# PREPARATION OF AN ENGINEERING GEOLOGIC MAP OF THE HOMESTEAD QUADRANGLE MONTANA [1]

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## SYNOPSIS

The increased engineering demand for geologic data has focused attention on the engineering geologic map. Four basic requirements for this kind of map are: 1) avoidance of highly technical geologic terms; 2) emphasis on the physical differences and similarities of both rock and soil materials; 3) a three-dimensional quality to aid in subsurface interpretation; and 4) emphasis on deposits of constructional material. The engineering geologic map of the Homestead quadrangle in northeastern Montana attempts to fulfill these requirements by using several special techniques of presentation. The map is accompanied by a tabulation of engineering properties of each of the map units.

Within recent years, the increasing demand for comprehensive engineering planning has made evident serious inadequacies of essential technical information. Prominent among these is the lack of geologic information that is readily adaptable to engineering needs. Diverse engineering planning studies such as for highways, industrial and urban developments, flood control, power, and reclamation, have all shown in one way or another the need for interpretation of geologic data. In an effort to fill this need, the U.S. Geological Survey has directed a part of its current geologic program to the field of engineering geology and is experimenting with the problem of the engineering geologic map as one phase of this work.

The geologic map made specifically for civil engineers - the engineering geologic map - is not a new concept nor yet has it ever been crystallized into any conventional form. One reason for this is the extreme range of interest covered by civil engineering. Geologic maps made especially for the study of a dam are no new story, nor are those made for structures with critical foundation requirements, nor those for highway route surveys. The conventional areal geologic map has often been profitably used by engineers trained in geology. Moreover, one of the duties of the geologic staffs retained by the larger engineering offices is to interpret such maps for engineering use.

The integration of the pedologic map and the geologic map has impressed Olmstead[2] as a necessary step in preparing the highway engineering map. Jenkins, Belcher, Gregg, and Woods[3] have pursued the

[1] Published by permission of the Director, U.S.Geological Survey.

[2] Olmstead, F. R., "Systematic Planning of Low Cost Roads," *Proceedings*, Association of Asphalt Paving Technologists, Vol. 12, 1940.

[3] Belcher, D. J., Gregg, L. E., and Woods, K. B., "The Formation, Distribution, and Engineering Characteristics of Soils." Purdue University, *Engineering Bulletin*, Research Series No. 87, 1943. Cont. next pg.

"engineering pedology" map to great length. They have indicated a relatively fast and inexpensive kind of regional mapping based on the synthesis of geologic and pedologic factors. A study of the Fairfax quadrangle, Virginia, by V. P. Sokoloff and A. H. Nicol of the U.S. Geological Survey, now being prepared in cooperation with the Public Roads Administration, is another example of a type of highway engineering map that can be made. Some of the recently published county soil surveys of the U.S. Bureau of Plant Industry, Soils, and Agricultural Engineering satisfy many of the requirements of a highway engineering map. The terrain intelligence maps prepared by the Military Geology Unit of the U.S. Geological Survey are noteworthy attempts to interpret geology for the military engineer.

Despite the efforts that have been made from time to time by various groups, there still is a very real need for maps that present the wide range of geologic data that are of interest to engineers in a form that is readily comprehensible to them. To be of maximum usefulness in planning engineering structures, such maps should fulfill the needs of the small independent engineer as well as those of municipal, state, and federal agencies. On the other hand, the range of possible future construction projects in any area large enough to be considered in a regional study is probably too great to be taken care of by any one geologic map. A certain definition is therefore required as to what engineering problems can be economically answered by a single map.

Broadly speaking, the requirements of an engineering geologic map are relatively simple. First, all technical geological terms that are of no practical use to the engineer should be eliminated or subordinated. Foremost in this category are historic and genetic terminology which, although of great interest to the geologist, are often an encumbrance to the engineer. Second, emphasis should be placed on materials, and map units should be adjusted, insofar as possible, so that lithologically similar rocks and texturally similar soils are identified as such on the map. Conversely, different rocks and different soils should be sufficiently differentiated. In addition, fully as much attention should be given to overburden or soils as is given to the underlying bedrock. Third, a three-dimensional quality should be given to the map so that the engineer will be able to "look" under the surface and estimate with some degree of assurance what materials and conditions will be encountered at depth. Fourth, deposits and workings of natural construction materials should be conspicuously indicated.

The map of the Homestead quadrangle is an attempt to resolve the requirements described above by clarifying the presentation of data that are usually shown on an orthodox areal geologic map. The map itself is a geologic map in every sense of the word; the text which accompanies it is concerned only with the engineering aspects of the map data. Part of the map is shown in Figure 1.

The area covered by the map is a

Belcher, D. J., Discussion on paper, "Geology in Highway Engineering," *Proceedings*, American Society of Civil Engineers, May 1944.

Belcher, D. J., "Engineering Significance of Soil Patterns," *Proceedings*, Highway Research Board, Vol. 23, 1943.

Jenkins, D. S., Belcher, D. J., Gregg, L. E., Woods, K. B., "The Origin, Distribution, and Airphoto Identification of United States Soils," *Technical Development Report No. 52*, Civil Aeronautics Administration, May 1946.

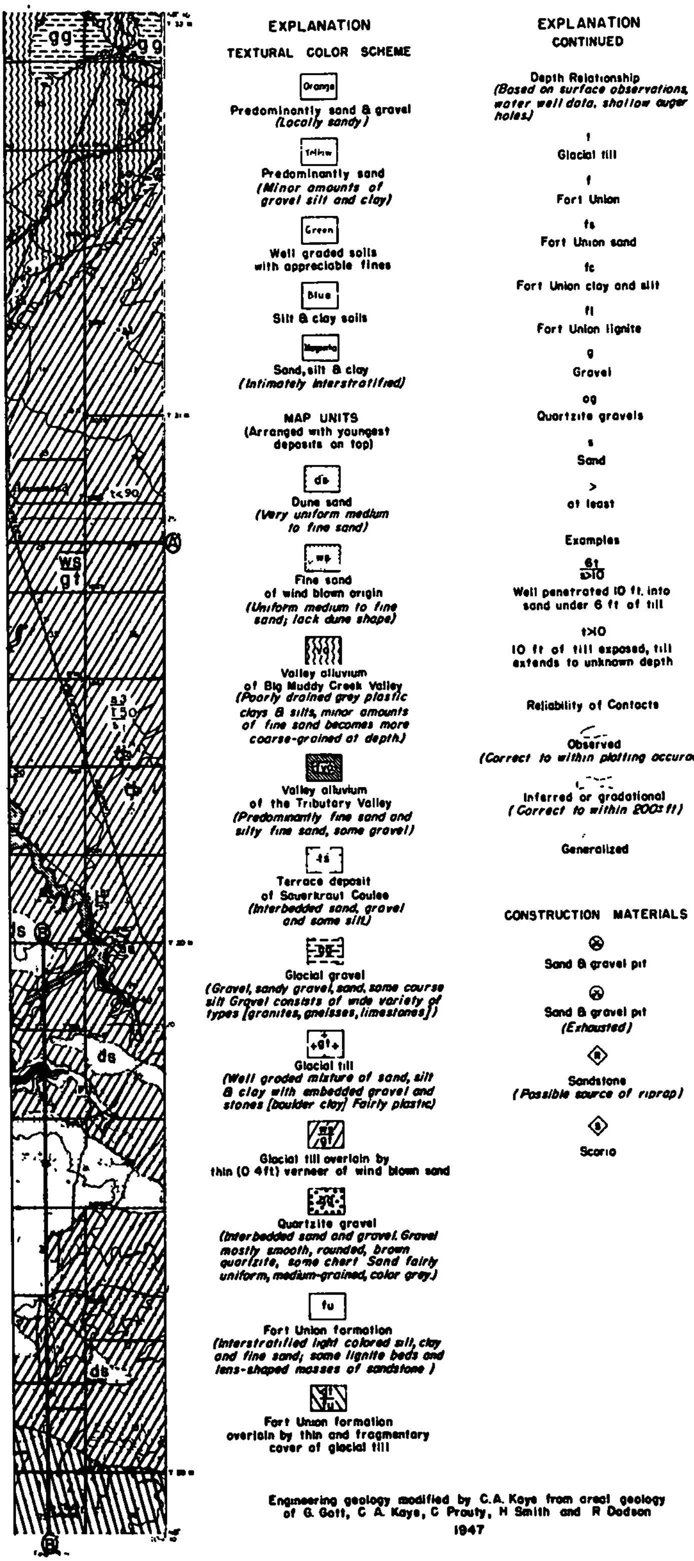


Figure 1. Engineering Geologic Map of the Homestead Guadrangle showing the Map Legend and Part of the Map-USGS

standard 15-minute quadrangle located in Roosevelt and Sheridan counties in northeastern Montana. The study was made as part of the Geological Survey's investigations in the Missouri River Basin, and the particular quadrangle was chosen because it fell within the area of the proposed Missouri-Souris unit of the Interdepartmental Missouri River Basin development plan. The region is largely given over to wheat farming and grazing, and contains few engineering structures of any importance. No hard-surfaced roads occur within the quadrangle. The selection of this area for the preparation of an engineering map was somewhat influenced by the proximity, just south of the quadrangle, of the site of a proposed large earth-fill dam. Because the area contained no hard bedrock and the relief was nowhere very great, a full range of geologic conditions was not encountered in making the engineering geologic map. The area is, however, fairly typical of the northern glaciated Great Plains and as such is of interest from a regional point of view.

The Homestead quadrangle consists chiefly of a moderately well-drained glacial till plain of low to moderate relief. The soft bedrock (silt, clay, and sand of the Fort Union formation) crops out in a number of places. The flood plain of Big Muddy Creek is a conspicuous feature of the quadrangle. It is underlain by clay and at greater depth by sand and gravel. Several large areas of sand dunes occur in the southern half of the quadrangle. A gravel, consisting predominantly of quartzite pebbles, crops out on the valley sides where it rests on the Fort Union formation and underlies the glacial till.

Field mapping consisted of the systematic examination of all outcrops and road cuts. The bedrock was examined in detail in the sides of the deeper valleys and ravines. Auger holes were put down where road cuts and outcrops were scarce Well logs were collected from farmers and drillers, and, after a certain amount of interpretation, were incorporated into the geological picture. Most of the area was accessible to automobile by a network of section-line roads. Mapping at a scale of 1:20,000 was done on aerial photographs. The geology was later transferred to the published topographic map of the quadrangle (scale 1:62,500).

As in most geological work, the aerial photographs were an invaluable aid. The broad features of the glacial geology of the area were relatively simple and in many cases could be interpreted from a study of the photographs. The slightly undulating and imperfectly drained till plain was clearly distinguishable from the flat clayey floodplain of the river and creeks. Low gravel terraces in the river valleys were indicated by a difference in pattern and the sand dune areas were clearly visible. Outcrops of sediments of the Fort Union formation were identified from the light coloration and the characteristic shape of slopes. All of the interpretations made from aerial photographs were checked and confirmed in the field.

The use of aerial photography in engineering geologic mapping has been ably described by Eardley[4] and by Jenkins, Belcher, Gregg, and

[4] Eardley, A. J., *Aerial Photographs: Their Use and Interpretation*, Harper and Bros., 1942.

Eardley, A. J., "Aerial Photographs and Distribution of Constructional Materials," *Proceedings*, Highway Research Board, Vol. 23, 1943.

Woods[5]. The writer's experience indicates, however, that accurate mapping by this method requires considerable ground checking. Characteristic land forms possessing typical material associations occur too rarely in nature to permit extensive armchair mapping. It is safe to say that the accuracy of the final map is in direct proportion to the amount of energy expended in actual field mapping.

The Homestead, Montana, topographic map, published by the U.S. Geological Survey on a scale of 1:62,500, with a 20-foot contour interval, served as a base map on which the engineering geologic data was plotted. The finished map and a text in tabular arrangement are printed on one double folio-size sheet. Distribution has been limited to official of the federal agencies concerned with Missouri River Basin development.

In order to emphasize the distribution of materials on the Homestead map, certain colors were adopted as standard for materials of different textures. This color scheme is explained separately on the side of the map sheet. Because the quadrangle is almost entirely lacking in hard rock, the textural classification is necessarily limited to unconsolidated sediments. Materials that occur in the quadrangle were subdivided into five groups: 1) predominantly sand and gravel, locally sandy; 2) predominantly sand, minor amounts of gravel, silt, and clay; 3) well-graded soils with appreciable fines; 4) silt and clay; and 5) sand, silt, and clay intimately interstratified. All map units that are predominantly sandy are given the same color on the map (yellow), and similarly all units that are clayey or gravelly are given their characteristic colors. The advantage of establishing colors for easily definable lithological or textural types lies in the fact that the textural picture is in that way made clear and obvious. As an example of its application, one can imagine that the engineer looking for gravel will be able to appraise an area rapidly by looking for the orange color. In order to satisfy the needs of a broad regional program of engineering geologic mapping a more comprehensive textural and lithologic breakdown, perhaps along the lines suggested by Belcher[6], should be adopted and standardized. The relatively simple textural legend used in the Homestead quadrangle seemed adequate, however, for that particular area.

An additional breakdown of map units is necessary in order to facilitate the interpretation of stratigraphic relationships and to distinguish essential differences between materials of the same predominant texture. Map units of the same texture, and therefore the same color, but of different origin or stratigraphic position, are distinguished by different letter symbols and by print patterns. This type of map presentation for engineers differs from the traditional geologic map only in the use of similar colors for similar textures or lithologies, instead of similar colors for similar geologic ages.

The three-dimensional quality of the map was handled by adopting directly several features long employed in German geologic mapping. A mappable area that is character-

5 Jenkins, D. S., Belcher, D. J., Gregg, L. E., Woods, K. B., "The Origin, Distribution, and Airphoto Identification of United States Soils," *Technical Development Report No. 52,* May 1946.

6 Belcher, D. J., "Engineering Significance of Soil Patterns," *Proceedings,* Highway Research Board, Vol. 23, 1943.

ized by one type of material mantling another is shown by a striped color pattern combining the two colors employed to symbolize the two materials. Thus, a thin sand mantle overlying glacial till is visually suggested by a striped yellow (sand) and green (till) pattern. In addition, the letter symbols of the two soil types indicate this superposition by being combined in the manner of a fraction, the symbol of the upper material over the symbol of the lower. Abbreviated well logs or sections measured in the field were also noted on the map in order to give a clearer picture of relative thicknesses and depths of materials. This was done by a small notation that again resembles a fraction. Each map unit and soil type was indicated by a letter and the sequence of materials encountered in the well are shown by the appropriate letters ranged correctly in vertical order and separated by short horizontal lines. The thickness of each material is shown to the right of the small letter symbols. These notations should prove a definite aid to the engineer in helping him form an idea of foundation materials. It would seem advisable to record this sort of data as densely as is compatible with the legibility of the map.

Sand and gravel pits are shown on the Homestead map by solid red circles rather than by the inconspicious conventional symbol of the black crossed shovels. Deposits of potential construction materials are similarly indicated by brightly colored symbols which are explained in the lengend.

The report that accompanies the map is arranged in tabular form. The map units are described under the following headings: 1) the textural and lithologic classification; 2) distribution and thickness; 3) terrain and natural slopes; 4) stability (both undisturbed and reworked) and the probable frost-heaving characteristics; 5) drainage and permeability; 6) workability; 7) use in highways, and as construction material; and 8) the pedologic soil series equivalent. Because of space limitations necessitated by the folio format, only a brief paragraph was devoted to each map unit under the above headings. The soil description and properties were mainly empirical qualitative judgments by the writer, and no soil tests were made in this study. Although it is recognized that some local variation in texture and physical properties may occur within the map units, the physical characteristics described are probably valid for the unit as a whole. The fact that the geologic map units more or less conform to pedologic soil units is of especial significance to the usefulness of the map for highway engineering. In explaining the term "engineering pedology," Belcher[7] wrote: "Regardless of geographic distribution, soils developed from similar parent materials under the same conditions of climate and relief are related, and will have similar engineering properties which in comparable positions will present common construction problems and produce like pavement performance."

It is evident that an engineering geologic study of a type suggested by the Homestead quadrangle does not eliminate the need for detailed foundation investigation. Each structure carries with it a series of foundation problems sufficiently unique to render impossible anything but a presentation of more or less generalized information on a map of this type. The

[7] Belcher, D. J., "Engineering Significance of Soil Patterns," *Proceedings,* Highway Research Board, Vol. 23, 1943.

greatest usefulness of the engineering geologic map is in planning and in preliminary site studies. Further refinements of the map are obviously indicated, although in its present state it answers a number of engineering questions. Additional mapping will lead to a wider interest in this type of work and improved forms of map presentation.