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

T. M. Bushnell, in Charge, Soil Survey,
Agricultural Experiment Station, Purdue University

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 obtained? (2) How and where may soil maps be obtained? (3) What help is available for understanding and utilizing the soil data?

Aerial Photographs

The matter of aerial photos has been well taken care of. The entire state has been covered for the A.A.A., some counties more than once. Sets of enlargements of each county are found in the county A.A.A. offices. Under wartime regulations there are some restrictions on the use of these pictures, but normally they are available for consultation at these offices or copies may be obtained from the A.A.A. at Washington, D. C. Purdue also has negatives covering twenty-one Indiana counties taken before the A.A.A. program of aerial photography was started.

A stereoscope is a great aid in viewing aerial photos, because it makes the topographic features visible on the pictures. Commercial instruments are unavailable now because of priorities, but it is a simple matter to make a stereoscope by using four pieces of mirror supported in a simple frame.

Soil Maps

Soil maps are available for many parts of the country. In Indiana the status is as follows:

Maps of 22 counties have been published but are now out of print and unavailable except in libraries. These counties are Allen, Benton, Boone, Clinton, Delaware, Elkhart, Grant, Greene, Hamilton, Hendricks, Lake, Madison, Marion, Marshall, Montgomery, Posey, Scott, Starke, Tipton, Warren, Wells, and White.

Maps of the following 23 counties have been published and copies are available at Purdue: Adams, Blackford, Clay, Decatur, Dubois, Gibson, Hancock, Jennings, Kosciusko, Lawrence, Miami, Monroe, Ohio, Pike, Porter, Putnam, Randolph, Rush, Steuben, Switzerland, Vermillion, Washington, and Wayne.

The following 19 counties are in the course of mapping or publication: Bartholomew*, Brown*, Carroll, Cass, Daviess, Franklin, Fulton*, Jasper, Johnson, Knox*, LaPorte*, Martin*, Morgan*, Newton, Noble, Parke, St. Joseph, Tippecanoe, and Vanderburgh*.

The following 28 counties are unsurveyed: Clark, Crawford, Dearborn, DeKalb, Fayette, Floyd, Fountain, Harrison, Henry, Howard, Huntington, Jackson, Jay, Jefferson, Lagrange, Orange, Owens, Perry, Pulaski, Ripley, Shelby, Spencer, Sullivan, Union, Vigo, Wabash, Warrick, and Whitley.

---

* Indicates eight areas to be issued soon.

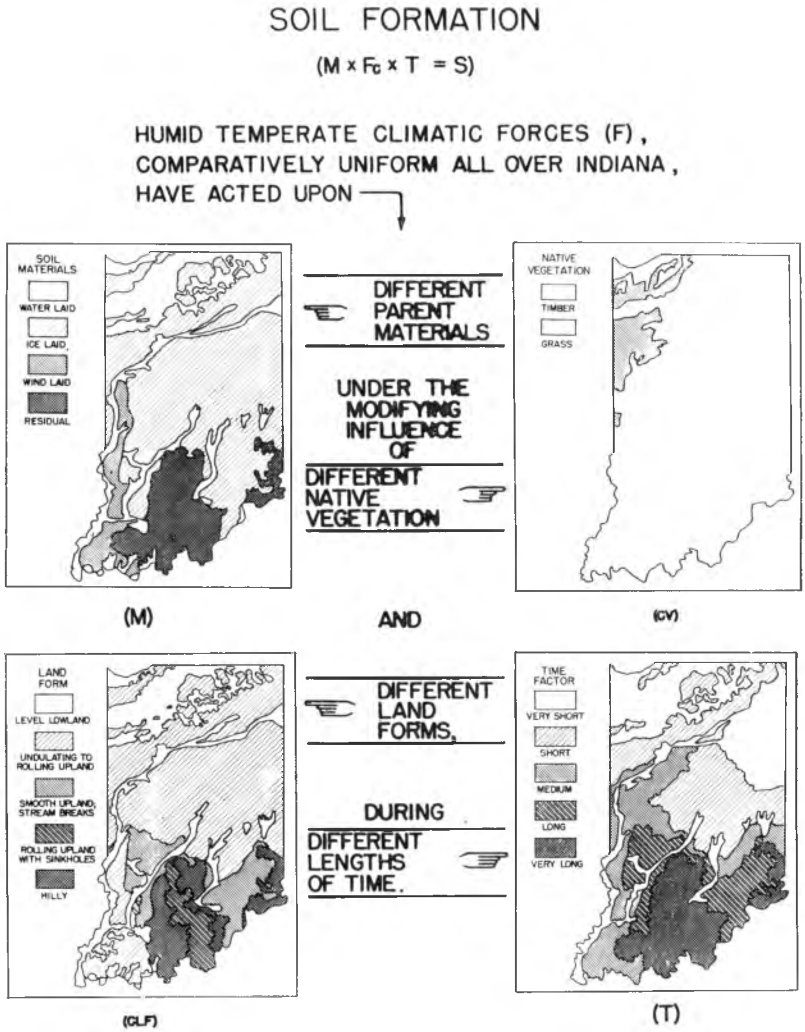

Fig. 1. Equilibrium between soils and their formation factors.

These county soil survey maps have been made in small numbers each year since 1901 and naturally show a great evolution in detail and accuracy so that each county map and report must be considered as a unit, although many of them correspond quite closely in nomenclature and style of mapping. All areas covered since 1930 have been mapped with the aid of aerial photos, which make them more accurate in details than any previous surveys.

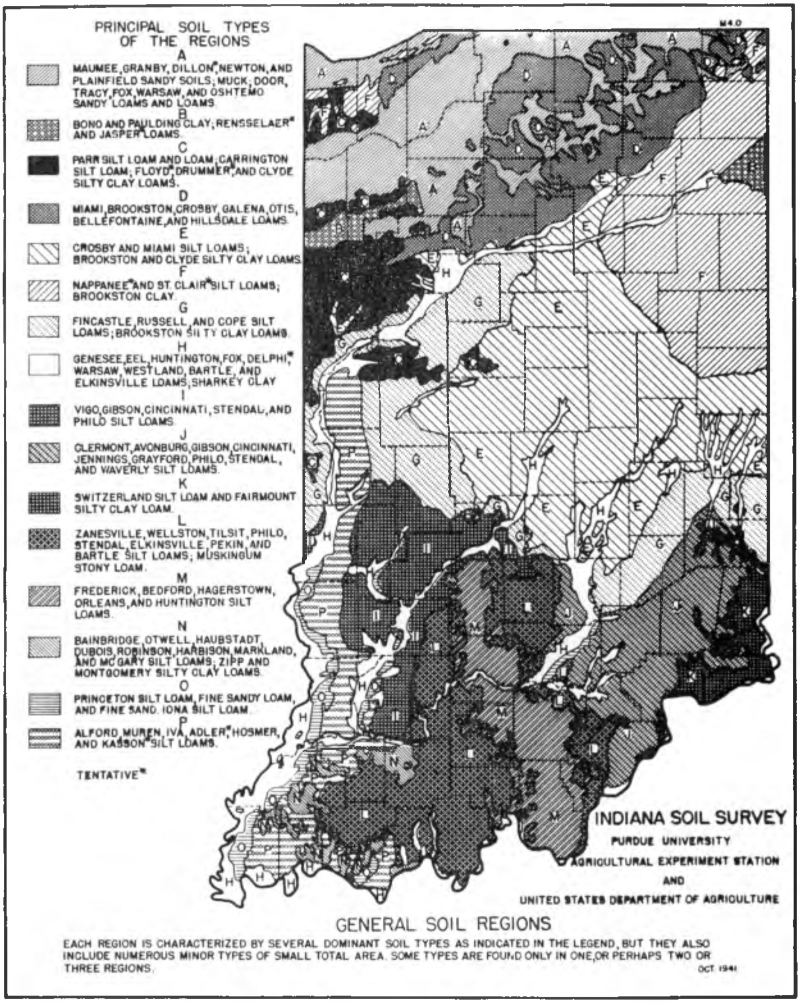

Fig. 2. The geographic pattern of soils for Indiana.

There are also available at Purdue copies of a small regional soil map and also a larger generalized soil association map on which the up-to-date nomenclature of the soils is shown for all counties, even those mapped forty years ago.

Aids to Understanding

Soil classifications and maps made primarily by agricultural organizations naturally exhibit some viewpoints and

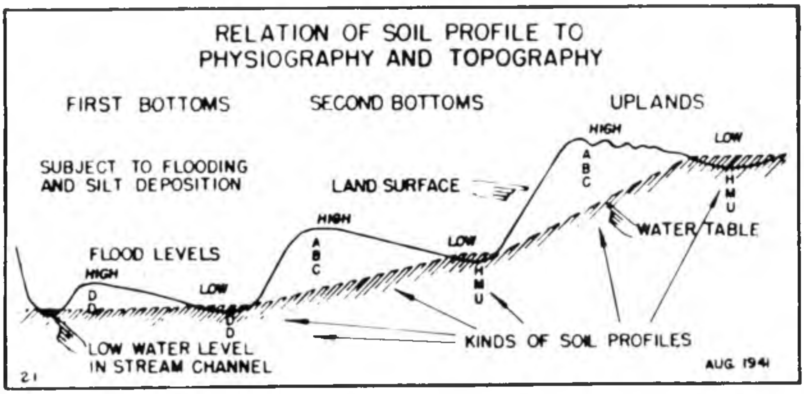

Fig. 4. Illustrating the principal situations in which soil forms under our climatic conditions.

terms which may not be entirely familiar to engineers or others. Each individual soil survey explains to some extent the classification and terminology used. In addition, we are preparing at Purdue a circular on general soil regions, which explains in a comparatively simple way the soil factors which are observed and considered in describing, identifying, classifying, and mapping different kinds of soils.

One basic idea is that the soils are products of materials, environment, and time. This equilibrium between soils and their formation factors is illustrated by Figs. 1 and 2, which also show the geographic pattern of soils for Indiana.

The characteristics and relationships of all kinds of soils observed so far in Indiana are summed up in the Indiana Soil Key (Fig. 3)*. This key may seem very complicated, but it is really constructed on a very simple plan based on the formation formula. Some of the primary factors considered are illustrated by Fig. 4. This shows the principal situations in which soil forms under our climatic conditions. You might say that all soils fall into three general classes, depending largely on water relationships. In the stream bottoms the constant deposition of sediments by annual flood waters makes the soils what they are, considering, of course, the nature of the sediments. On the terraces and uplands, where soil materials remain long enough for environment to modify them, water relationships, again, group soils into two broad classes, which farmers call "high ground" and "low ground". (Fig. 5.)

This basic relationship between land surfaces and water surfaces at the time of soil formation largely controlled the trend of soil development.

Gradations in the conditions found in the high ground and low ground lead to soil differences which are recognized by

* See loose sheet inserted between pages 96 and 97.

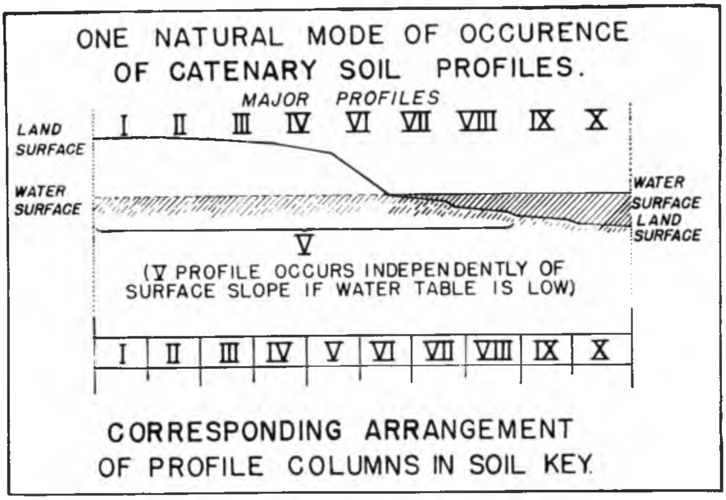

Fig. 5. Illustrating effects of water relationship on soil classification.

ten major profiles in the soil key, but these may be grouped even more simply somewhat as follows: 1. On the high ground flats the soils tend to be imperfectly drained, especially if there is enough clay in the material to form a tight subsoil. 2. On the moderate slopes, soils tend to have a relatively open structure and an oxidized color. 3. On the very steep slopes geological erosion has tended to remove products of soil formation almost as rapidly as they accumulate so that the parent material lies at or near the surface. 4. In the low ground, varying depths, or duration, of flooding are reflected in corresponding gradations in the accumulation of organic material. 5. In the extreme case of low, wet land the soil consists largely of the remains of organic matter which forms the mucks and peats.

It should be helpful to realize that all of the hundreds of soil types described in detailed soil surveys may be grouped in the five classes indicated above or, if a little more detail is desired, into the ten major profiles shown by the Indiana Soil Key. As long as topography and drainage are the principal considerations, the various types of soil may be thought of in these very simple terms. However, the nature of the parent material may become the dominant factor in some soil relationships, so that the various major profile groups will have to be divided according to whether the soil was made of sand, gravel, silt, or clay, etc. These facts about the different soils are also covered by the Soil Key.

Anyone trying to utilize a soil map will immediately observe that almost every type of soil is called some kind of loam.

I understand that the word "loam" does not mean much to engineers, or perhaps means a great variety of things. I believe that the word "loam" might be defined as a "mixture", and it is certainly true that practically all soils are made up of mixtures of different sizes and kinds of particles. When a soil surveyor calls a type merely a "loam," he should mean an evenly balanced mixture. On the other hand, a "clay loam" is a mixture with much of the sticky, plastic nature of clay. A "sandy loam" possesses the gritty, granular nature imparted by sand, while "silt loam" has the smooth, floury nature given by silt, even though it also contains considerable amounts of sand and clay.

Fig. 6 shows the general relationship between the common terms used by soil surveyors and the engineering terms for different kinds of soil, when both are expressed in terms of relative content of sand, silt, and clay.

Full information about this will be found in the new publication prepared by the Joint Highway Research Project at Purdue, which in my opinion should be a very valuable contribution to the field of highway engineering.

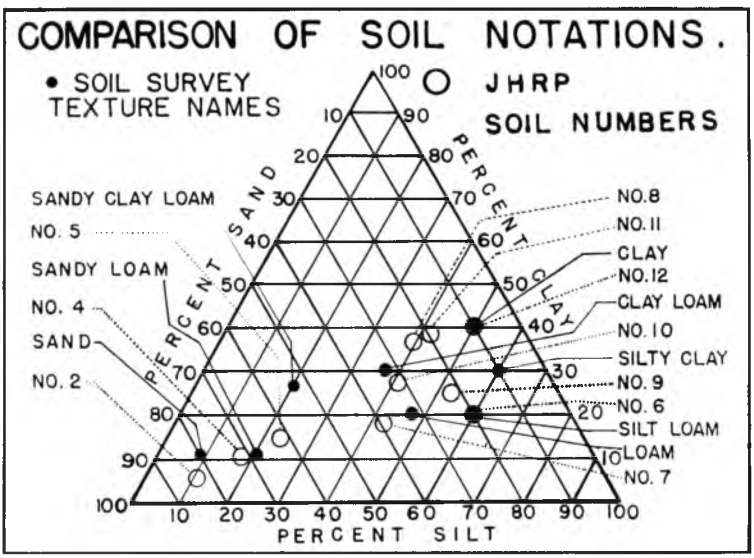

Fig. 6. General relationship between soil survey texture names and soil numbers used by the Joint Highway Research Project.