photograph is supporting evidence of the presence of granular material. However, note the dissected land forms on the left side of the photograph, whereas the lower center portion has an appearance of being flat and level but with no evidence of external run-off. The logical conclusion is that this area is being drained internally through a granular medium consisting of sand and gravel.

Granular deposits also occur in the form of mounds called kames or eskers. This type of deposit was also established during glacial times and can be recognized by its contrast to the surrounding topography. Typical examples of this type of deposit are found in northeastern Indiana where the last stages of the Wisconsin glacier deposited numerous kames and eskers; however, kames and eskers do occur singularly in isolated areas throughout central and northern Indiana and can be easily located by using stereoscopic pairs of aerial photographs.

While the examples of the various types of granular deposits cited herein are more easily recognized when the deposit is a large one, it should be remembered that there are hundreds of other lesser deposits which, when located and developed, can provide sources of granular material for base courses, fill construction, and county roads, and sand and gravel for aggregate.

## THE DEVELOPMENT OF ENGINEERING SOIL MAPS

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The development of engineering soil maps is based upon the engineering problems created principally by the position and texture of soils and their influence on highway and runway performance. The object is to indicate those areas in which similar engineering soil problems can be expected to occur. The details can be carried to extremes, or only very general areas may be shown, according entirely to the use to which the map will be put and the extent of the area or accuracy of detail available. In the example herein developed, the final map contains areas of gravel soils, suitable for borrow; alluvial soils; depression soils, in which fills are desirable; soils occurring on 16 to 4 percent slopes, in which rather deep cuts are made; and soil areas occurring on 4 to 0 percent slopes, in which shallow cuts are common.

The source of information for such a map is fundamentally the science of soil development, known as pedology. The specific source may be either a soil map, as it is in this instance, aerial photographs, or merely a field reconnaissance.

We speak here of engineering soil maps as new, although similar developments from the same sources for other purposes are common. Obviously each use will be based upon some of the factors used originally to identify the soils. For instance, a soil map may be converted to a drainage map showing watersheds, streams, areas of soils requiring drainage, and areas of easily drained soils as well as of those in which drainage is difficult or impossible.

In a very similar way a general topographic map can be obtained. In some western states soil maps are now being generalized to show soil areas on which various rubber-producing plants can grow, to enable the government to buy or lease areas of suitable soil. Likewise, these soil maps may be converted to irrigation maps in arid areas, or to locate certain types of rock—high-magnesium limestone, for example, used for the production of magnesium.

When specialized uses may depend upon one or several of the soil characteristics, the phases concerned with highway and runway construction are concerned principally with drainage, texture, and relief.

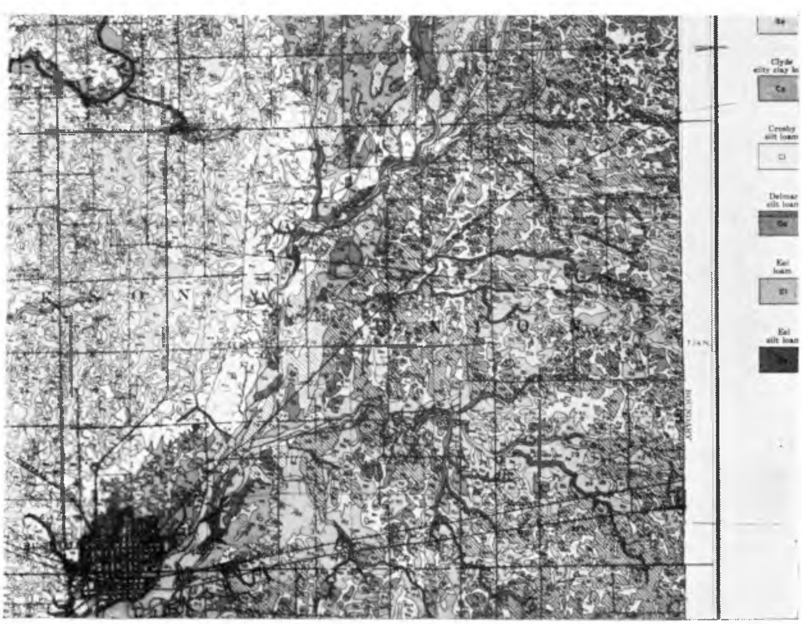

**Fig. 1. A section of a soil map.**

It is important to note that such a map is more general than the ordinary soil map with which we are familiar. Engineering soil maps can be made quickly and will give a maximum of information. Such maps are an excellent source of information for planning county road programs and they afford an excellent source of information on soil conditions for engineers planning new construction within the area.

Fig. 1 shows an area of a soil map having a scale of approximately one inch equal to three miles. The seemingly complex soil pattern shown will be found simple when the map is examined in a systematic manner. The area shown includes the border of the Early and Late Wisconsin drift sheets. The soils mapped in the light-colored lobe covering the left one-third of the area are those derived from the weathering of Late Wisconsin drift. Soils derived from the Early Wisconsin drift are found on the uplands to the right of the stream running diagonally from lower left to upper right. Because of their similarity these areas are not separated on the basis of engineering soil problems. Areas of alluvial soils are found in the bottom lands of both the central stream and the minor tributaries. The minor streams have produced soils of recent origin, while those occupying the larger areas of the central stream are weathered from beds of gravel or sand deposited during glacial times.

In this area the soils identified as Miami and Russell occupy slopes in the 16 to 4 percent class. Crosby and Fincastle are found on the more moderate slopes (4 to 0 percent) and Brookston and Clyde soils occupy the depressed areas.

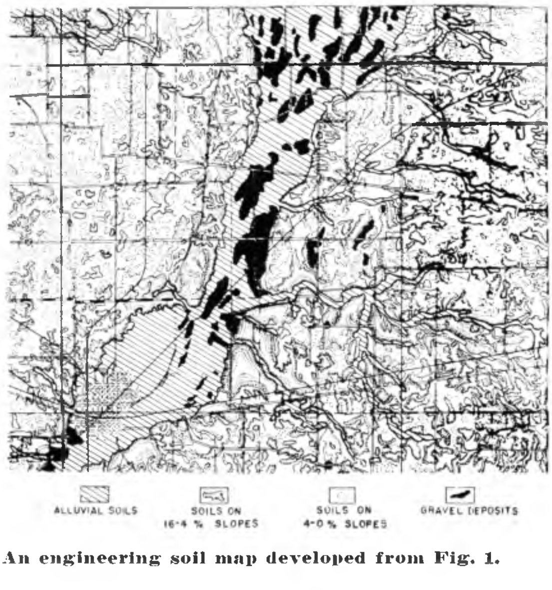


**Fig. 2. An engineering soil map developed from Fig. 1.**

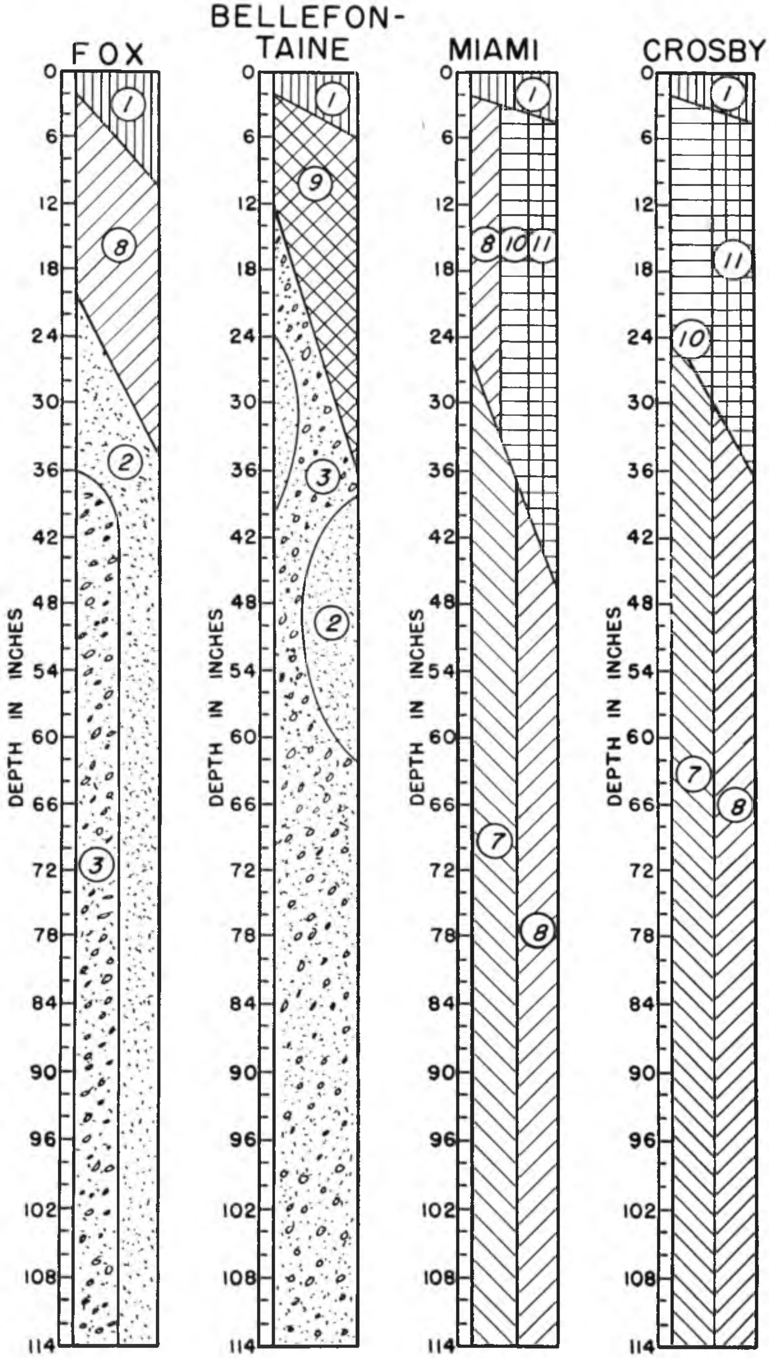


Fig. 3. A group of typical soil profiles (see Table I for interpretation of soil numbers shown in profiles).

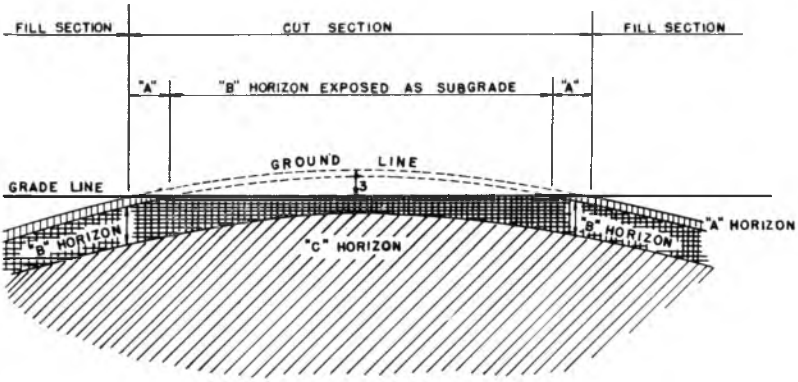


**Fig. 4. Soil conditions in cut section in soils occurring on 4-to-0-percent slopes.**

Examination of Fig. 2 will indicate these topographic subdivisions as well as areas of alluvial soils, bottom land gravel deposits, and upland gravel beds. Fig. 3 indicates the typical soil profiles that are related to those soil areas found in Fig. 2. The Fox profile indicates the depths and textures found in the low-land gravel deposits; the Bellefontaine profile is characteristic of the upland gravel beds; the Miami, of the soils on 16-to-4-percent slopes, weathered from glacial till; and the Crosby, of soils on 4-to-0-percent slopes. A profile of depression soils is omitted for brevity and because it resembles the Crosby profile in depth and in texture.

The significance of the individual areas outlined on the engineering soil map may then be evaluated in terms of soil

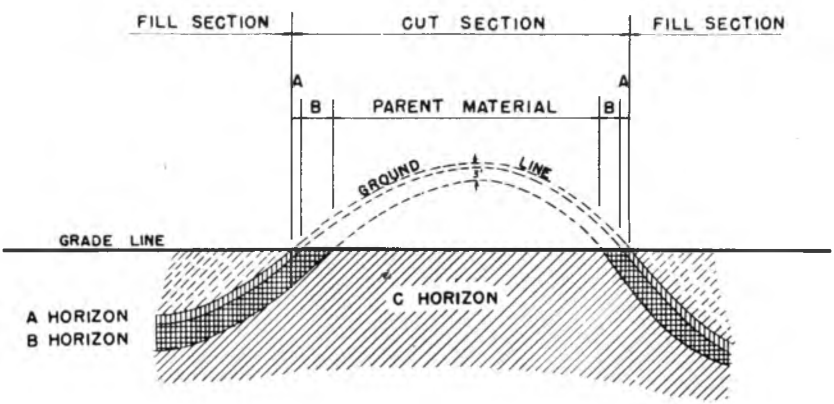


**Fig. 5. Soil conditions in cut section in soils occurring on 16-to-4-percent slopes.**

Fig. 6. A view of an area of Fox soil showing the level relief and the granular texture of the subsoil.

problems and construction problems. Depression areas contain highly plastic, poorly drained soils that are unstable and do not provide sufficient support for standard pavements carrying modern loads. Areas of soils occurring on 4 to 0 percent slopes present a condition of relief in which slight cuts are required because of the flat grades common on both highways and runways. Fig. 4 is a section drawing of this condition, showing the subgrade to be of plastic B horizon material. The liquid limit of this material may range from 45 to 60.

Soils occurring on 16 to 4 percent slopes present a condition shown in Fig. 5. In such a cut the subgrade, within a distance of a few feet, passes from compacted fill to the plastic B horizon to parent material, and then repeats the sequence.

Fig. 7. View of an esker showing the general appearance of this form of Bellefontaine soil.

Between B horizon material and parent material the liquid limit may vary 25 points, with a corresponding difference of 15 pounds in the unit dry weight of the materials. The difference in unit weight between the compacted fill material and the natural B horizon material will be of an order of 30 pounds per cubic foot. This is an indication of the performance to be expected in unimproved cuts in these soil areas.

Fig. 6 is a photograph of a lowland gravel deposit showing the level relief and the granular texture of the material. This is typical of the areas shown in Fig. 2 indicated as black and included in the alluvial (shaded) soils. Fig. 7 is a photograph of an esker (Bellefontaine soil) similar to those elongated black areas shown as gravel deposits on upland areas.

TABLE 1

| | *LL* | *PI* | *Max. Dry Wt. Lbs./Cu. Ft.* |
|---|---|---|---|
| 1. Topsoil | ..... | ..... | ....... |
| 2. Sand | ..... | ..... | 100-110 |
| 3. Gravel and Sand | ..... | ..... | 115-130 |
| 7. Silt with sand and/or gravel | 20-25 | 6-12 | 110-125 |
| 8. Silt with sand and clay | 25-35 | 10-15 | 100-120 |
| 9. Silt-clay (expansive) | 30-45 | 9-18 | 85-105 |
| 10. Clay with Silt and Sand | 35-45 | 15-30 | 100-110 |
| 11. Clay with Silt (Plastic) | 45-60 | 20-35 | 95-105 |

## DISCUSSION OF PAPERS DEALING WITH USES OF AERIAL PHOTOGRAPHS AND SOIL MAPS

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Mr. Hittle's paper entitled "The Use of Aerial Photographs in Identifying Granular Deposits and Other Soils" and Mr. Belcher's paper entitled "The Development of Engineering Soil Maps" are based on much study and experience with these materials. As a soil surveyor, I believe that they have ably interpreted soil survey data in relation to engineering uses. My discussion of these topics might easily consist largely of agreeing with all their main points, or in supplying some additional details and illustrations. I can testify that the more you study aerial photos and soil maps in the field, the more you can get out of them. Their usefulness should rapidly increase.

However, instead of merely reemphasizing the information presented by the previous speakers, it may be better for me to deal with questions which will come up if you are sold on their suggestions about aerial photos and soil maps. Some of these questions may be: (1) How and where may aerial photos be