Use of Geologic Strip Maps in Highway Location and Design

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Under a cooperative program between the Massachusetts Department of Public Works and the U.S. Geological Survey, the state is securing valuable information relative to the surficial and bedrock formations for the location and design of highway projects.

● IN THE DESIGN and construction of modern major highways the engineer faces a diversity of problems. These are in considerable measure concerned with the topographic characteristics of the terrains, and the physical properties and structures of the underlying materials. In the days of narrower and lower-speed highways there was greater latitude in choosing a road site. Today the highway route must be as direct as possible, and the design must meet all the requirements of modern highway standards, with curves of adequate sight distances, easy grades, and well-drained foundations capable of sustaining heavy traffic loads. To fulfill these requirements, less favorable topographic features must be traversed rather than avoided in many places, so that deep and wide cuts, and long, heavy fills are frequently necessary. Costs of excavation are greatly increased because many of the cuts penetrate well into bedrock. Likewise, costs of filling rise, because the greater volume of suitable material to be provided is often obtainable only at a considerable distance from the fills. In places, as in boggy areas, unsuitable materials must be removed and suitable ones substituted. Shallow or perched water tables may exist and require special construction to provide good subgrade drainage. Footings of heavy bridge piers must, in places, be spread in soft or even in plastic materials instead of on sound bedrock. In the design of such piers it is advantageous to know if bedrock can be reached economically, or if the overlying unconsolidated material is uniform and can adequately support the loads to be imposed. Thus, the engineer is faced with problems of design and construction that involve many geologic factors. The concern, therefore, is with the techniques of the engineering geologist insofar as they can contribute valuably to the analyses and solutions of the problems, or facilitate the work of construction. The engineer is not ordinarily prepared by either training or experience to make geologic interpretations.

The engineer who is untrained in the applications and techniques of geologic science is, therefore, not only unable to project his local experience from point to point in a glaciated area with reasonable assurance, but many times he cannot interpret even the local soils and rocks with sufficient certainty. It is the third dimension that is not disclosed to him, and it is the variation in this vertical dimension of the terrain with which he is particularly concerned. The surface deposits may be misleading, the soil zone greatly variable even within shallow depths, and hidden boulders may, and often do, mislead or confuse him with regard to the position and nature of the bedrock. It is true, of course, that the geologist cannot always make accurate interpretations from surface data alone, but must rely on some other techniques; nevertheless, even where surface data are inconclusive to him, the geologist's guess is considerably better than the engineer's and is based on laws of geologic probability as suggested by the local surface geology. He is, by virtue of training and experience in his science, in a far better position to make directive interpretations and give warning of probable or possible difficulties. He should, in general, be better equipped to work with specialists in the fields of seismology and soil mechanics, and, indeed, should be in a position to advise when such collateral services are needed or desirable; moreover, he should not be reticent or hesitant in recommending such services.

The geologist's aim is to call the attention of the engineers to the kinds of data available through geologic techniques, and to make such data as directive and quantitative as possible. It is helpful if he knows something about the technical methods of the engineer, but he should not presume to advise in purely engineering methods. Upon the engineer, on the other hand, rests the responsibility to seek and use all available data that will contribute to sound and economic design or construction of highways and bridges. This, then, is the philosophy that determines the pattern for engineering geologic work under the Massachusetts program.

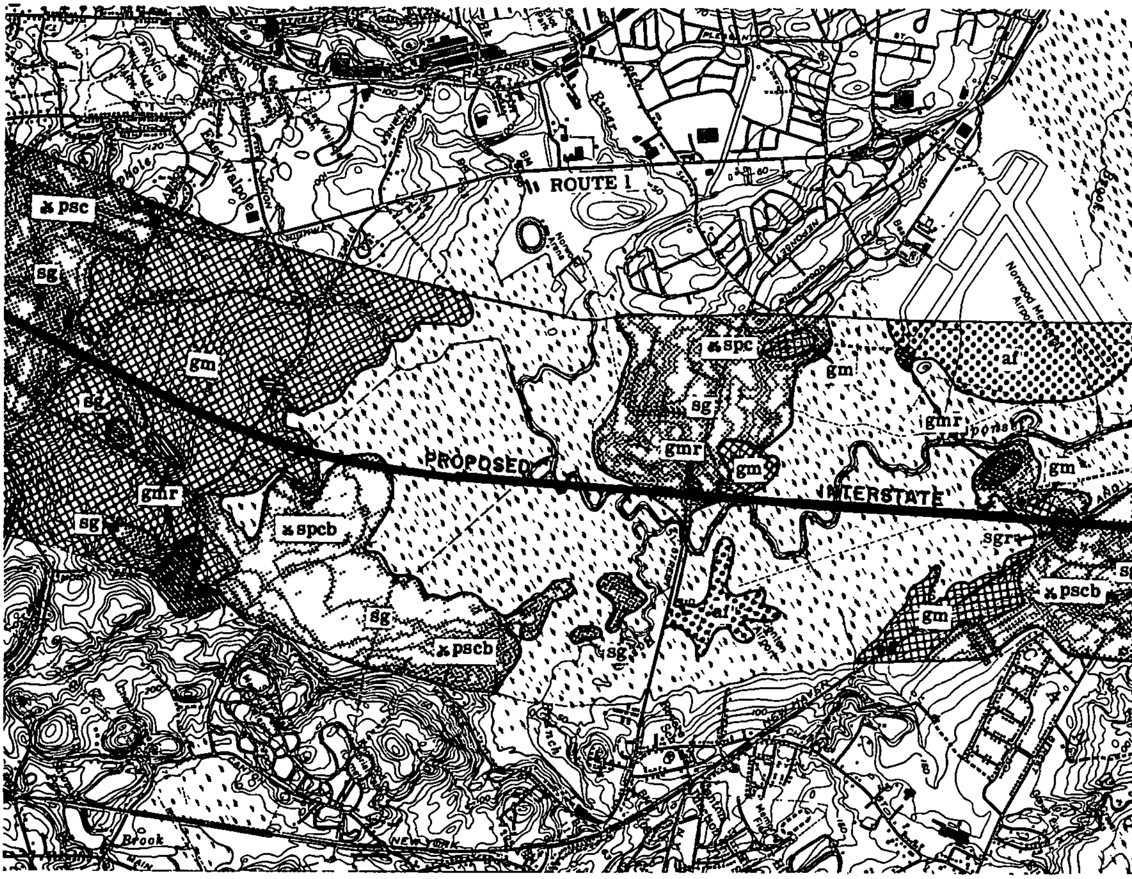
The Massachusetts geologic program was started in July 1938, as a cooperative project between the Massachusetts Department of Public Works and the U.S. Geological Survey. The primary purpose is to make a complete and detailed geologic study of the state, the results of which are to be embodied in two geologic maps and accompanying brief reports. The maps are to be printed in colors. One of them is to show the distribution and structures of bedrock units beneath the soil mantle, as interpreted from bedrock exposures and available subsurface data; the other is to show the distribution and nature of the unconsolidated, superficial formations, the "soils" in an engineering sense, that overlie the bedrock, and also to show the actual bedrock exposures. Among the mineral resources to be indicated on these maps are the materials used in highway construction, such as gravel, sand, and rock for crushed stone. Mapping is being done by quadrangles, on new 7½-minute topographic base maps, the scale being 1 in. = 2,000 ft and the contour interval, 10 ft. These maps permit considerable detail and accuracy, and engineers and geologists engaged in either public or private work will thus have fundamental geologic control for their own more detailed work in small areas or on special problems. Two compiled geologic maps of the state will be prepared from the quadrangle maps, on a scale of 1:125,000, or about ½ in. to the mile.

Special geologic studies are made under the program at the specific request of the location engineer of the department. These studies are of four types, as follows:

1. Gravel and sand resources of particular areas. For areas of projected highways where the resources are as yet unknown, or the known deposits are unavailable or inadequate, detailed geologic maps are made to show the distribution and land forms of all deposits of sand and gravel. An accompanying table indicates for each potentially important deposit the approximate volume, areal extent, dimensions, accessibility, and type of material. Pertinent general observations are made regarding the quality of the material, pebble sizes, proportion of sand, freshness of pebbles, and probable utility. No grade sizing tests are made, as these are considered to be outside the province of the geologic program. The map is intended as a guide to point out apparently favorable deposits for further investigation by engineers of the department.

2. Reconnaissance geology. When a segment of a proposed highway has been located by engineers, a detailed geologic map is made along the centerline for the purpose of determining the kinds of materials, the geologic structures that may have a bearing on engineering operations, and the distribution of bedrock outcrops (Fig. 1). Usually, the reconnaissance strip so mapped is from ¼ to ½ mile wide, but may be greater or less according to the complexity of the area and the need for finding additional data to aid in the interpretation of the geology along the centerline. A brief report summarizes the geology and calls particular attention to features that may prove troublesome. Where the geologic data appear to be clear and unequivocal no further studies are made. Where geologic conditions are complex or obscure, and more specific data are needed, other kinds of studies (such as ground-water investigations or seismic tests) are indicated by the geologist. Occasionally this preliminary reconnaissance study leads to a consideration of other possible locations for the highway segment. It is always desirable to have an engineer review the strip in the field with the geologist; in this way interpretations are clarified and pointed up, the geologist becoming more acute with respect to the engineer's problems, and the engineer learning how to use the geologic data with greatest profit and to judge the limitations of geologic studies.

3. Ground-water investigations. The highway engineer is concerned with ground-



EXPLANATION

Swamps, composed of peat and sandy peat; underlain by clay, silt, sand, gravel, or till, generally similar to the surrounding material. Generally unsuitable as a source of granular material.

Sand and/or gravel of variable texture, including some large boulders. Generally suitable for construction purposes.

Ground moraine (till); a heterogeneous to poorly sorted deposit of mixed boulder to clay sizes; known locally as "hardpan." Generally good for subgrade and fill only.

r Rock outcrop

Areas of scattered ro
covered by surficial d

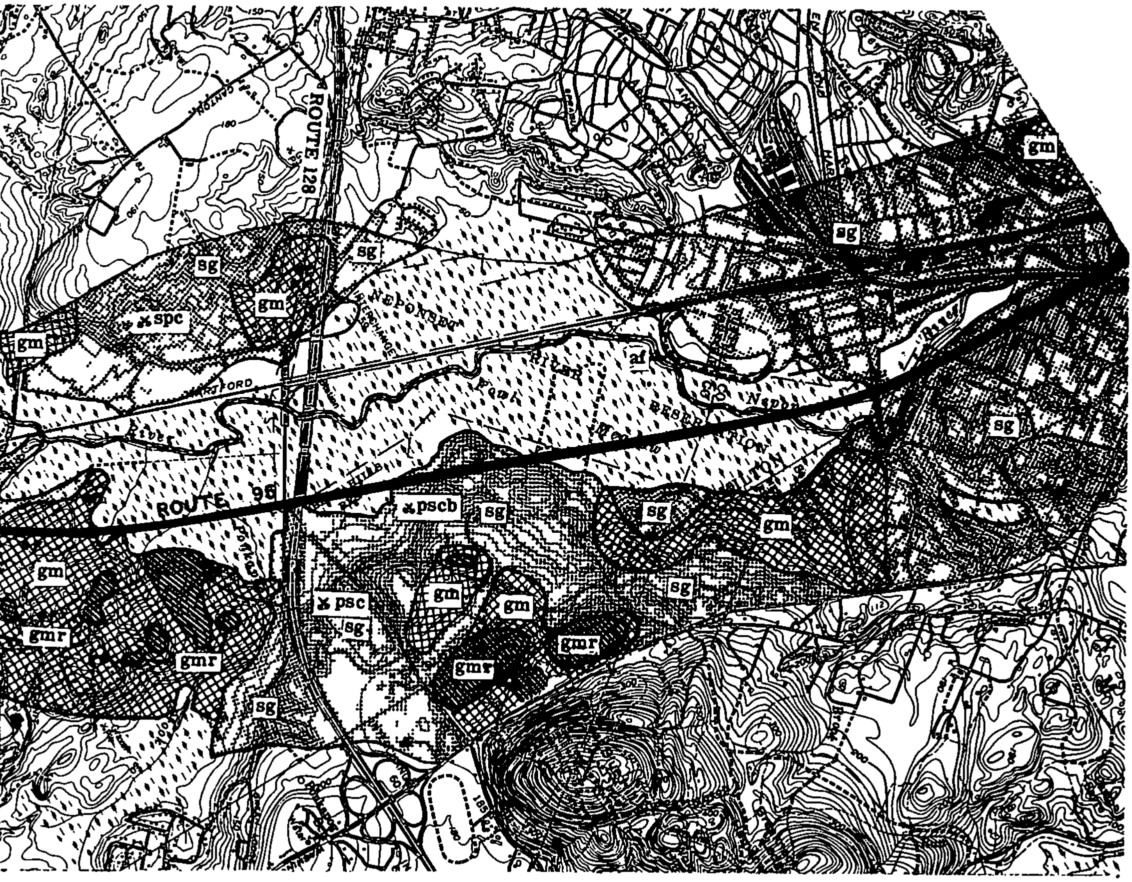
Mantled by ground mo

Mantled by sand and/c

pbsc Sand and/or gravel pi
in decreasing abundan
c = cobble).

AF Artificial fill

Figure 1. Surficial geologic



Geology compiled by Carl Koteff;
geology modified from Newton E. Chute

and of bedrock thinly

SCALE 1 24000

1 ½ 0 1 MILE

1000 0 1000 2000 3000 4000 5000 6000 7000 FEET

1 .5 0 1 KILOMETER

CONTOUR INTERVAL 10 FEET
DATUM IS MEAN SEA LEVEL

s indicated by letter symbol
le, b = boulder s = sand,

; proposed Interstate Route 95.

water conditions along the highway site because of the effects of ground saturation and seepage upon the stability of the subgrade, especially in freezing weather, or on the walls of cuts that have reached to or even penetrated the local water table. Perched water tables are quite commonly found in glaciated regions where lakes have once existed. Even certain types of compact till overlain by loose till or sand and gravel are so impervious as to cause seepage into the walls of a cut during the more humid seasons. The engineer wishes to foresee such conditions and to provide for adequate drainage. The conditions vary from place to place and the variations are direct functions of the geologic materials, structures, and topography. In places, the possible effects on highway construction of local ground-water supplies and individual wells present problems that require study by ground-water specialists. When necessary, ground-water problems are referred to geologists of the ground water division of the geological survey, working also under a continuing cooperative program with the department of public works, for ground-water studies in Massachusetts. Separate reports or statements are prepared by this division on request of the supervising geologist.

4. Seismic studies. Where more exact knowledge of the subsurface materials is needed and especially where the depths to bedrock or to compact or hard till is desired, seismic tests are recommended by the geologist.

When seismic surveys are deemed necessary, they are made by a field party consisting of one geologist from the United States Geological Survey and one engineer and four laborers from the Massachusetts Department of Public Works. At present, two parties are performing this work.

In addition to the other elements that control the location of the highway such as the traffic desire lines, geographic obstacles, land use, service to the communities along the right-of-way, the data furnished on the strip maps allow the location engineer to get a better picture of what may be encountered during construction. The line thereby established will have introduced a new dimension in economy that would not otherwise have been possible.

The Strip Map will indicate:

1. Exposed bedrock location which should, if possible, be avoided—due to the increased cost of this type of excavation.
2. Material which may be unsuitable for roadway fill and, therefore, would have to be disposed of as waste and replaced by suitable material.
3. Areas where soil stabilization of existing material may become necessary.
4. Areas where soil conditions would not allow sufficient absorption of surface water and, therefore, cause excessive run off which could create a problem of embankment erosion.

With this information at hand, the best possible locations are established and become the basis for flights from which the photogrammetric plans, at a scale of 1 in. = 200 ft, are made. On these plans are plotted the final location of the baseline of the highway and mark the final stage in the determination of the approved location.

As the highway construction program of the Massachusetts Department of Public Works continues to expand, the geologic and seismic studies will continue to play their very helpful part in providing Massachusetts with highway facilities designed to meet existing subsoil conditions.