# MAPS FOR CONSTRUCTION MATERIALS [1]

Frank E. Byrne, Geologist, United States Geological Survey


## SYNOPSIS

The basic materials that the engineer needs for construction are the rocks and sediments of the earth's crust. The geologist, because of his experience in mapping these same rocks and sediments, is well qualified to prepare the maps the engineer needs in his search for construction materials. The completion of short- and long-range construction programs requires great quantities of these basic materials. The use of the geologist in preparing materials maps will result in considerable reduction in the cost of engineering construction.

The three principal kinds of construction-material maps are discussed: material-site, mateerial-distribution, and surface-geology.

*Material-Site Maps* - The material-site map is the least expensive of the three kinds to prepare. It is an excellent inventory of materials that have already been found and tested, but it includes only those known to the compiler by reason of the basic data with which he has been supplied. It does not show other construction materials that may be present in the same area but have not previously been needed and tested. It is a poor basis for the search for additional materials.

*Material-Distribution Maps* - The map is based on the geologic maps available for a region. Each outcropping formation shown on a geologic map is classified as to the kind of construction material that can be produced from it. The area of outcrop of that geologic formation, then, is the area of distribution of that material.

The cost of a material-distribution map is only moderate. The map is an excellent inventory of all kinds of material available in a region, and it shows the potential production areas for each material.

*Surface-Geology Maps* - The surface-geology map combines many of the useful features of the other two kinds. It is constructed to a relatively large scale; it shows the outcrop areas of all geologic formations and the locations of existing pits and quarries in the area.

A field party maps the geologic formations, both consolidated rocks and unconsolidated sediments, usually on aerial photographs. The party plots the locations of all existing pits and quarries, locates additional materials, and collects samples for laboratory testing.

The surface-geology map is the most expensive of the three to prepare. The expense, however, is a self-liquidating one and the money expended is returned many times over. The map itself serves indefinitely as a completely adequate base for the efficient search for materials, and is also a valuable source of information for the planning engineer, for the design engineer, and for the engineer estimating the cost of construction.


*Basis of this Evaluation* - This paper is based upon experiences as a geologist assigned to the mapping of engineering construction materials in Kansas and the preparation of maps to be used in the search for materials in the western part of the United States. The work in Kansas is a cooperative project of the Geological and Materials Departments of the State Highway Commission of Kansas and the Engineering Geology Branch of the United States Geological Survey. It is a continuing project that was started in 1946. The work in western United States is in cooperation with the Military Geology Branch of the Geological Survey.

*Definition of Engineering Construction Materials* - As the term is used in this paper, engineering construction materials are defined as the naturally occurring materials of the earth's crust that require no more than inexpensive processing before use in construction. Sand, gravel, silt, limestone, and granite are some of the materials included in this restricted definition. Products derived from the rocks of the earth's crust that must be given expensive processing or

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manufacture before they can be used in construction are excluded.

*Need for Construction Materials* - The basic materials for engineering construction, such as sand-gravel, limestone, and granite, are needed in greater quantities than ever before. They are needed under short-range programs to repair the damages resulting from the shortages in manpower and materials prevailing during the war years. They are needed under long-range programs in ever greater quantities to complete the construction already far along in the planning stage.

These basic materials are a major item of cost in every construction project, whether it be a highway, an airport, or a dam. Through the preparation of adequate maps and by the effective use of those maps in the field exploration for materials, the nearest source of acceptable materials to the project can be located. Haulage costs, therefore, can be reduced to the minimum. In many cases this saving alone will repay the expense of map preparation many times over.

*Kinds of Materials Maps* - There are three principal kinds of materials maps: (1) material-site, (2) material distribution, and (3) surface-geology. The material-site map is a familiar one; maps of this kind have been prepared for many regions of the United States. The other two, the material-distribution and surface-geology maps, have been adapted for use in material exploration as the result of the work now being carried on in western United States and Kansas.

## MATERIAL-SITE MAPS

*Description* - The material-site map shows the location of pits and quarries that are now being operated or that have been operated in the past. (See Fig. 1, Example of a Material-Site Map.) The map is usually prepared to a relatively small scale, 1 in. equals 10 or 15 mi., but may be constructed to a much larger scale if it is to be used as a part of the construction program of a single project. Although generally constructed in the office from available pit and quarry data sheets, and not field checked, this kind of map can be checked very thoroughly in the field and amplified by that field work.

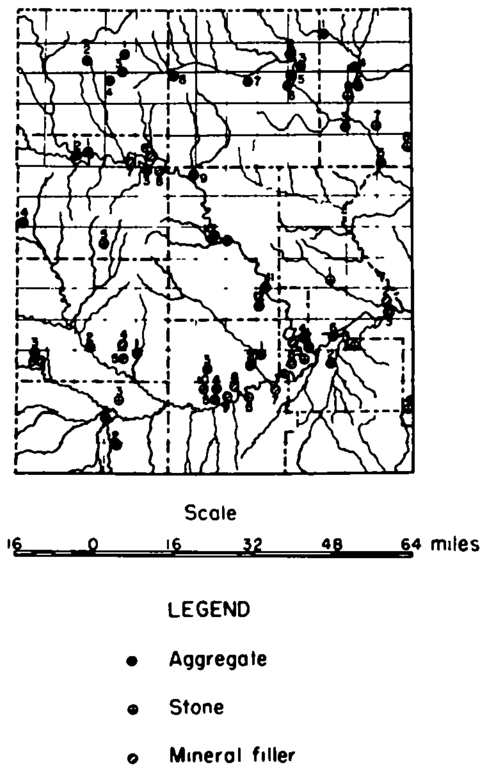



Figure 1. Example of a Material-Site Map

Most material-site maps show the kind of material available at any one place by the use of identifying symbols, which may be black and white or may be colored. In addition, each one of the pit and quarry locations shown is keyed through an index number to a source of basic data on the test properties of that material.

*Advantages of Material-Site Maps* - Among the advantages inherent in a material-site map is that of the relatively low cost of preparation. The basic data needed by the compiler are already available in the files of the materials department. Probably the cost of such a map for Kansas would range from $10,000 to $15,000, and would include the expenses of compilation, drafting, and publication. It would not, however, provide for collecting and testing additional samples of materials.

A material-site map is of great value in a short-range construction program. It serves as the record of materials known to be immediately available in every part of a wide area, and also indicates the existing pits and quarries from which these materials can be produced. The statistical data correlated with the map will show the quantity and quality of the material available at each site as of the date of compilation of the map. It is a useful inventory of construction materials.

In some circumstances, the material-site map is the only kind that can be prepared for a region. During World War II, for example, material-site maps were prepared by the US Geological Survey to show the available sources of construction materials in enemy-held territory. Even though the maps were prepared from no more than library data, they were found to be very useful to Army engineers after invasion had been accomplished.

*Disadvantages of Material-Site Maps* - Several disadvantages are inherent in a material-site map. It includes only those material-site locations known to the compiler by reason of the basic data with which he has been supplied. It is entirely possible that some agency unknown to him has opened pits and quarries in the region. Data on such sites are not available for his use and, therefore, his inventory of construction materials cannot be complete.

Nor does a material-site map show all of the kinds of construction materials available in a region; it shows only the sources of materials used in past construction. In one year, for example, a field party may explore an area for sand-gravel. This party, seeking only sources of acceptable sand-gravel, probably would take little note of other construction materials in the area. But five years later a new construction project in the same area might require limestone for use as riprap. A second materials party would then have to go over much of the area covered earlier by the first party. And with each new material requirement there would be the accompanying expense of re-exploring the area. A material-site map is not a complete record of the past exploration for materials.

## MATERIAL-DISTRIBUTION MAPS

*Description* - The material-distribution map can be used as the basis for materials exploration in regions in which little exploration has yet been done or for which data are inadequate or are not available. The map is usually prepared to a small scale, one in. equals 10 or 15 mi. However, it is entirely possible to prepare such a map to a larger scale, one in. equals one or two mi., if there is an adequate source of information.

The map is generally prepared in the office, but a field check may be undertaken if the circumstances indicate its advisability. Maps of this kind are now being prepared for a number of states in the western part of the United States.

The material-distribution map is constructed on the basis of whatever geologic maps are available for the region. Each outcropping formation shown on the geologic map is classified as to the kind of material that can be produced from it. The area of outcrop of a geologic formation, therefore, is the area of outcrop of that construction material. Instead of depicting the outcrop areas of geologic formations, the map shows the outcrop areas of sand-gravel, limestone, granite, and other basic materials needed for engineering construction.

In one part of western Montana (see Fig. 2, Geologic Map of a Part of Western Montana), the geologic map shows the areas of outcrop of deposits laid down by present-day streams (Qa),

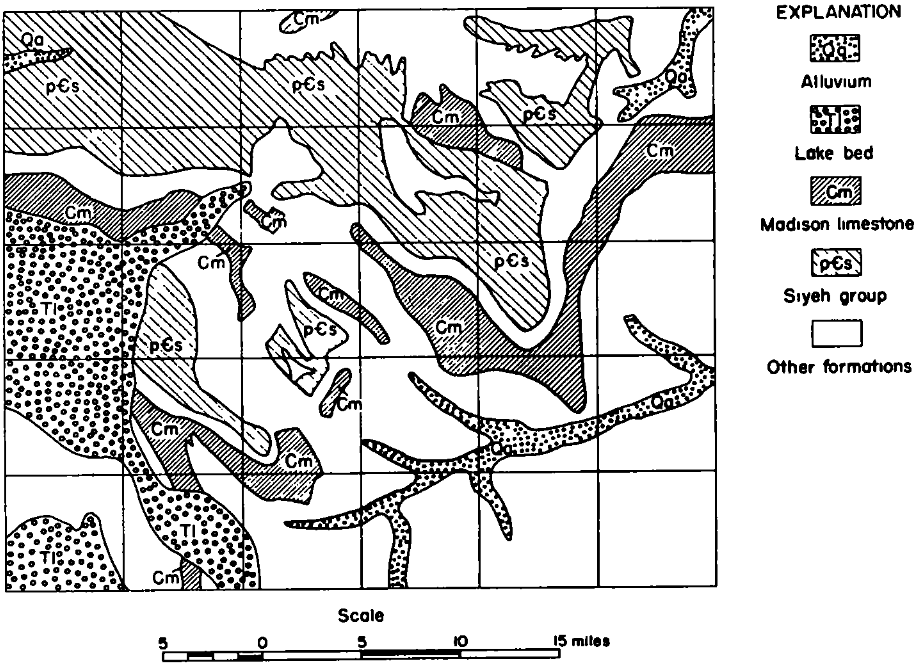



Figure 2. Geologic Map of a Part of Western Montana

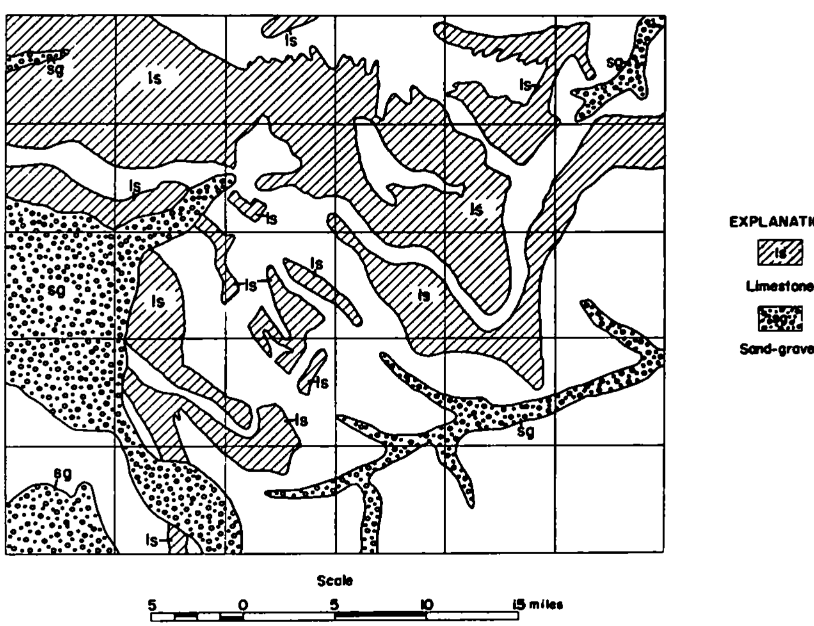



Figure 3. Material-Distribution Map of a Part of Western Montana

somewhat older deposits laid down on the floors of ancient lakes (Tl), the Madison limestone (Cm), the Siyeh group (p€s), and the outcrop areas of still other geologic formations not designated by symbols on the map. The stream and lake deposits are known to be composed predominantly of sand and gravel, and would be classified as a single materials unit, sand-gravel. The areas in which the stream- and lake-deposited sediments are shown on the geologic map would be the source areas for sand-gravel shown on a material-distribution map. (See Fig. 3, Material-Distribution Map of a Part of Western Montana.)

The Madison limestone shown on the geologic map would be classified as limestone and so, too, would the Siyeh group of formations, although the latter includes some thin beds of shale. (See Fig. 2.) The outcrop areas of the two formations, when transferred to a material-distribution map, would then show the potential production areas of limestone in this part of the State. (See Fig. 3.)

*Advantages of Material-Distribution Maps* - The example described above demonstrates the principal advantages of a material-distribution map. It shows the areas from which all kinds of construction materials in the region might be produced. Further, the map shows also the areas in which any one material cannot occur. A materials party, using this map as the basis for its field exploration, knows exactly the areas to search for a specified material, areas of outcrop of other materials can be eliminated from the exploration program even before the party goes into the field. Time and money are saved.

As another point in its favor, the material-distribution map serves as an adequate inventory of all the construction materials in the region it depicts, in which respect it is an improvement over the material-site map. The material-distribution map shows the areas of outcrop of all available materials, not just the places from which materials have been produced for past construction.

Although the preparation of a material-distribution map is more expensive than that of a material-site map, its final cost is still moderate. Unless a field check is undertaken, the only expenses are the salaries of a geologist to make the materials conversion and a draftsman, and the cost of publication. Using Kansas as the basis for the estimate, the total cost of the project probably would be about $20,000, including publication of the map.

*Disadvantages of Material-Distribution Maps* - The principal disadvantage inherent in a material-distribution map is the possible inadequacy of the geologic maps available for a region. If the geologic map is not adequate, the material-distribution map cannot be adequate. And, unfortunately, adequate geologic maps are available for only a small part of the United States, although various State and Federal agencies hope to remedy this deficiency by completing a series of long-range mapping programs.

The map does not have in it the basis for correlating test and performance data with the materials it shows. Some limestones are sound and wear-resistant; they are acceptable sources of riprap. Other limestones are unsound, or wear or slake rapidly. The acceptable limestones are not distinguished from the unacceptable on a material-distribution map. Whatever their test properties, all limestones are shown by the same map symbol and pattern.

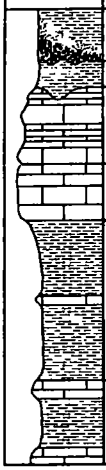
## SURFACE-GEOLOGY MATERIALS MAPS

*Description* - A surface-geology materials map combines many of the useful features of the other two kinds. However, it is by far the most expensive of the three to prepare. The map is usually constructed to a relatively large scale, one in. equals one mi. or two in. equal one mi. It shows the areas of outcrop of all geologic formations, both the consolidated rocks and the unconsolidated sediments. And its scale is large enough that all pits and quarries can be clearly and accurately shown and indexed.

About 20 counties in Kansas have been mapped with the materials objective as the primary one. Surface-geology maps have already been published for an even greater number of counties by the cooperating Ground-Water Divisions of the Kansas and United States Geological Surveys; each of them can be readily adapted so as to show the areal distribution of sources of construction materials.

visit all pits and quarries reported in the files of the State Highway Department's testing laboratory. The location of each one is plotted on a map, and the geologic formation from which the material was obtained is noted for future correlation. They also collect samples from new prospective material sites and send them to the testing laboratory.

The materials inventory for each county consists of a combined surface-geology and material-source map, a tabulation of materials tests, and a



| Legend | Description | Geologic formation | Construction materials |
|---|---|---|---|
| | Clayey silt and gravelly sand | Terrace deposit | Mineral filler<br>Aggregate |
| | Clayey silt | Sanborn formation | Mineral filler |
| | Thin to massive beds of hard, dense limestone | Fort Riley limestone | Riprap<br>Dimension stone |
| | Hard, very flinty limestone | Florence flint | |
| | Clay shale and a very thin limestone | Matfield shale | |
| | Two very flinty limestones separated by a clay shale | Wreford limestone | |

Figure 4. Geologic Formations of Northeastern Kansas

Materials mapping in Kansas is done in this way: A two-man field party is sent to a county in which there is a known shortage of materials for construction already in sight. One man is employed by the Geological Department of the Kansas Highway Commission, and the other is a member of the Engineering Geology Branch of the US Geological Survey. The party generally uses large-scale aerial photographs as the map base. Experience has demonstrated that the photos serve as a means of reducing field time without sacrificing map accuracy. The outcrop areas of all geologic formations in the county are drawn directly on the photographs.

As the field men map the distribution of the geologic formations, they also

written text. The text describes the geology of the county and the construction materials available in the county. The correlation of the test characteristics of the various materials with the geologic formations from which they can be produced is also a part of the text.

*Disadvantage of a Surface-Geology Materials Map* - One dubious disadvantage is inherent in a surface-geology map: it is expensive to prepare. This kind of a materials inventory costs about $5,300 for the average county in Kansas. But this sum is close to the minimum; the total cost might be several times greater for many regions in the United States in which more complicated geology is

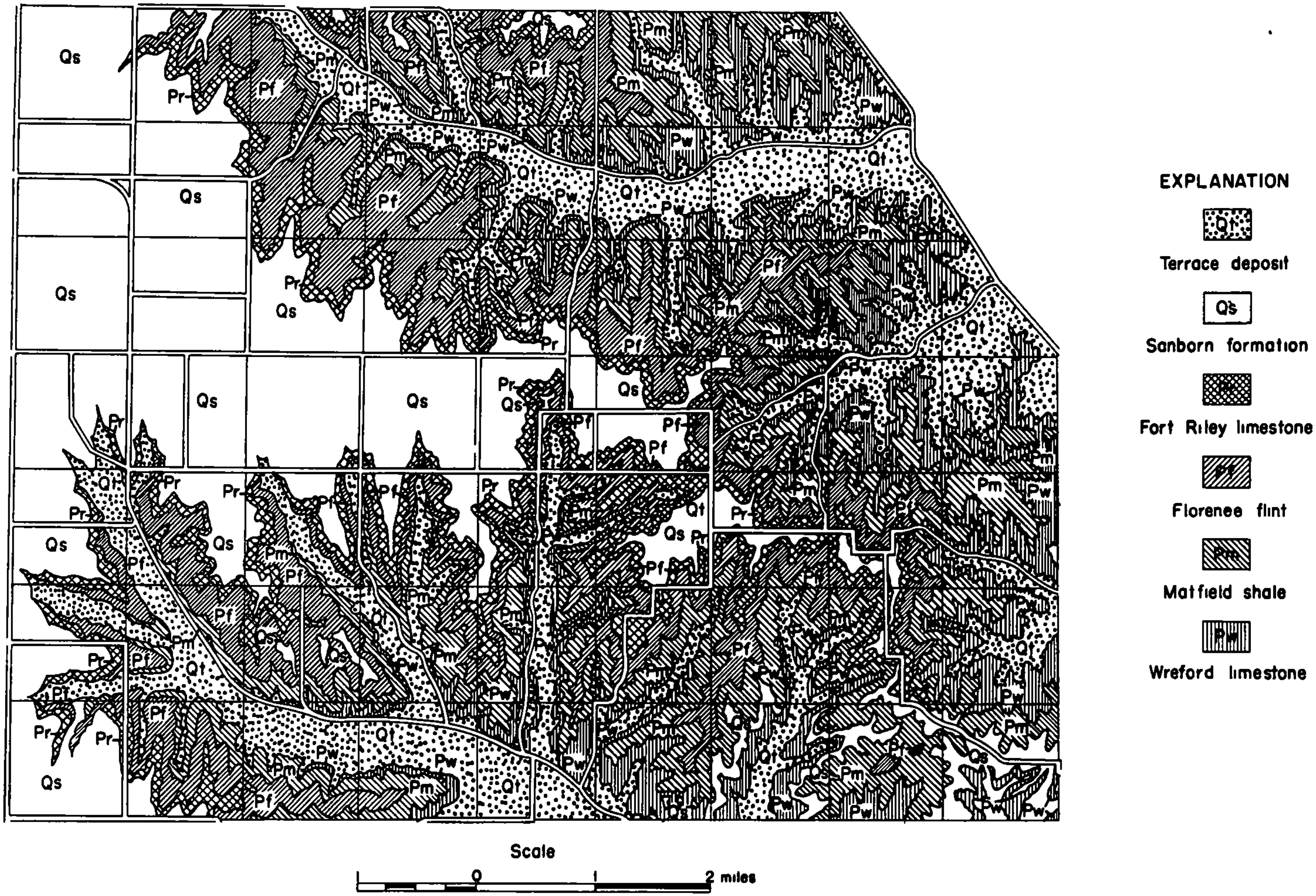
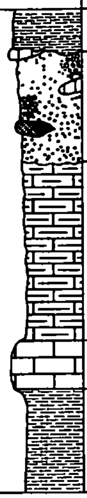



Figure 5. Surface-Geology Map of a Part of Northeastern Kansas

encountered. In preparing a cost estimate for the average Kansas county, $2,500 is allotted for the salaries and subsistence of the field men; $900 for transportation and other field expenses, $200 for laboratory tests of additional samples collected in the course of field work; $900 for the expense of drafting illustrations and writing the report; and $800 to defray the cost of publication.

possible sources of riprap. No one of them contains a material useful as riprap, as is shown in the descriptions of these formations.

However, the two limestones and the flint formation are potentially productive of acceptable riprap. The Florence flint and the Wreford limestone are flinty limestones and test data already at hand show that they are unsound and therefore fail to meet specifications.



| Legend | Description | Geologic formation | | Construction materials |
|---|---|---|---|---|
| | Clayey silt | Sanborn formation | | Mineral filler |
| | Interbedded lenses of sand, sandy gravel, mortar bed, and quartzite | Ogallala formation | | Aggregate<br>Riprap<br>Dimension stone |
| | Interbedded layers of chalky shale and chalky limestone | Niobrara formation | Smoky Hill chalk member | Calcareous binder |
| | Massive beds of chalky limestone | | Fort Hays limestone member | Dimension stone<br>Calcareous binder |
| | Soft clay shale | Carlile shale | | None |

Figure 6. Geologic Formations of Northcentral Kansas

*Advantages of a Surface-Geology Materials Map* - Two examples illustrate the usefulness of a surface-geology map in the exploration for construction materials. In one part of northeastern Kansas, outcrops of the following geologic formations occur: alluvium and terrace deposits in the valleys of streams, the Sanborn formation on the tops of the interstream areas, and the Fort Riley limestone, the Florence flint, the Matfield shale, and the Wreford limestone. (See Fig. 4, Geologic Formations of Northeastern Kansas.)

If it is assumed that stone for riprap is needed in construction planned for this area, the alluvium, terrace deposits, Sanborn formation, and the Matfield shale can be eliminated immediately as

But tests of the Fort Riley limestone indicate that it is sound, develops little abrasion loss, and has a specific gravity of 2.6; obviously it is the best local source of stone for riprap.

Using the surface-geology map of the area as its guide, the materials men locate the quarry site in an outcrop of the Fort Riley limestone at the most accessible point nearest the construction project. (See Pr on Fig. 5, Surface-Geology Map of a Part of Northeastern Kansas.) The absolute minimum of field time and expense is required, and the engineer can be confident that riprap produced from the Fort Riley limestone will give good service in the construction.

Another example selected from an

entirely different geologic setting demonstrates the same usefulness of a surface-geology map. The Sanborn and Ogallala formations, the Smoky Hill chalk member and the Fort Hays limestone member of the Niobrara formation, and the Carlile shale outcrop in a part of north-central Kansas. (See Fig. 6, Geologic Formations of North-Central Kansas.) Sand-gravel for use as mixed aggregate is needed for nearby construction. The descriptions of four of the geologic formations show that they are not potential sources of sand-gravel. The Sanborn formation is composed of clayey silt, and if not too clayey, might be a source of mineral filler; the Smoky the Sanborn formation, Smoky Hill chalk, Fort Hays limestone, and Carlile shale from the field program. (See Fig. 7, Surface-Geology Map of a Part of North-Central Kansas.) The areas nonproductive of sand-gravel are avoided, and the search is confined to the outcrop areas of the Ogallala formation as shown on the surface-geology map. The most economic source of sand-gravel is then located with the least expenditure of field time and money.

It is possible also to estimate the quantity of material available at any one place and the overburden to be expected there from information contained in the surface-geology map and the report that

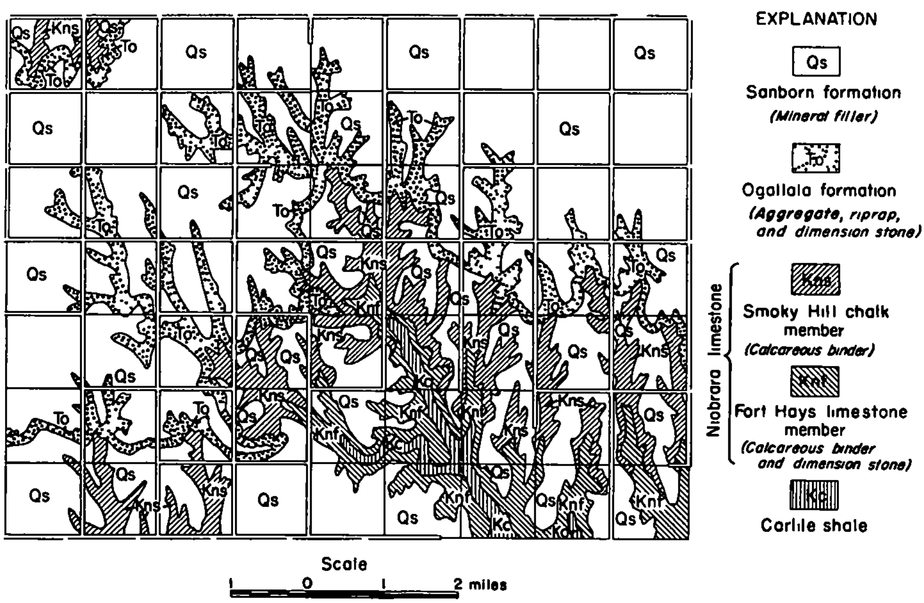



Figure 7. Surface-Ceology Map of a Part of Northcentral Kansas

Hill is a chalking shale and is a source of calcareous binder; the Fort Hays is chalky limestone and is a source of binder and dimension stone; and the Carlile is a clay shale. But the Ogallala formation contains numerous beds of gravelly sand, and the test characteristics of the Ogallala material indicate that it probably will be acceptable for use as mixed aggregate.

Basing its exploration on the surface-geology map of the area, the materials party eliminates the outcrop areas of accompanies it. The physical characteristics, including thickness, of a geologic formation composed of consolidated rock are fairly consistent over a moderately extensive area; unconsolidated sediments vary more rapidly. If a layer of limestone is known to be 10 ft. thick, the approximate quantity of it available at any one place can be estimated by determining the areal extent of its outcrop, as shown on a surface-geology map, at that place.

The character and thickness of overburden also can be interpreted from a surface-geology map. A geologic formation composed of consolidated rock that overlies a potentially material-productive formation probably will prove more difficult and expensive to remove than an overburden formation composed of unconsolidated sediment.

The surface-geology map is not only useful as the basis for materials exploration, but it can be employed also to advantage in engineering planning and design. A flinty limestone, for example, often discharges significant amounts of water. Knowing that, the engineer may want the alignment to avoid as many of the outcrops of that limestone as possible, or will specify that appropriate drains be designed for those places where avoidance is not possible. Then, too, the engineer can determine the kind of excavation to be expected at all places along an alignment from the information presented to him by the surface-geology map. Some geologic formations require rock excavation, others require common excavation, and the kind can be interpreted from the geologic map. Such a map, therefore, serves a multiple purpose in civil engineering.

## SUMMARY

A material-site map serves as a useful inventory of construction materials immediately available in a region. A material-distribution map provides an excellent base for the exploration for construction materials, and is a complete inventory of all materials available in a region.

A surface-geology map, although expensive to prepare, is the most satisfactory of the three kinds of materials maps because in itself it is a complete inventory of all available construction materials and provides the best possible basis for the search for a material to meet certain specifications. It is useful also for estimating available quantities of material, the character and thickness of overburden, the existence of possible causes of failure of construction, and the kind of excavation to be expected at any one place.