Geologic Considerations in Relation to a Materials Survey

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SYNOPSIS

IN materials surveying, geology should be of maximum benefit, not as a complete informant but as a foundation for reconnaissance, assembly, and cataloging of materials. Geology in essence is a materials survey on a grand scale. Use of this science for engineering purposes involves some primary knowledge of geologic nomenclature, the basic historic approach of geologists, and the use of resources and data published by state, federal, and private agencies over a period of 75 years.

Recognition of the need for information on surface conditions as an aid to engineering and allied sciences is emphasized; and in response to this need, a new system of mapping is cited and illustrated in which a special map of surficial geology is prepared in conjunction with the traditional "bedrock" geologic maps.

The importance and the difficulty of converting geologic data to engineering uses are considered, and in lieu of a universally satisfactory means for accomplishing this, a few specific conversions are discussed and illustrated. Each is considered separately from the standpoint of possible materials requirements and the application of geologic methods to the location of usable materials.

● GEOLOGY has some application in practically every phase of a materials survey. It might be considered a starting point for every study of naturally-occurring materials. Certainly geology paves the way for such specialized techniques as airphoto interpretation and geophysical prospecting. Beyond that, the geologic approach within itself is a practical way of examining a locality and estimating the character and extent of its deposits. At the very least, a geologic system for classifying materials puts information on a universal basis, provides continuity from source to source, and serves as a means for correlation from state to state or region to region.

Many services and vast stores of information applicable to materials surveys have been developed through geologic interests and geologic endeavors. In addition to the many universities with geology departments and state geologic surveys, the federal government has several agencies dealing with geology - the principle one, of course, being the United States Geological Survey. The literature which has accumulated through the efforts of these and other organizations is tremendous, and by a conservative estimate as much as 80 percent of the reasonably populated area of continental United States has been interpreted geologically with some degree of intensity and accuracy. Usually the literature is accompanied by one or more maps, and most of these usable by persons having an elementary knowledge of geology.

BASIC PRINCIPLES UTILIZED

The basic unit of the geologist is a time unit. Practically all the maps and a large percentage of the written materials are concerned with this unit. When a name is assigned to a formation, the intent is to establish the age of that formation in relation to other formations, or simply the time this unit was deposited in geologic history. Within any given area, this time unit or formation will be continuous either beneath the surface or as an outcrop; or, if much of it has been removed at the surface, the formation will probably be recurring.

If the area considered is small enough and the depositional features attendant to the formation were constant enough, the

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material will have the same characteristics wherever it is encountered. However, where the depositional features were not constant, and particularly where the distances between points of identification are great, there may be vast differences in the characteristics of materials of a given age or time unit. Hence, deposits of sandstone in Kansas may have a geologic counterpart in deposits of limestone in Kentucky. They will without doubt carry different identifying names, but they were deposited at exactly the same time, as evidenced by the fossils embedded in the two stones.

A complete system of these time units has been worked out, and the science of stratigraphy attempts to correlate and simplify the massive groupings into a single integrated system. Every map has its own stratigraphic section, and usually the system within one state corresponds with that in an adjacent state, although quite often there are minor differences essentially unimportant.

The areal geologic map, one example of which is shown in Figure 1, is traditionally the favored mode of geologic expression, and it is by far the type map most frequently encountered. Often placed on a base with topo, this type map outlines the formations on or nearest the earth's surface. In effect, then, it outlines the materials which would be exposed if all the soil cover and vegetation were removed. In a great number of cases, the topmost deposits identified and classified geologically are unconsolidated, and in those instances there is but a fine line of differentiation between the soil actually exposed at the surface and the underlying formation which would be exposed if the soil were removed.

On the areal geologic map, the time units or formations are represented by colors or symbols. Along with the legend describing the significance of these colors and thicknesses of formations, there are written explanations or appropriate symbols describing the composition or characteristics of the different units, and also nomenclature identifying relative geologic ages. Sometimes cross sections are included to show structure which can be inferred by detailed examination of the map and the relative ages of surface formations appearing there. If all this type information, exclusive of the legend, does not appear directly on the map, it is generally included in some form within the report which is accompanied by the map.

INTERPRETING THE AREAL GEOLOGIC MAP

At a glance it is obvious to the person interested in surveying for usable materials that the areal geologic map does not tell him all he wants to know. His first impulse may be to disregard the map entirely because its primary basis of differentiating rock materials is age and not by composition, or chronologic and not petrographic. He would prefer to know, with relation to the area in Figure 1, that the most prevalent bedrock material is a "light-colored, moderately coarse-grained rock with a granular appearance," and that it is typically "composed of 25 to 50 percent of quartz, 35 to 65 percent of feldspar, and 3 to 13 percent of biotite," rather than to find that the symbol on the map represents "Monson gneiss" of the late Devonian period.

However, the petrographic description just quoted, and other references to the range of variations in Monson gneiss, are contained in the report (1) pertaining to this map. For one having no more than a rudimentary knowledge of geology, an areal geologic map and related information can be useful in many ways. First, if the problem is location of a specific rock type, such as limestone, granite, or gneiss, the map shows whether or where a material of this description is present within the area of interest. Thicknesses and possible locations for favorable investigation are indicated. If there are no outcrops, is it within reasonable depth for excavation or is mining the only feasible means for recovery? Perhaps a fault or break in the earth's crust has moved it from far underground up to a near-surface position.

Identification of formations in the field using this information is possible. Appearance or lithologic descriptions are always available, and there are references to fossils, which may be useful in establishing the continuity of a formation. For the most part, however, use of fossil evidence is reliable only when a geologist, palentologist, or someone trained in the

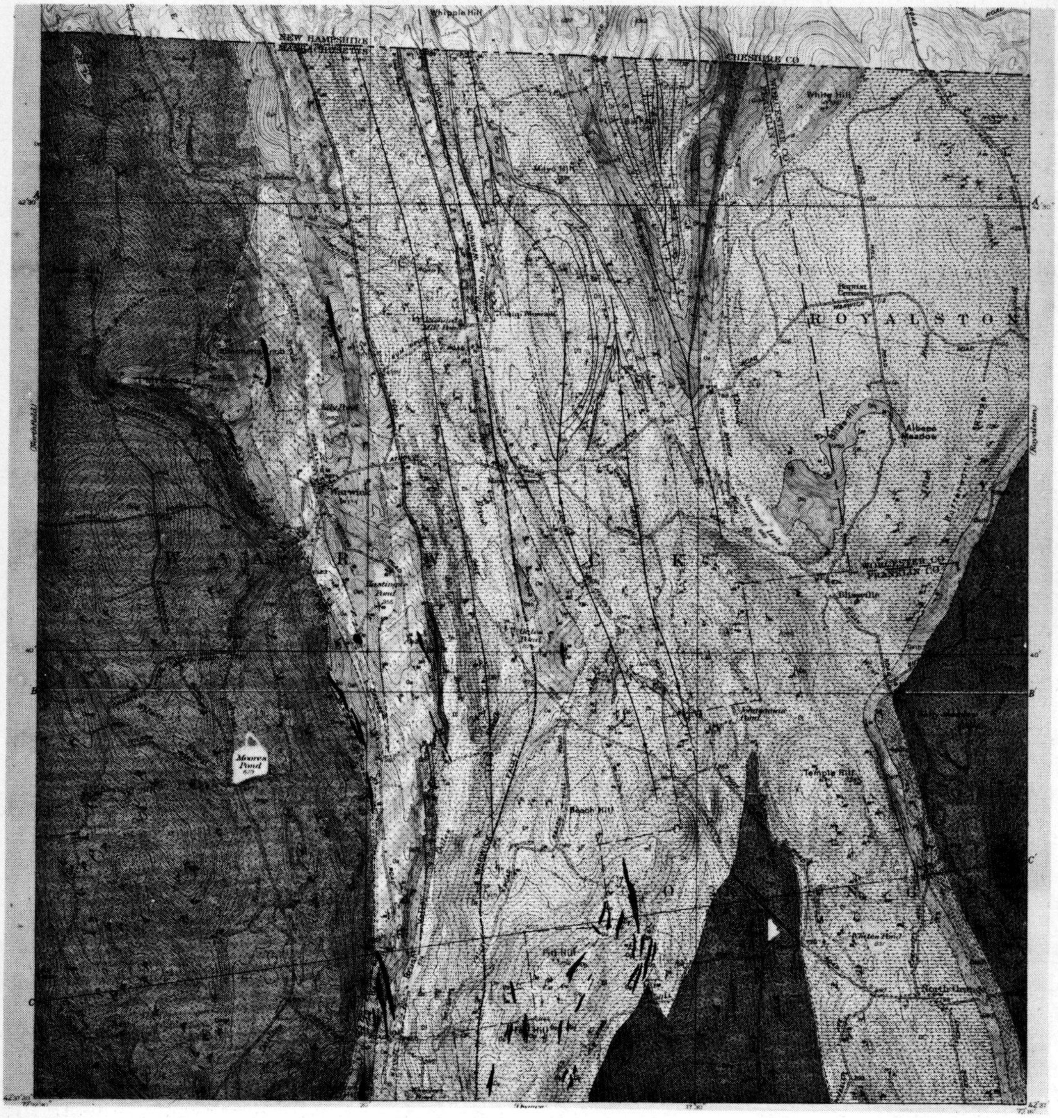

Figure 1. Map showing bedrock geologic features in the Mount Grace Quadrangle, Massachusetts.

identification and classification of fossils is engaged in the work. The geologic layman can, in many cases, record the position of a rock unit with reference to some very characteristic neighboring rock unit and, in that way, carry his survey from spot to spot with sufficient accuracy.

All this applies where consolidated rock formations are the principle sources of materials, and particularly in the regions where transported materials do not overlie bedrock. It is applicable in many regions (such as the Atlantic and Gulf Coastal Plain) where the formations to great depths are unconsolidated or poorly consolidated at best. These are identified and mapped areally in just the same way as the bedrock formations. However, for a considerable portion of the country, and particularly in the glaciated regions, the traditional geologic survey in most cases did not interpret the deposits of greatest concern as highway materials--the deposits near the surface.

Figure 2. Map showing surficial geologic features of the area illustrated in Figure 1.

SURFICIAL DEPOSITS INCLUDED

This was recognized more and more as time went on, and recently the policy of making a survey and map of surficial deposits has been instituted. Figure 2 illustrates the surficial geology of the same area represented by the map in Figure 1. Note that rock outcrops are just recognized as such, while emphasis is placed on materials of primary importance for highway use. Extensive kames and kame terraces, eskers, and late outwash sand and gravel predominate in the deep valleys, and till (which in itself is sandy) covers all the uplands.

Explanatory material with the legend, and more so the brief report (2) of this work, generalize on the character of the various deposits in order to cover the entire range. For example, the kames and kame terraces are described in the map legend as "deposits of sand and pebble gravel, cobble gravel, or boulder gravel," but in the report effort is made to reduce the generalities as much as possible. Ac-

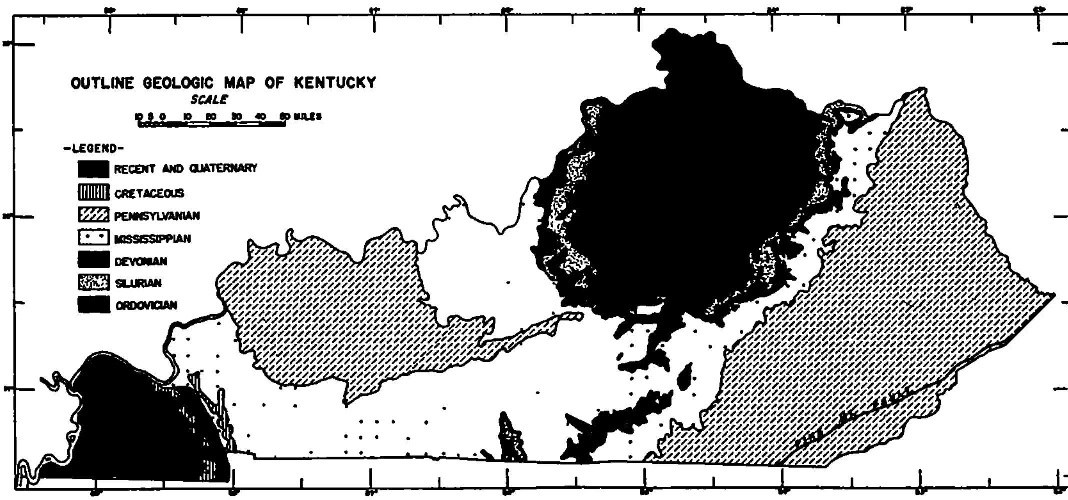

Figure 3. Outline geologic map of Kentucky showing the major divisions by geologic periods.

tually, an analysis of depositional processes might logically lead to the conclusion that the coarser materials (cobbles and boulders) lay near the middle of the valley or the logical main stream channel, and the materials would gradually become finer and finer as the valley walls were approached.

This is based on the assumption that the separation and deposition was accomplished by large volumes of melt waters flowing from the receding ice sheets in broad channels. In many cases, however, flow of water within, along the edges of, or beneath stagnant ice in the valleys caused peculiar variations, and so-called ice-hole deposits locally produced more uniform materials of graded sands and gravels. Numerous existing sand and gravel pits are indicated within the limits of these valleys, evidence that the deposits have been and undoubtedly still are utilized, for road construction. Of the 43-sq.-mi. area covered by the map and report, more than 10 percent is occupied by the granular formations of glacial deposition. Another 5 percent consists of recent alluvium which is dominated by rewashed granular materials.

The depths or the extent of deposits are not estimated. This would be added information of value if it were not for the fact that the proposed use determines the desired composition. It goes without saying that in any materials survey the suitability

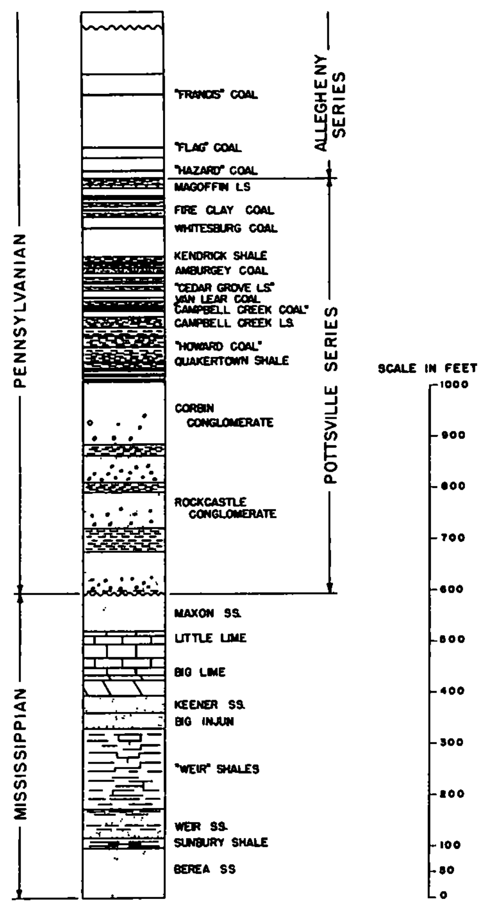

Figure 4. General stratigraphic section in the Paint Creek area of eastern Kentucky.

of a deposit for a certain use must be determined by tests; however, projection of test data from location to location can be done with approximations that satisfy the objectives of a preliminary survey at least.

STATE WIDE GEOLOGIC MAPS

Generally the survey for materials, as it applies to a project or projects within a certain locality, does not extend beyond

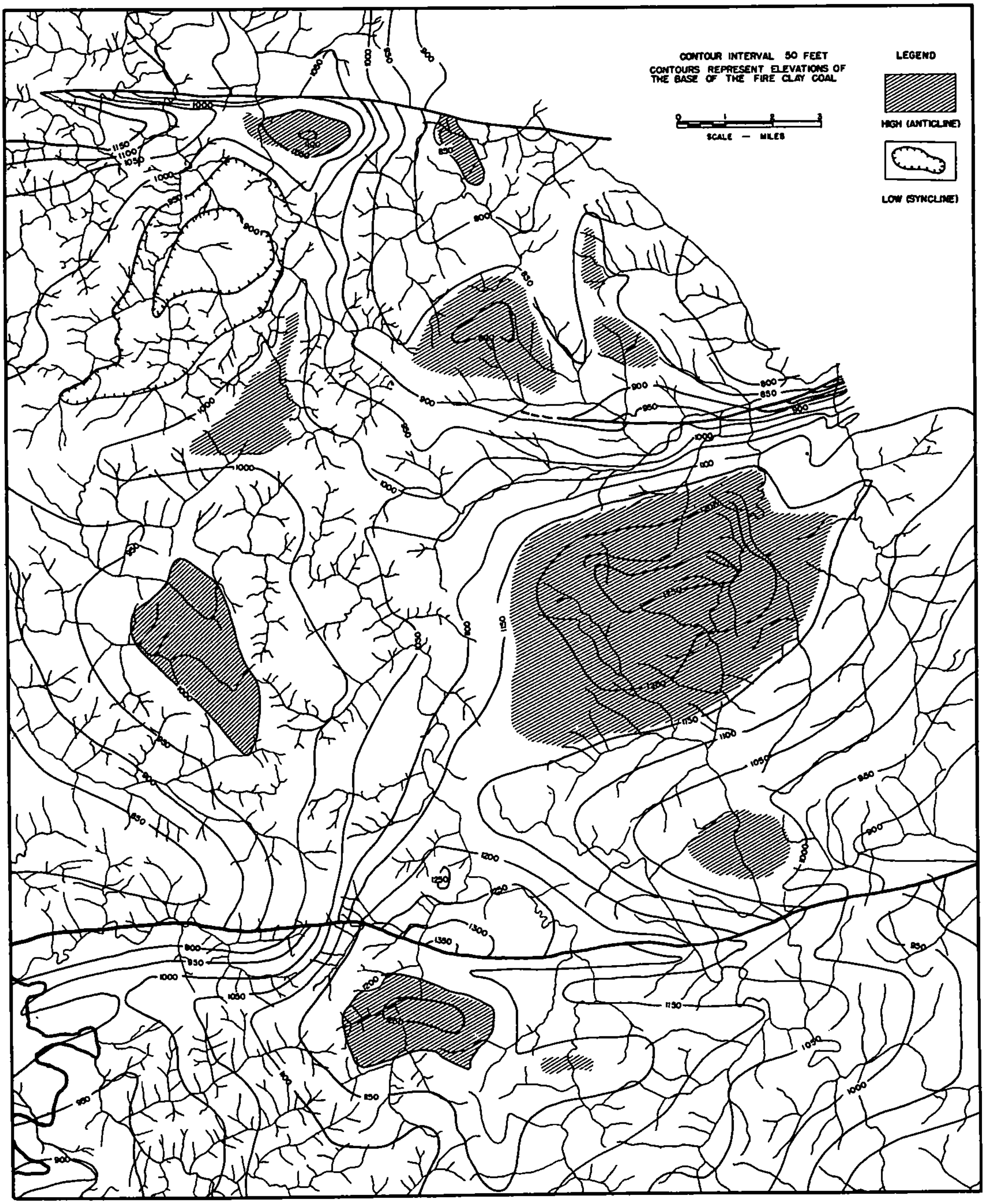

Figure 5. Simplified structural geologic map of the Paint Creek area in eastern Kentucky.

the limits of three or four adjacent quadrangles or an area three or four times as great as the maps which have been illustrated. However, transposing information from location to location or from source to source requires a use of the broader geologic classifications. This is where the time system of reference and the geologic nomenclature become more important.

In most if not all the states, the data from individual geologic studies and surveys have been gathered together and summarized in the generalized geologic map of the state. The outline map for Kentucky shown in Figure 3, represents a summary version of a much more specific map (10) of this description. Bedrock geology predominates, for unconsolidated materials on a broad scale are important only in the far western part of the state where the legend depicts Recent and Quaternary formations. This section, despite its distance from the present Gulf of Mexico, is a part of the Atlantic and Gulf Coastal Plain. It contains deposits that are related in age and have characteristics similar to those prevailing in Tidewater Virginia or the entire eastern quarter of Texas.

This fact alone justifies the use of state-wide geologic data as a basis for materials surveys, and certainly establishes the geologic approach as a foundation for materials reconnaissance. By the use of a map covering such a large area, one soon becomes accustomed to thinking of materials distribution on a time-area basis, and his concept of the relationships is thus broadened.

Throughout the eastern portion of Kentucky, in an area almost one fifth the size of the entire state, sandstones and shales of the Pennsylvanian period are practically the only formations to depths of several hundred feet. Only where faults have developed or uplifts occurred has a limestone deposit been placed in a workable position. Because of the variations in sandstone, and the limited use made of it as a construction material, other aggregates have been shipped into the region under circumstances where the shipping cost alone far exceeded the total cost of the same aggregates at other points throughout the state.

This fact stimulated the investigation and use of local deposits of sandstone, and also emphasized the importance of surveys for usable deposits of limestone. According to the generalized stratigraphic section shown in Figure 4, the so-called Little Lime and Big Lime formations of the Upper Mississippian period could be buried as much as 1000 ft. beneath the topmost Pennsylvanian formation existing in the east-central part of the area under consideration. However, there were obviously variations where uplifts had occurred and where different amounts of the overlying sandstones and shales had been removed.

These two limestones in combination represented a possible face of 90 to 120 ft. of high quality material, and the problem became one of finding where they might be within reasonable depths for profitable recovery. Near-surface conditions for quarry operations were hardly possible, but inasmuch as a mining operation for limestone at a depth of 250 ft. had been economically successful in central Kentucky under a similar set of circumstances the survey was based on locations of the limestone within 250 ft. of the ground surface.

The simplified structural geologic map (Fig. 5) shows the results of the survey. A key bed (the Fire Clay Coal) which has been logged extensively throughout the region was selected as a datum, and elevations were determined from drilling records. In many places these beds have been folded and faulted, so the upfolds or anticlines offered the best possibilities for near-surface locations of the limestone formations. These anticlines are shown as shaded areas in Figure 5, and it is within these that the specific investigations are being carried out.

Surveys with respect to the sandstone have been profitable, also. Here, however, the problem was different because sandstone as such is abundant. Yet, because of its variations, with dipping strata and beds that vary in thickness or "pinch out," there is no assurance of high quality sandstone for any great distance either horizontally or vertically at a promising quarry location. As an experimental proposition related to the surveys for these materials, the Kentucky Department of Highways developed a test road to determine what constitutes quality in sandstone as a bituminous paving aggregate.

Figure 6. Quarrying Pennsylvanian sandstone for construction of a bituminous test pavement on Kentucky Route 30. Unusual variations in the form and quality of sandstone deposits constitute problems in materials surveying.

One of the quarries from which sandstone for these tests was taken is shown in Figure 6. This quarry opening, which averaged about 35 ft. in depth, exposed three distinct and greatly different sandstones. As the quarry operations progressed laterally, the ledge composed of the intermediate-grade material pinched out within less than 100 ft. Conditions of this sort are the rule and not the exception among the Pennsylvanian sandstones, so practical use of sandstones was dependent upon broad specification limits encompassing a variety of material grades.

After 2 years of investigation and the placement of 25 mi. of hot-mix pavement sections of all types, it has been shown (7) that very soft sandstones (with Los Angeles Abrasion losses as high as 40 percent in 100 revolutions and 90 percent in 500 revolutions) can be used satisfactorily. This is so, provided the type of mix is conducive to the gradation which naturally results from the processing of such friable materials in a hot-mix plant and also from the action of 10-ton rollers on the paving mix. At any rate, sandstones having widely varying properties are usable; and from a materials-survey standpoint, the problem now is one of locating, cataloging, and making inventories of potential sources.

UNCONSOLIDATED DEPOSITS MAPPED STATE WIDE

While the state geologic maps as a rule show primarily bedrock geologic data, there have been a few surveys which have produced excellent state-wide maps of surficial deposits. As an example, one section of a map prepared as a part of a USGS professional paper (4) is shown in Figure 7. The area covered is in southeastern Minnesota, but the map in total extends over the entire state and somewhat beyond those boundaries.

This map is a generalized landform,

soils, and materials map in one, with the added advantage of detailed descriptions telling not only the basic composition of the materials but also the manner and sequence of their deposition. These descriptions, as in the case of the quadrangle discussed before, are contained in the report of the work. Materials from three stages of glaciation and some loess deposits, important only from the standpoint of soil problems, are outlined in relatively minute detail, but the greatest distinctions are made in the variety of materials left during the fourth and latest stage of glaciation.

The glacial tills designated as terminal and ground moraines dominate in area, and the separation of these is mainly on the basis of ice sheets with which they were associated rather than on the basis of differences in character. On the other hand, outwash sands and gravels associated with all the different ice sheets are scattered throughout the bulk of the state.

Unfortunately neither the map legend nor the report gives even a good indication of the properties of these granular deposits. They are hardly more specific in describing the terraces associated with major drainage ways, the numerous kames which are specifically marked, and the very prominent eskers, some of which are shown in the upper part of Figure 7. If the use of this information for materials reconnaissance had been visualized at the time the work was done, undoubtedly there would have been greater emphasis on the analysis and description of these

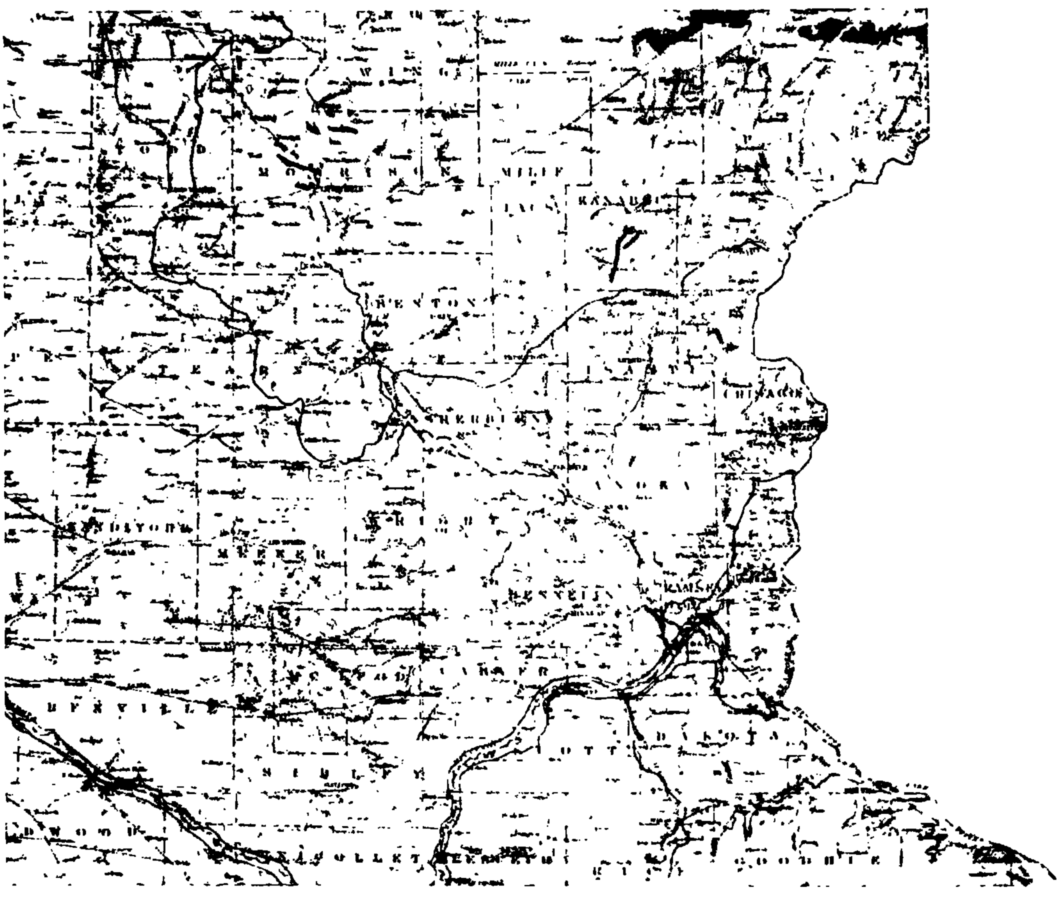

Figure 7. Excerpt from map showing surficial geologic features developed by glaciation in southeastern Minnesota.

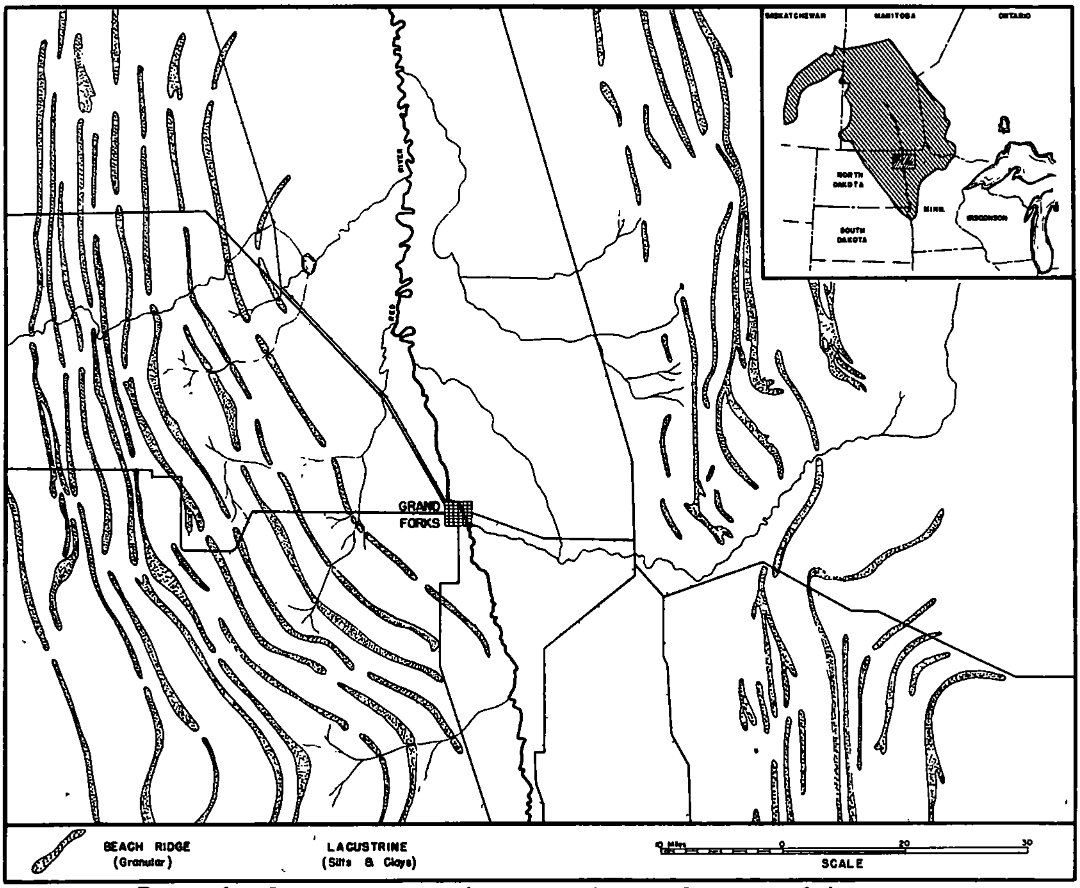

Figure 8. Location map and section showing features of deposits in the abandoned bed of glacial Lake Agassig.

deposits.

Probably because conditions were naturally more uniform over broader areas in the extinct glacial lake beds, descriptions of the lacustrine clays and sands were more specific. Beach ridges of sands and gravels were defined even better. By far the most extensive and best known of these lakes is the extinct Lake Agassiz which existed for a long period of time as the glaciers receded but normal drainage channels were blocked. The extent of this lake bed is shown by the shaded portion of a small diagram in the upper right of Figure 8. A small section of the lake bed is enlarged in the main part of the figure.

Clays and silts predominate in the central part of the abandoned lake, and topographically the land is flat. Drainage is slow, and ground water tables are high. Subgrade bearing for railroads, highways, and airports is obviously critical. It is told, by civil engineers who worked on the building of railroads in this territory near the turn of the century, that suitable material for raising grades was considered so important, lengthy searches on horseback were made in a haphazard manner. With but a hint of the origin of these deposits, these men would have reached the obvious conclusion that sorting of materials at the edges of such large bodies of water would have produced granular beaches in an orderly way.

The pattern of beaches is illustrated in Figure 8. Each set of beaches represents a different stage in the lake during its existence. Undoubtedly some of the sands of the beaches are too uniform or too fine for many requirements which must be met by granular materials, but the mere outline of such physical land features simplifies the reconnaissance and reduces the number of locations where detailed investigations must be made.

GEOLOGY THE BASIS FOR ALL SURVEYS

Certainly any detailed survey, whether carried out through extensive sampling alone, through use of airphotos, through geophysical methods, or some other means, should begin with geologic reconnaissance if there are such data available. Maybe the information is sketchy, and seldom will it provide more than just a guide. But to disregard it entirely is to disregard nature and natural processes of materials formation.

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