profits gained from these industries; and, indirectly, to seemingly unrelated enterprises that provide consumer goods and services to the above-mentioned labor supply and industries.

Proper planning will ensure retention of a large share of the value of dimension stone within the community. The planning elements that should be considered are: (1) preservation of adequate reserves of stone, (2) adequate space for mills and quarry installations, (3) transportation facilities that are both efficient and economical, (4) regulations that will ensure a labor supply and provide for its health, welfare, and recreation, and (5) maintenance of reasonable tax rates.

**Factors that influence the location of dimension stone quarries.**—Land use problems concerning dimension stone cannot be appreciated without
an understanding of the basic factors that influence the location of new quarries. Three properties—color, texture, and massive-
ness—generally are used to judge the quality of limestone for di-
mension stone production. (Strength and durability of the Salem
Limestone are adequate for most dimension stone uses and therefore
do not play an important role in locating quarries at the present
time.) The Salem Limestone contains lenses and layers of rock
that are regarded as high-quality raw materials for dimension stone
production. Because of lateral and vertical variations within the
Salem Limestone, it generally is necessary to study in detail the
color, texture, and massiveness of cores before the quality of stone
at a given location can be determined. The geologic map (pl. 1),
therefore, cannot be used to block out reserves. It can only be used
as a tool for the exploration of quality stone within the Salem Lime-
stone. Information from closely spaced cores is required for pos-
itive evaluations.

The amount of high-quality stone that is readily available must
be sufficient to warrant investment before a quarry can be developed
at a given site. Because mineral deposits are wasting assets (that
is, they become less valuable as the raw materials are removed),
investment is warranted only if sufficient reserves are available to
pay back the original capital investment and to provide a high rate
of interest commensurate with the risk. Reserves depend on (1)
the areal extent of the raw materials, (2) the thickness of the raw
materials, (3) the thickness and nature of overburden, (4) topog-
raphy, and (5) the availability and costs of land (including zoning
restrictions). It is essential for some operations to have a byprod-
uct, such as breakfront blocks made from overburden rock, to pay
for developing a new quarry.

Other factors that influence the location of dimension stone
quarries around Bloomington include (1) the location of mills and
the transportation facilities connecting mills and quarries, (2) the
locations of markets and the transportation facilities connecting
mills and markets, and (3) the overall supply and demand charac-
teristics of the industry and the current ideas concerning future
trends of supply and demand. Railroad transportation is no longer
a limiting factor in the location of a dimension stone quarry in the
Bedford-Bloomington belt, and the industry can utilize limestone in
areas that are not situated along railroads. Mills still can be most
efficiently and economically operated if they are on railroad lines.
Roads built for large trucks are now essential, however, for trans-
porting stone from quarry to mill.

Most of the factors mentioned above can be analyzed in terms
of the amount and quality of stone at a given site and the economics
of production at that site. Other factors that are difficult to evaluate
in terms of the future of the dimension stone industry in this area are the effects of new technological developments in mining, milling, transporting, and marketing dimension stone and the amount of competition from other building materials.

**LIMESTONE AGGREGATES**

Most aggregates that are produced today are used (1) to mix with portland bituminous cements to make concrete, (2) as subbase and fill material in the construction of highways and foundations, and (3) as "road metal" for secondary roads. Because of such varied uses, large quantities of aggregates are used in any expanding community. Aggregates are high bulk-low value products; their current value for Bloomington is about $1.40 per ton at the plant. Sand and gravel, not available locally, and crushed limestone aggregates can be shipped in from other areas, but the high cost of transportation relative to the value of the aggregate can make construction costs prohibitive if the raw materials must be transported over long distances. In the aggregates industry large areas of low cost land are required for plant sites, loading facilities, and quarries. Still another factor must be considered in analyzing the supply of aggregates; aggregates must conform to rigid specifications, particularly when they are used for projects of the local, State, and Federal governments. Specifications are published by various organizations that use aggregates.

The most suitable local rock for aggregates production is the Ste. Genevieve Limestone (pl. 1), and, under existing conditions of specifications and urban and industrial development, reserves of this limestone are adequate in the vicinity of Bloomington. Bloomington is fortunate in having good sources of aggregate close to the city but away from densely populated areas. The city should maintain an interest in the continued development of its supply. A related consideration is transportation of the aggregates to market, and, presumably, dispatch to local markets will continue to be by truck; reserves along railroads are presently sufficient for shipment to other market areas.

The Harrodsburg Limestone formerly was used as a source of limestone for aggregates, but its quality is marginal for concrete aggregate production under existing specifications. The Salem Limestone is similar to the Harrodsburg in this respect, and as long as reserves of Ste. Genevieve Limestone are adequate, the other formations in the Bloomington area probably will not be utilized for aggregates production.
CEMENT RAW MATERIALS

Characteristic features of the cement industry. - Cement is a manufactured product made from limestone and other ingredients. Quality cements can be made economically only in large plants capable of producing large quantities of cement. Thus "economics of scale" (the minimum size of plant that can operate economically) is a major consideration of the cement industry. The moderately high value of cement compared to its weight allows cement plants to operate at considerable distances from markets. The economics of scale and transportation factors cause production of cement to be localized in a relatively few large centers. The density of centers is a function of the size of the markets in proximity to each plant.

Although fuel and labor supply, transportation facilities, and position of markets determine the general location of areas that are most suitable for producing cement, the availability of adequate reserves of high-quality limestones determines the specific location. The plant for producing cement is nearly always adjacent to the source of limestone in order to keep production costs to a minimum. Large reserves of limestone are required adjacent to the plant because cement plants are permanent fixtures and a dependable source of raw material must last long enough to return the initial investment and provide a profit commensurate with the risk involved. In addition to limestone, cement manufacture requires alumina, iron oxide, and silica; these ingredients are supplied by shale and sand or by soils. It has been a common practice in the past to utilize sources of alumina, iron oxide, and silica from other areas, but attempts have recently been made to obtain these materials from sources near the plant.

Bloomington as a potential cement-producing center. - Until the present time the demand for cement probably has not been great enough to warrant development of a cement industry in the Bloomington area. Future expansion of this industry in Indiana, however, very likely will favor utilization of the cement raw materials and facilities near the city (McGregor, 1958). Geologically, the rocks that are exposed a short distance west of the area covered by plate 1, particularly the Ste. Genevieve Limestone and overlying formations, are

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It is interesting to compare the transportation factor for aggregates, cement, and dimension stone. The ratio of value to bulk is lowest for aggregates and highest for dimension stone. The Salem Limestone has provided dimension stone for export and is sold in most States in the United States. The ratio of value to bulk for cement, however, restricts its market area to an intermediate position between dimension stone and aggregates.
excellent potential sources of cement raw materials. Alumina, iron oxide, and silica can be derived near or with the sources of limestone.

The Ste. Genevieve Limestone and overlying formations in this area have great potential value because they provide large reserves of high-quality, homogeneous raw materials which have a bulk composition well within tolerances for impurities as established by the traditional specifications for cement raw materials.

Other sources of raw materials are available for cement manufacture in the vicinity of Bloomington. The Salem Limestone and the upper part of the Harrodsburg Limestone in the area south of Bloomington could serve as a source of limestone for cement. The chief disadvantages associated with using limestones from the Salem and Harrodsburg are the lack of large flat areas for plant sites and possibly the lack of finding an area with sufficient reserves. Engineering studies would be required to determine how serious these problems are.

The exact sites near Bloomington that are suitable for the production of cement cannot be determined without a more complete geologic-economic-engineering appraisal. Individual companies weigh factors differently, and authorities may not agree on which sites are most desirable even after intensive study. Therefore, it would be wise to have flexible plans concerning transportation facilities (highway and railroad), fuel supply, and labor supply, so that the establishment of a cement industry in a fringe area could be facilitated.

Population increases are commensurate with the development and growth of industries, and the prospect of a cement industry in areas close to Bloomington undoubtedly would affect the growth of Bloomington.

CHEMICAL AND AGRICULTURAL PRODUCTS

Limestones suitable for the production of agricultural limestone, lime, general purpose high-calcium limestone, and fluxstone are plentiful in the vicinity of Bloomington (table 1). Increases in demand for high-calcium limestone near markets may someday bring a major new industry to the area around the city. Some chemical and agricultural products are manufactured currently as byproducts of dimension stone and aggregates. A larger demand is necessary, however, to support an industry which primarily manufactures chemical and agricultural products.

Factors influencing the location of quarries are similar to those for dimension stone quarries, but processing plants for manufac-
1.3 MINERAL RESOURCES IN THE BLOOMINGTON AREA

turing agricultural and chemical products, unlike dimension stone, are commonly adjacent to quarries. Adequate space is a limiting factor in the location of many processing plants, and thus quarries and plants probably would be located outside populated areas. Blasting is used to break up stone in quarries where limestone is obtained for making chemical and agricultural products and for aggregates; thus hazardous conditions may be created by these facilities.

More than 1 billion tons of limestone with calcium carbonate ranging from 97 to 98 percent lies in the area southwest of Bloomington and northwest of Arlington within the plan area (pl. 1). Although these limestones do not have purity high enough for some uses, they nonetheless are valuable assets for the community. Most of these potential reserves are within the area mapped as Salem Limestone (pl. 1), but the Salem underlying areas within the city or developed areas outside the city has not been included in the estimate of reserves. Large reserves of limestones with similar quality are available in areas to the north and south of the plan area (pl. 1). In addition, parts of the Ste. Genevieve Limestone also may provide a source of high-calcium limestone to the west of Bloomington.

FILL AND EMBANKMENT MATERIALS

The chief fill and embankment materials in the Bloomington area are residual, colluvial, and alluvial soils. (See section on soils engineering.) The residual and colluvial soils, which are formed primarily from limestones, are impervious when they are compacted. The use of these red-clay soils commonly presents problems, however, because of their adsorptive and hydration qualities.

Because of the large supply of impervious fill materials derived from limestone soils in areas near Bloomington, reservation of borrow areas probably is not necessary. Where specifications call for previous fill materials, sources outside of Bloomington will have to be utilized. Porous fill materials are not plentiful in or near Bloomington, but limited supplies are available in adjacent areas.
Lack of an adequate water supply is a limiting factor for industrial and population growth. Lake Lemon and Griffy Reservoir provide a presently adequate water supply for residential and industrial areas with city water service, but urbanizing fringe areas without city mains have critical shortages of water because of local geologic conditions. These conditions in the Bloomington area result in generally unreliable ground-water supplies from wells and in limited opportunity to build satisfactory reservoirs in the limestone bedrock areas.

Wells that are drilled into the rocks of the Borden Group (pl. 1) generally do not yield adequate quantities of good-quality water for household use. These rocks lie at considerable depth under the Bloomington area (pl. 1, cross section A-A'3).

Wells drilled into limestone commonly reach water near the base of the Harrodsburg Limestone, at the base of the Salem Limestone, near the base of the St. Louis Limestone, in cavernous parts of the St. Louis Limestone, and in several zones within the Ste. Genevieve Limestone. The amount of water obtained generally is low, ranging from less than 2 gallons to (rarely) 10 gallons per minute.

As in other limestone regions, water pumped from the ground or issuing from springs is not filtered as well as water that is taken from sand or gravel aquifers, and pollution of the water supply by refuse from stock or septic tank fields is a serious problem in some areas. This problem is found even in areas where water is derived from relatively deep wells, particularly if well casings have not been sealed through the soil. Superchlorination-dechlorination systems commonly may be required to purify well water.

The relatively low yield of wells in this area prohibits extensive utilization of ground water for industrial, urban, and suburban use. Rural areas underlain by limestone, however, are afforded moderately reliable sources of water. Rainfall is adequate to supply household water for cisterns of sufficient capacity to withstand the dry seasons.

3 General information on ground water in Indiana can be found in Klaer, 1950, and Indiana Department of Conservation, Division of Water Resources, 1958.
The history of the Bloomington water supply is too lengthy to be included in this report. The mistakes made in the early development of the Bloomington water supply are of value, however, in emphasizing why geologic advice should be accepted on problems of water supply. Prior to the construction of Griffy Lake, all reservoirs had been located in areas known by geologists to be underlain by limestones that allowed water to escape through underground passages. Griffy Reservoir and Lake Lemon are underlain by impervious siltstones of the Borden Group and do not present leakage problems; the proposed Monroe Reservoir is underlain by similar siltstones. Although some areas underlain by limestone might serve as suitable reservoir sites, careful consideration must be given to the properties of rocks beneath reservoirs, dams, and spillways. Reservoirs for domestic, industrial, or conservation use should not be constructed without adequate engineering and geologic studies. Abandoned quarries commonly are filled with water, but the water is stagnant.

SURFACE DRAINAGE

Although disastrous floods are unlikely in the vicinity of Bloomington, flooding problems do exist. These problems may be referred to more aptly as drainage problems. Small-scale floods can seriously damage structures near streams. Adequate precautions must be taken to ensure the safety of structures along areas susceptible to flooding. Particularly, the areas underlain by Recent alluvium (pl. 1) are commonly subjected to flooding. Drainage is a problem in the areas underlain by Salem and Harrodsburg Limestones, as is indicated by the topography shown on plate 1, principally because of the gentle slopes, low stream gradients, and minor but significant karst features formed on these limestones. For example, the stream that is colloquially called the Jordan River and that flows through the campus of Indiana University cannot carry a sufficient quantity of water in seasons of heavy rainfall. The new addition to the Indiana University Memorial Union Building has been built over the stream by the use of large-

4 The following reports should be consulted for a complete description of the history and problems of the Bloomington water supply: Beede, 1911; Cumings, 1912; Thornbury, 1954, p. 555-556; and Consoer, Townsend and Associates, 1950.

5 Alluvium is a deposit of silt and other sediments left by floodwaters on a flood plain.
diameter tubes that are able to transmit large volumes of water. Clear Creek and its tributaries downstream (pl. 1) are subject to similar floods, and bridges and abutments have been washed out or damaged during seasons of heavy rain. Comprehensive data on streamflow or flood damage is not available, and thus a more accurate appraisal is not possible without additional study.

The karst area underlain by the St. Louis and Ste. Genevieve Limestones (pl. 1) also is occasionally damaged by floods. Sinkholes commonly cannot accommodate large quantities of water, particularly when the water is mud laden because of heavy rain. The choking of some sinkholes causes the formation of temporary lakes that may persist for several weeks or longer. Sinkholes are easily recognized, and structures likely to be damaged should not be located in them.

One of the chief problems connected with the subdivision of land and also with industrial use of land in this area is a lack of adequate drainage facilities. After natural drainage has been destroyed by grading and leveling, new drainageways must be provided. The most satisfactory means to dispose of rainwater is probably through a network of storm sewers.

SOILS ENGINEERING

NATURE OF LOCAL SOILS

The soils that cover the area included on plate 1 are of three general geologic types—residual soils, colluvial soils, and alluvial soils. Most soils in Bloomington and vicinity are of residual and colluvial origin and are derived largely from the weathering of limestones. Residual soils are those that were formed in place by the progressive weathering of rock, and colluvial soils that were formed by the downhill sliding of soils from higher slopes to form accumulations. Colluvial soils generally are thicker, less homogeneous, and less well compacted. The third type of soil mentioned above (alluvial) is restricted to the larger stream valleys in the Bloomington area and is not discussed in this report. Similarly, residual and colluvial soils that are formed on rocks of the Borden Group do not present common problems and are not included in this discussion.

All four of the limestone formations (pl. 1) are overlain by residual soils on the flat upland slopes, but colluvial soils are dom-

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6 The report on the soils of Monroe County by Bushnell and Fowler, 1928, should be consulted for information on the agricultural use of soils in Bloomington and the surrounding areas.
inant on the steep slopes and along the sides of valleys near stream level. The thickest colluvial soils are found at the base of the steep slopes in areas mapped as St. Louis Limestone. Most colluvial areas, however, are characterized by gently rolling topography without steep slopes. Certain areas underlain by the Salem and Harrodsburg Limestones also contain thick colluvial deposits, and fissures in the bedrock may be filled with soil to great depths. The topography of the gentle slopes overlying the Ste. Genevieve Limestone can be attributed partly to the filling of sinkhole depressions with colluvial soils, and soils as much as 40 feet thick have been measured. Thus limestone soils in general have extremely variable thicknesses that are partly a function of topography.

The chemical and mineralogic composition of colluvial and residual limestone soils is similar regardless of the parent material, that is, whether the soils were formed from the Ste. Genevieve, St. Louis, Salem, or Harrodsburg Limestones. The thin upper zone of a typical soil profile generally is silty loam that is formed by the mixing of windblown silt (loess) and materials that are derived from the underlying limestone. A middle soil zone is dominantly composed of clay-sized material. A lower soil zone is less clayey than the middle zone and contains particles and boulders of limestone or chert. The "surface" of bedrock beneath the lower soil zone is highly irregular in most places, and large blocks may be completely cut off from other limestone masses by the soil-forming process.

FOUNDATION PROBLEMS

Two features of the limestone soils in this area particularly result in problems of foundation preparation and construction. The first concerns the composition of the soils. Minerals and compounds in the clay fraction of soils are highly hydrated and deficient in alkali and alkaline earth elements. This means that serious damage to concrete emplaced directly on soils may result because of the affinity of the soil for certain elements in cement. For example, concrete decomposes to the point of failure when sufficient calcium is removed by soils. The second feature concerns physical properties. The plasticity of soils of varying moisture contents is a common means of classifying engineering materials. On the basis of accepted engineering tests, the limestone soils in this area are classified as having high plasticity and may be referred to as "problem soils." Also, dry soils swell considerably when water is added.

Housing construction in the vicinity of Bloomington is plagued by failure of basement walls and seepage through walls below ground.
level. These problems are related to the methods and materials used in backfilling foundations and basement walls of block construction. Backfill problems are particularly severe in areas that have been graded and where soils have dried out. Additions of gypsum, lime, or other compounds that relinquish positive ions to backfill soils theoretically will lower the affinity that this type of soil has for water and will greatly reduce some of the problems. Research is needed, however, to confirm the reliability of adding such compounds to the soil.

There are three principal causes of wall leakage or failure: (1) excessive hydrostatic pressure of saturated backfill materials, (2) expansion of soils and fill materials because of a change in moisture content, and (3) alkali reactions between concrete and soil. These problems can be alleviated during construction if (1) backfill materials are free of trash and scraps, (2) soils used in backfills contain enough water (25 to 30 percent by weight) to allow compaction into an impervious fill, (3) in places where previous fill is used in part, adequate drains are provided to allow excessive water to be removed, and (4) all interfaces between concrete and fill are waterproofed to prevent alkali reactions or ordinary leakage. (Some blocks and masonry draw moisture through pores by capillary action.)

Large construction projects that require sound foundations generally are built on bedrock. The bedrock surface is erratic in the Bloomington area, and it is important to determine whether the first rock that is found is a large boulder or the surface of bedrock, because clay soils underlying boulders may flow under only moderate stress.

Roads in the Bloomington area are susceptible to damage, particularly during the spring, from freeze and thaw of subgrade materials. The texture and composition of limestone soil and especially the more clayey soils of the middle zone referred to above allow a considerable amount of moisture to be retained by these materials. Thus freezing and thawing by creating alternating stresses cause pavement to break up. The limestone soils are also highly plastic when enough moisture is available and are quite mobile when stresses are applied. Heavy traffic, therefore, increases the severity of damage during freeze and thaw periods. These conditions require in the Bloomington area special attention to subgrades for roads carrying heavy traffic and to drains for all roads.
Limestone soils in their natural state can accommodate only a small amount of excess fluid. They also are nearly impermeable. For these reasons, large seepage fields for septic tanks are required, and pervious filter materials surrounding the tile must be adequate to compensate for the poor adsorptive qualities of the soils. Because of the large seepage fields, lot size must be correspondingly large to maintain sanitary conditions. These relationships commonly have not been maintained in the Bloomington area, and thus dangerous and otherwise unsatisfactory conditions have resulted. Moreover, fluids commonly migrate to the bedrock surface and then along the top of the bedrock to wells. Wells thus have to be cased to an adequate depth and placed at a considerable distance from all septic tank fields.

Excavations for pipelines to be used for water, gas, or sewage transmission are considerably more costly in areas of thin soil because it is necessary to remove rock by drilling and blasting. As indicated above, the thickest soils in the Bloomington area are associated with colluvial terrace deposits along slopes and in sinkholes that are now filled with colluvium. Resistant rock strata commonly crop out in areas of thin soil, but some areas of very thin soil have no visible expression or relationship to topography. The only reliable means of determining soil thickness is through the use of closely spaced test boring, perhaps in conjunction with a geologic investigation.
1. Areas that are zoned for normal industry should be suited environmentally for mineral exploitation if the industrial zones correspond to areas that may contain economic mineral deposits. If mineral producers have adequate reason to believe that the value of mineral resources in the Bloomington metropolitan area warrants special consideration in zoning regulations, measures for the objective collection of data for accurate economic appraisals should be taken, and the ultimate decisions should be based on established and accepted valuation procedures.

2. Industrial, business, and housing development areas should be located where city water mains can be extended economically.

3. Storm sewers generally are necessary in areas where natural drainage is altered because of housing or other construction development. Special precautions should be taken to ensure the safety of construction near natural drainage lines.

4. Foundations of dwellings and larger construction projects should be carefully prepared: backfill materials should be free of trash and scraps, have sufficient water to allow compaction into an impervious fill, and if pervious fill is used in part, adequate drains should be provided at the base of the fill; all interfaces between concrete and fill should be waterproofed to guard against alkali reactions and leakage; large buildings should have foundations built on bedrock, and precautions should be taken to ensure that the foundations are on bedrock and not on boulders underlain by soils; where foundations are built on the soil of slopes, precaution should be taken to ensure against damage resulting from plastic flow of the soil under moderate stress; road construction and repair should be planned and designed with special consideration of the subgrades and drainage facilities that are needed to ensure against damage resulting from freeze and thaw and soil flowage under the weight of traffic.

5. Especially in areas where lots are small, sewers should be considered as the only satisfactory means of sewage disposal; where private disposal of sewage is necessary, special consideration should be given to the spacing of septic tank drain fields, so that effluent will not contaminate water supplied from wells or otherwise impair the health of the inhabitants; wells should be completed carefully to ensure that undesirable fluids do not enter.

6. Before subdivisions are laid out, the thickness of soils generally should be determined, especially by closely spaced test boring, to learn if water, sewer, and gas lines can be extended economically to the area.
LITERATURE CITED


Indiana Department of Conservation, Division of Water Resources, 1958, Geologic map of Indiana showing ground-water conditions.


