82. Frost, Robert E., and Hittle, Jean E., "Report of 1946 Field Survey on Aerial Photographic Reconnaissance Investigation of Frozen Soils In The Territory of Alaska," *Engineering Experiment Station*, Purdue University, Transmitted to District Engineer, St. Paul District, Corps of Engineers, February, 1947.
83. Hittle, Jean E., "Special Survey Report on a Landslide Condition on the Alaska Railroad," Unpublished report by the *Engineering Experiment Station*, Purdue University, for the Corps of Engineers, St. Paul District, January, 1948.
84. McCullough, C. R., "Evaluation of Soils by Means of Aerial Photographs in the Vicinity of Bettles, Alaska," *Engineering Experiment Station*, Purdue University, for the Corps of Engineers, St. Paul District, February, 1948.
85. Frost, Robert E., Hittle, Jean E., and Woods, K. B., "Summary and Statement of Technique Aerial Photographic Reconnaissance Investigation Frozen Soils in the Territory of Alaska," *Engineering Experiment Station*, Purdue University, Appendix No. 3 of "Comprehensive Report Investigation of Airfield Construction in Arctic and Subarctic Regions," 2nd Revision, May, 1948.
86. Pollard, William S., Jr., "Special Airphoto Investigation of Soils and Permafrost in the Vicinity of Bethel, Alaska," *Engineering Experiment Station*, Purdue University, for the Corps of Engineers, St. Paul District, September, 1948.
87. Frost, Robert E., "Evaluation of Soils and Permafrost in the Territory of Alaska by means of Aerial Photographs," *Engineering Experiment Station*, Purdue University, for the Corps of Engineers, St. Paul District.

ENGINEERING SOILS MAPPING OF INDIANA FROM AIRPHOTOS*

Pacifico Montano, Research Engineer, Joint Highway Research Project, Purdue University

ABSTRACT

This paper is in two main sections: Background and procedure, the first; and a Photo Interpretation key to major soil areas of Indiana, the second.

Until recent years, engineering soils mapping has been dependent on topographic, geologic and pedologic information. In Indiana, topographic mapping and geologic mapping, by the U. S. Geological Survey, have given limited coverage. Agricultural soils mapping has made considerably greater progress. Engineering soils mapping, however, lacks adequate data from these sources. In recent years, airphoto-interpretation of engineering soils materials has been most encouraging in filling the need for engineering soils information.

A program of engineering soils mapping of Indiana from air photos was started at Purdue University in 1946. Studies of air photo patterns of soils and engineering significance of such patterns have been made and the principles and limitations governing air photo-interpretation of engineering properties of soils have been studied. The major work has been done by graduate students on a county unit basis, under supervision of a staff member of the Joint Highway Research Project of Purdue University, with thesis work on a regional unit basis.

The student's work in an area is divided into laboratory research and field investigation. Laboratory work consists of: (1) assembly of background material, (2) assembly of the area mosaic, (3) delineations of geologic parent materials on the mosaic, (4) detailed stereoscopic study of mosaic materials. Field investigations, the next step, is for verification of the delineations marked on the mosaic, and to obtain soil samples of the various delineations for testing in the laboratory. Returning to the laboratory, the student transfers the data from the mosaic to one inch to a mile base maps, using classroom delineascope. The final map is then prepared by tracing from the base map according to a system of symbols set up at Purdue University. The staff member then takes over the incorporation of the final maps into the state engineering soils map at a scale of one inch equal to four miles.

DAVID CROCKER

* Paper read at Eighteenth Annual Meeting of the Society, Hotel Shoreham, Washington, D.C., January 9 to 11, 1952.

Introduction

ENGINEERING soils mapping, prior to recent years, has been almost entirely dependent on topographic, geologic, and pedologic information. However, the topographic mapping of Indiana has been accomplished only to a limited extent, as is revealed by the leaflet, "Topographic Mapping in the United States," by C. F. Fuechsel, of the Department of the Interior, Geological Survey. The Geologic Folios, published by the same governmental organization, disclose that the geologic mapping has been carried out to even a lesser degree. Agricultural soils mapping, though, has made considerably more progress, as can be seen from the status map published in one of the latest soil survey reports. Consequently, Indiana has found itself short of the necessary material to furnish the engineering profession with adequate data on the distribution and engineering properties of soils.

The results obtained in the studies of airphoto-interpretation of engineering soil materials during the past few yers, have been most encouraging; and to a large degree, they have filled the pressing needs of engineering in the compilation of necessary soils information.

Appreciating the unquestionable possibilities of this new method, a program of Engineering Soils Mapping of Indiana from Airphotos was instituted at Purdue University in 1946, as a joint endeavor between the State Highway Commission of Indiana, and the University, and as a part of the Airphoto Laboratory of the Joint Highway Research Project.

Throughout the several years of research, conducted at Purdue University, in the field of airphoto-interpretation of soil materials, a great deal of literature has been published as theses and bulletins. Considerable study had been made of the airphoto patterns of soils and the engineering significance of such patterns. In addition, much attention has been given to the principles and limitations governing airphoto-interpretation of the engineering properties of soils. It would be needless repetition, therefore, to review the basic material of airphoto-interpretation; it will be sufficient to refer the reader to the bibliography at the end of this paper (1, 2, 3, 4).

When the mapping program of Indiana was initatied, the work was delegated to graduate students on a county basis (5), under the supervision of a staff member of the Joint Highway Research Project of Purdue University. During the early part of the program, a student interested in doing graduate work in airphoto-interpretation prepared an engineering soils map of some county in the state, as a part of his thesis in partial fulfillment of the requirements for the degree of Master of Science in Civil Engineering. Several counties were mapped in this way until the techniques of airphoto-interpretation reached a rather high degree of refinement. Following this, thesis assignments were made on regional bases (6), sometimes embracing an entire physiographic region of the state. The work continues under this arrangement at the present time; but mapping is also being conducted on the county basis by graduate students, as a special project within the regular university curriculum.

The staff member in charge of the project, as well as the graduate students, are constantly endeavoring to improve the interpretation and mapping techniques. The scope of the program includes determining how much detail can be obtained in the engineeering soils mapping from aerial photographs, and how much detail can be incorporated in a soils map. This scope has been broadened to provide for the design of a system of graphical soil symbols to be applicable, for the entire state. The program of photo-pattern research by the graduate students is coordinated with the over-all mapping plan, the end-product of which will be a State Engineering Soils Map.

PURPOSE

The primary purpose of this paper is to report on the procedures and techniques used in this mapping project, as well as the progress made.

PROCEDURES

For a given thesis assignment on soils mapping from airphotos, each student chooses a certain area of the state which contains essentially the same type of parent material throughout it extent, or a portion thereof if the area is too large. The work may be divided into two parts: laboratory research and field investigation.

The laboratory research includes literature search for geologicial, topographical, and pedological information. When this background material is

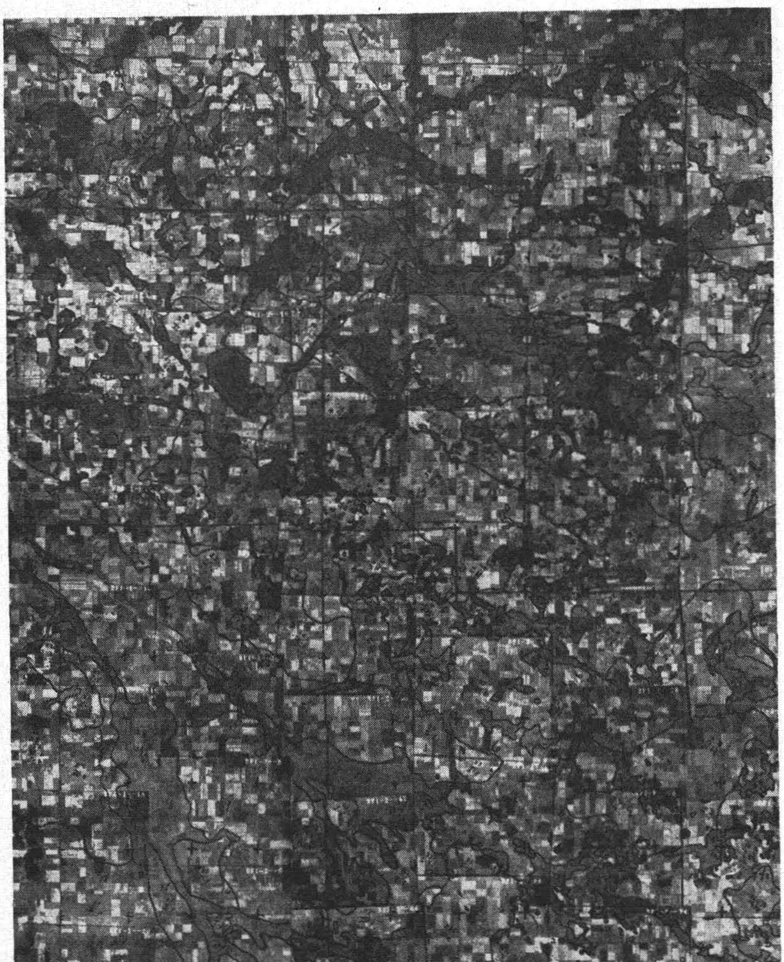

FIG. 1

gathered and reviewed, the airphoto mosaic of the area under study is assembled on celotex boards. With the background in airphoto-interpretation that the student receives by taking the courses offered on this subject by the University, and with the literature background, he is able to delineate on the airphoto mosaic the various parent material areas. Figure 1 illustrates a marked airphoto mosaic.

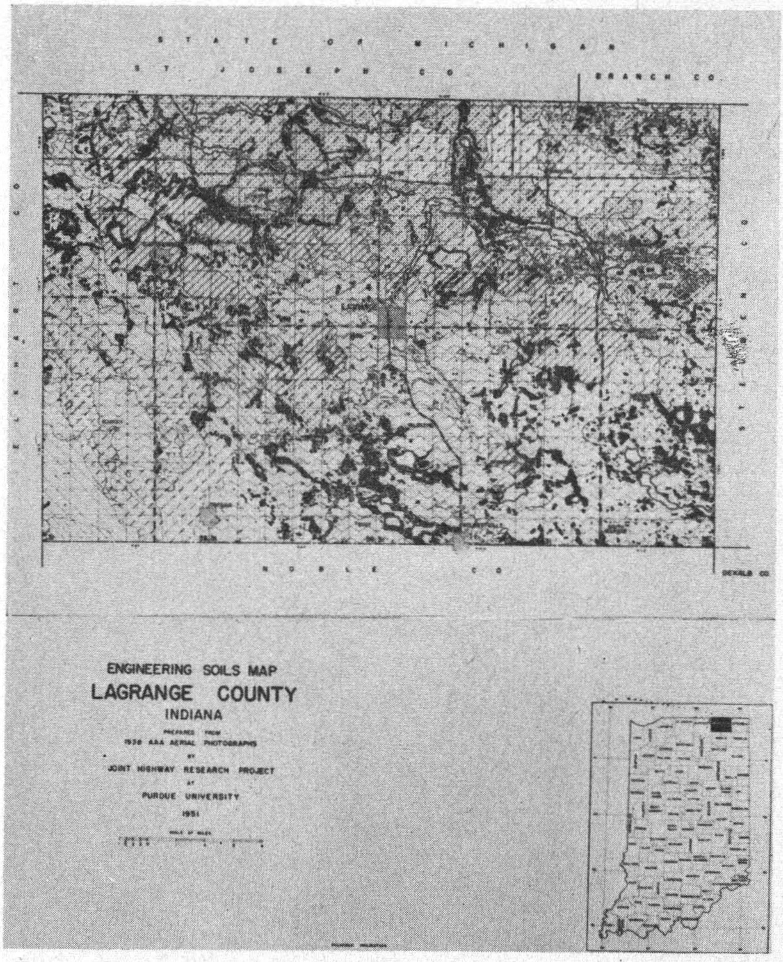

FIG. 2

This step is followed by a detailed stereoscopic study of the mosaic with the aid of a pocket stereoscope. This step accomplishes two purposes: it defines the parent material boundaries, and it incorporates relative soil textural borders into the mosaic. Special care is exercised at this point to obtain as much detail as possible regarding the soil textural areas. The references mentioned in the first part of this paper show how it is possible to obtain a considerable degree of soil textural detail by studying and interpreting the surface features of a given area.

Field investigation is the next step in line and serves the purpose of verifying the borders marked on the mosaic. From time to time it is necessary to make small modifications of the laboratory predictions in the field, but these modifications become increasingly less as the experience of the student is increased.

During the field investigation, representative soil samples of the various textural areas are taken; these samples are then tested in the laboratory, and the results are compared to the original predications of the relative soil textures.

The interpreter is then ready to transfer the data from the mosaic to base maps, which are prepared by counties. The scale is reduced during the transfer operation from approximately three inches to one mile—the scale of the contact prints used in this project—to one inch to one mile. Transferring is accomplished by means of a fairly simple device, the main part of which is a classroom delineascope.

A final map, illustrated by Figure 2, is then prepared by tracing the information from the work base map. The black areas shown on this illustration are peat and muck deposits. The soil symbols used in this final map are based on the system of symbols developed at Purdue University in recent years. As shown by Figure 3, this system of graphical representation of soils consists of symbols for types of parent materials on which soil textural symbols, illustrated by Figure 4, are superimposed. The system seems to be quite well adapted for our purposes, since it portrays the characteristics of soils which are of primary importance;

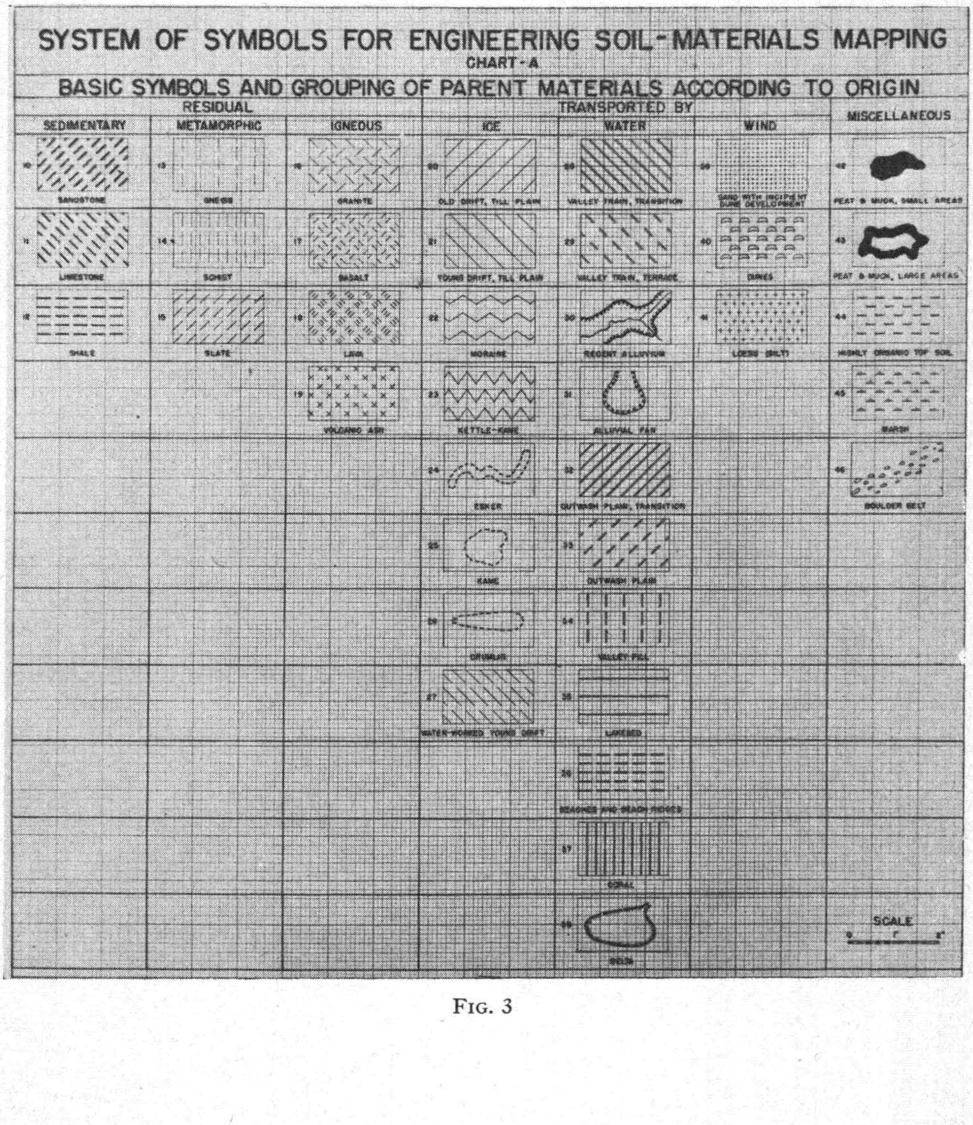

FIG. 3

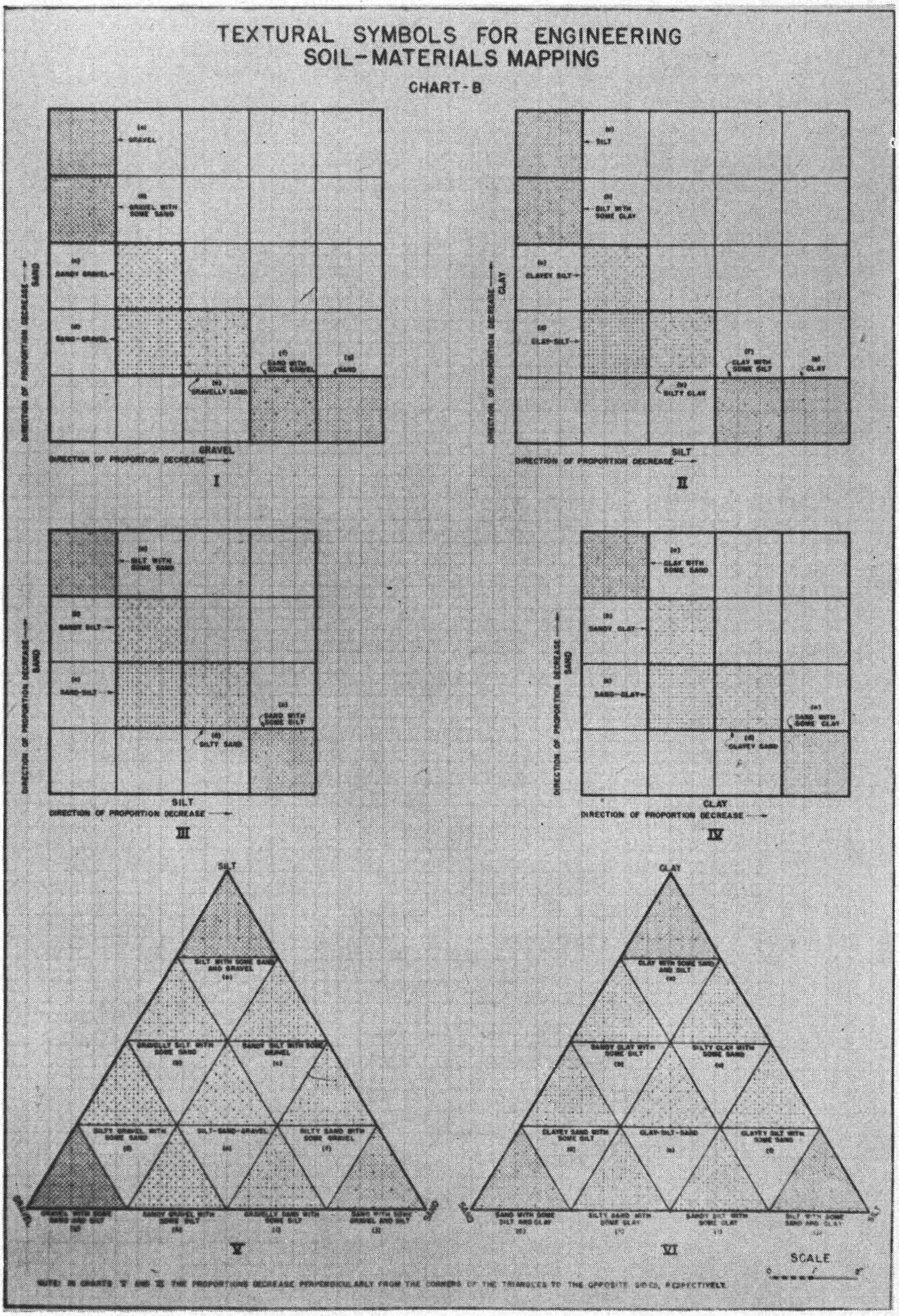
TEXTURAL SYMBOLS FOR ENGINEERING
SOIL-MATERIALS MAPPING
CHART-B
GRAVEL
SAND-GRAVEL
GRAVELLY SAND
SAND
DIRECTION OF PROPORTION DECREASE
I
SILT
CLAY
II
III
IV
V
VI
SCALE

FIG. 4

namely, type of parent material, relative textures, and in an indirect manner, the internal drainage properties. The type of parent material readily suggests the topographic features that are normally created by such a parent material.

From the standpoint of soils mapping, the work of the graduate students ends with the preparation of the final maps at the scale of one inch to one mile, a unit of these maps being a county. From here on, it is the task of the staff member in charge of the project to see that the work of each student is incorporated into the state engineering soils map which is being prepared at the scale of one inch to four miles. This means the reduction of four times the scale of the county maps; it is accomplished by photographing and printing the county maps at the reduced scale, and then by tracing the prints on the previously prepared state base map.

When a map is prepared on a county basis, as a part of the regular course work of the student, the time spent may be illustrated by the following, from the report prepared by one of our graduate students in connection with mapping of Grant County, approximately 400 square miles in area.

	Hours
Literature search	12
Assembly of mosaic and stereoscopic delineation	50
Field checking (by student and supervisor)	45
Transfer of data to base map, by draftsman	20
Checking transfer	6
Drafting of final map	120
Writing of report	15
Total spent by student	128
Total drafting work	140
Total spent by supervisor in the field	45

Attention is directed to the small number of hours necessary for this work. As it is rather difficult to keep an accurate account of the hours spent by the supervisor with the student in the laboratory, this information is not given in the above table.

FIG. 5

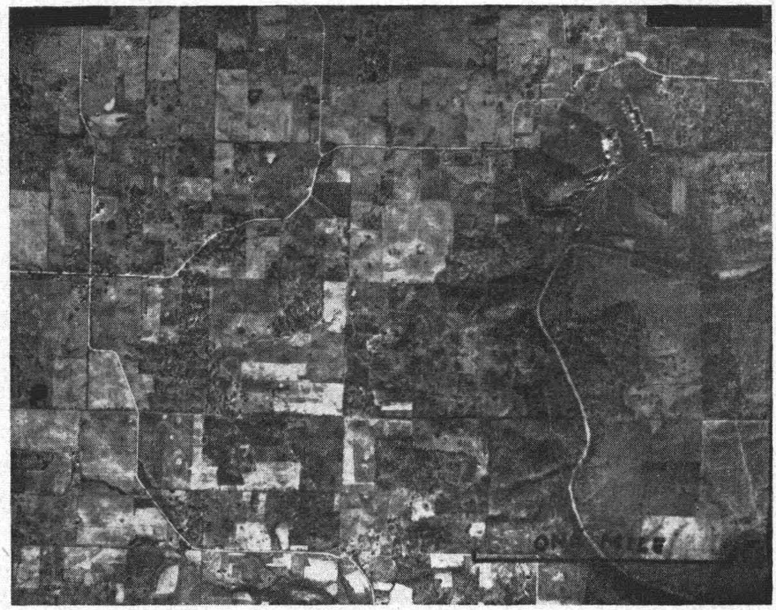

FIG. 6

MAJOR SOIL AREAS

The major soil areas of Indiana are of residual, glacial, aeolian, and fluviatile and lacustrine origin (7). Each type of parent material produces its own characteristic airphoto pattern, and each possesses one or more outstanding features.

1. RESIDUAL

The residual materials in Indiana have been developed from limestones, sandstones and shales. These range in age from Ordovician rocks to the sandstones and shales of Pennsylvanian Age. Figure 5 illustrates the sandstones and shales; the rough topography and the scraggly appearance they assume with erosion should be noted. Many of the limestones, illustrated in Figure 6, are typified by the numerous "sinks." Interbedded limestones and shales are located in the southeastern portion of Indiana. These rocks, shown by Figure 7, present a somewhat rough topography but rounded slopes; the bedding planes are unusually clear on airphotos when viewed under the stereocsope.

2. GLACIAL

Glacial materials of the Illinoian and Wisconsin ice advances cover most of Indiana. The Wisconsin deposits are located in the northern part of the state, and the Illinoian materials are encountered south of the preceding soil area. From the several patterns created by the Wisconsin glacial till, unquestionably the most remarkable of all is that which belongs to the till plains, an area of which is shown in Figure 8. These are level to gently undulating expanses; the light and dark mottled appearance is caused mainly by differential topographic positions, the dark areas being slight depressions and containing larger accumulations of organic matter and moisture. Other prominent Wisconsin glacial formations in Indiana are moraines, which are elongated areas of rolling to rough terrain; kettle-kames, which, as the name implies, are composed of domelike hills intercalated by depressions; and kames and eskers, which respectively

FIG. 7

are rounded hills and elongated winding ridges. The till plains and moraines consist mainly of glacial till, and the kettle-kames, and kames and eskers of sand and gravel. Figure 9 shows an area covered by Illinoian till; note the peculiar white-fringed gullying developed on this parent material area.

FIG. 8

FIG. 9

3. AEOLIAN

The largest area of aeolian (windblown) materials in Indiana is located in the southwestern portion of the state. This deposit consists largely of loess with scattered areas of sand. The Kankakee region, in the northwestern part of the state, contains rather large areas of windblown sand. The most outstanding feature on the airphoto pattern of loess, shown in Figure 10, is the surface drainage system which resembles the arrangement of fern leaves.

4. FLUVIATILE AND LACUSTRINE

Fluviatile soil areas consist of alluvium, terraces, and outwash. These forma-

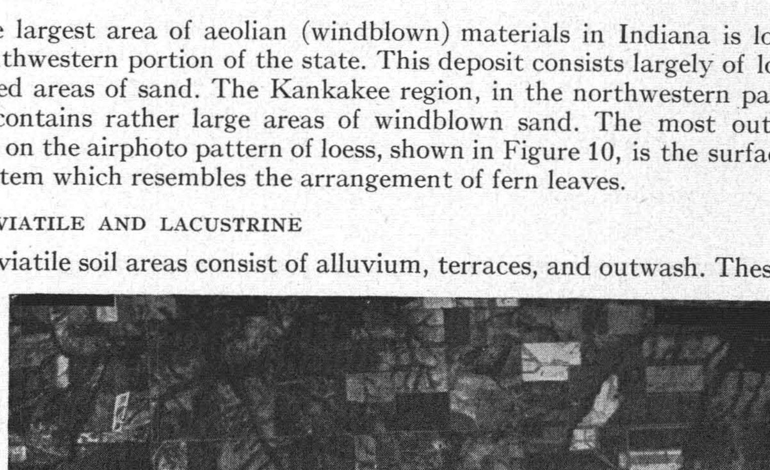

FIG. 10

FIG. 11

tions are scattered throughout the state, and the first two are associated with the major drainage-ways, while deposits of the third type are associated with glacial till. Alluvial sediments are mainly composed of gravels, sands, and silts, and terraces and outwash of sands and gravels. An example of outwash is shown in Figure 11 and it will be seen that it is characterized by a rather level topography, and by uniform and light color tones, which often assume softly speckled expressions. Lacustrine areas are also found dispersed in many parts of the state, but the southwestern region contains a sizeable accumulation of these formations. The Maumee lakebed, located in the northeastern part of Indiana, however, is the largest deposit in the state. The outstanding features of lacustrine areas, as shown by Figure 12, are very level topography and dark airphoto color tones; these formations are mostly composed of silty clays.

FIG. 12

Conclusions

1. Although there has been a total of 13 graduate students, including those with us at the present time, engaged in this mapping project since 1946, and although a great deal of the work has already been accomplished, there is much work still to be done, and there is room for several more graduate students who may be interested in this kind of work.

Figure 13, shows the status map, illustrating the progress reached by this mapping program up to November, 1951; all of the cross-hatched areas with closely spaced lines and by criss-crossing have been mapped, while the mapping of the area cross-hatched with widely spaced lines is in progress.

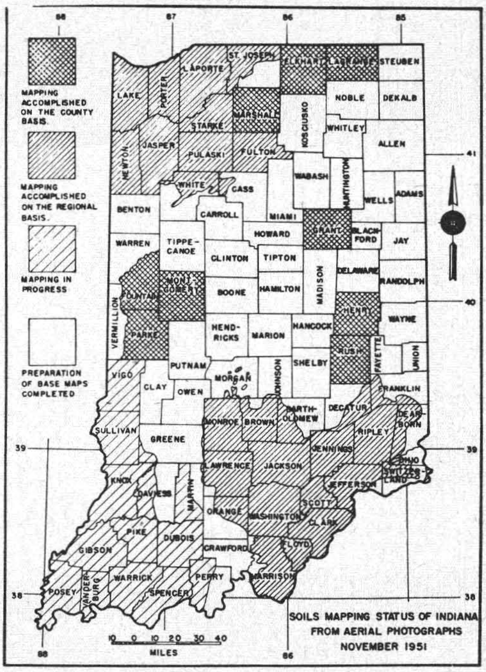

Fig. 13

2. It has been found that the airphoto method is rapid, economical, as well as reliable for engineering soils mapping. Form the data earlier given on the time consumed in the preparation of a county soils map, it will be readily seen how efficient this method is when compared to the conventional procedures of soil surveys, which for the same areal extent would require several months of field work, as well as countless soil borings. Because it is impossible to duplicate the composite impression that an airphoto-interpreter gains by studying the airphotos of an area, the conventional methods lend themselves to unnecessary duplication of soil borings.

3. When this mapping project is completed, the end-product, that is, the State Engineering Soils Map, will be of primary importance. It is hoped that Indiana will set the precedent of being one of the first states to complete an engineering soils mapping program of its territory by the use of aerial photographs. The composite state soils map will fill the needs of the highway, railroad, and airport construction industries, through furnishing the necessary informa-

tion on the distribution and properties of soils, for adequate location work and design of highways, railroads, and airports.

BIBLIOGRAPHY

1. Belcher, D. J., "The Engineering Significance of Soil Patterns," *Proceedings*, Highway Research Board, Vol. 23, 1943.
2. Frost, Robert E., "Airphoto Patterns of Southern Indiana Soils," A thesis, Purdue University, in partial fulfillment of requirements for the degree of C.E., June, 1946.
3. Montano, Pacifico, "The Engineering Significance of Airphoto Patterns of Northern Indiana Soils," A thesis, in partial fulfillment of requirements for the degree of M.S.C.E., June, 1946.
4. Jenkins, D. S., C.A.A.; Belcher, D. J., Gregg, L. E., and Woods, K. B., Purdue University, "The Origin, Distribution, and Airphoto Identification of United States Soils," *Technical Development Report No. 52, C.A.A.*, Washington D.C., May, 1946.
5. Parvis, M., "Airphoto Interpretation of Soils and Drainage of Parke County, Indiana," A thesis, Purdue University, in partial fulfillment of requirements for the degree of M.S.C.E., June, 1946.
6. Stevens, John C., "Airphoto Interpretation of Illinoian Glacial Drift Soils in Southeastern Indiana," A thesis, Purdue University, in partial fulfillment of requirements for the degree of M.S.C.E., February, 1949.
7. Belcher, D. J., Gregg, L. E., and Woods, K. B., "Formation, Distribution, and Engineering Characteristics of Soils," *Research Series No. 87, Purdue University*, Vol. 27, No. 1, January 1943.

NOTE: The airphotos used in this paper were photographed for Field Service Branch—P.M.A.—U.S.D.A., 1938–1940. These airphotos have been unclassified.