How to Use Airphotos and Maps for Material Surveys

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SYNOPSIS

IN areas where either geologic maps or soil-survey maps are available, materials prospecting is relatively simple if the engineer or soil surveyor understands and interprets the terminology and mapping units used by the agriculturalist and the geologist. The use of airphotos and simple field checks reduces the cost considerably.

This paper presents information on how to classify engineering materials in an area using aerial photographs, agricultural soil maps, topographic maps, geological maps, and combinations of these. Its scope is limited to a demonstration of procedure and a comparison of methods based on surveys of four areas in southwestern Indiana. Several types of materials are mapped and the materials and the methods used to identify them are discussed in detail. For purposes of comparison the discussion about each method of survey has been divided into: (1) principles, (2) techniques, (3) keys, (4) limitation, and (5) examples. The techniques used are based on evaluation of natural and physical environmental features as recorded in the airphotos.

A suggested procedure for conducting a material survey using airphotos is proposed. For the purpose of this paper the analysis of materials in an area is based on the use of the "pattern elements" as the primary interpretation key. Each situation is analyzed from the standpoint of what the various natural elements suggest about the probable characteristics such as drainage, soil profile development, relative textural range, and workability.

The limitations of the airphoto method fall into three general categories: natural, photographic, and human. The natural limitations are caused by variations in climate, erosional features, and vegetation. Photographic limitations include the type of photography, the scale of photographs, and the completeness of stereo coverage of the area under study. The human limitation is obvious and affects every phase of the process of interpreting airphotos.

The interpretation and application of agricultural soil maps, topographic maps, and geological maps for materials survey are discussed in a similar manner. The four areas used to illustrate each method in this paper provide a practical means of comparing the relative virtues of each method. The combined use of maps and airphotos is shown to be exceedingly practical.

● ONE of the most important phases of highway and airfield engineering is the survey for the location of suitable engineering materials for use in improving the subgrade. As far as road location and airfield-site selection are concerned, the best sites are those containing well-drained, granular soils which offer good support even in their natural state. However, there are many factors which influence site selection or route location and it is not always possible to pick the best site from the standpoint of engineering soils. Some of these factors might include high cost of right-of-way, inability to obtain land, location difficulties, and inadequate data about the soils of the region. In such instances, material location becomes extremely important. Available sources of suitable material must be found in order that good performance can be assured throughout the life of the project.

There are many methods of conducting material surveys for use in highway or airfield engineering, some of which include: study and analysis of geologic and pedologic literature; study of well-log data; personal contacts with land owners, contractors, and materials interests; field reconnaissance of an area either on foot, on horse, by car, or from the air; detailed soil boring operations; the use of geophysical methods; and the use of aerial photographs. Some of these methods are

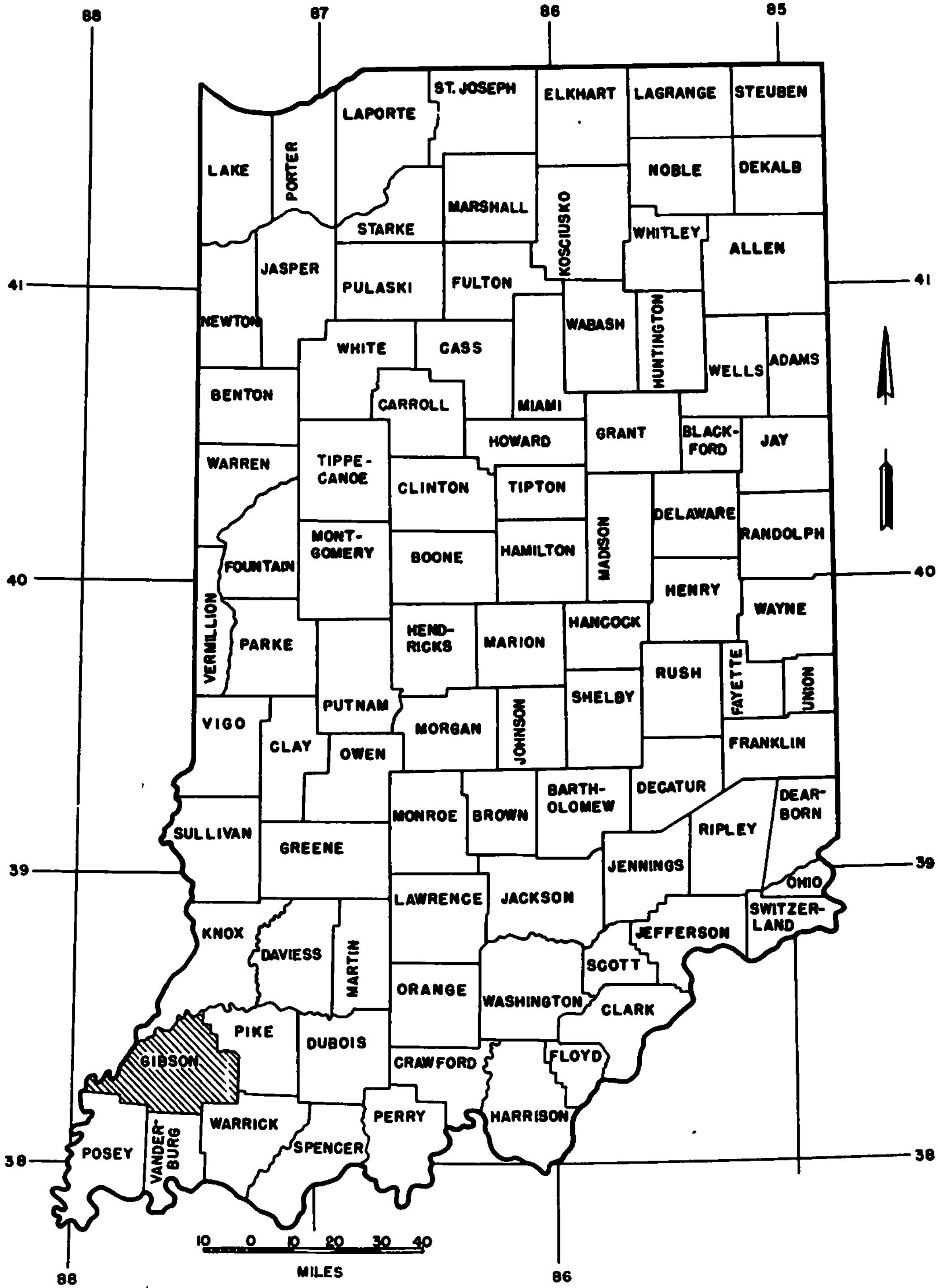

Figure 1. Map of Indiana showing location of example areas. The four site areas studied are within the blocked-in area of Gibson County.

rather detailed and will result in accurate findings. Many of them merely serve as guides for the materials prospector, showing him where to look or where to sample.

In connection with using well-log data for materials prospecting, such data are often impossible to locate since many well drillers do not file their data with state agencies. In some areas it may not be possible to gain access to an area for survey because of difficult topography, dense timber cover, lack of convenient transportation facilities, or lack of permission on the part of the land owner. From the military standpoint, an area may be inaccessible because of enemy activity. Conversations with land owners about materials are apt to be misleading because of the wide differences of opinion on what constitutes good sand and gravel. Many potential deposits may have been overlooked simply because of lack of information about their expected occurrence in an area.

Surveys of a reconnaissance nature made on foot or by horse, car, or aircraft are costly and time consuming but can be made quite reliable if the prospector grasps the areal perspective of deposits or topographic situations, viewing such as entire units. On the ground it is difficult to recognize the features associated with certain types of materials simply because of the inability to see great distances or because of natural or man-made obstructions. Occasionally a rapid reconnaissance survey for materials may be made from the air using a small, slow plane flying at low altitudes. This permits the observer to cover a considerable area in a short time. It may be difficult to identify all features associated with granular deposition or certain rock types by an aerial reconnaissance. Many outstanding deposits may be located in this manner if the vegetative cover, the human perspective, the influence of crop cover, and field patterns are used to assist gathering details. Some of these methods are much more useful and more quickly accomplished if done in conjunction with airphotos, agricultural soil survey maps, geology maps, or topographic maps, when such information is available.

Need for Information to Assist Material Surveys

The materials prospector has available four reliable methods of locating materials for use in engineering construction. They are not easy to use, but once the principles of their application have been learned and tested, it will be found that considerable time and expense can be saved through their use. These methods, or tools, require the materials prospector to learn a new language—to reorient his concepts of

Figure 2. Topography typical of the top of Mumford Hills.

materials occurrence and location. The methods referred to are: (1) the use of aerial photographs; (2) the use of agricultural soil survey maps; (3) the use of geological maps; and (4) the use of topographic maps.

These tools cannot be used without previous study directed toward developing an understanding of the principles and techniques. Basically there are two approaches to the use of any or all of these four methods: (1) the use of prepared keys and (2) the application of the principles of the method itself. Research personnel can prepare keys for use by others. These keys must be translations of the data into engineering terminology. Proficiency of the key method depends on the completeness and clarity of the key, as well as upon the user being able to grasp its significance. Considerable background study coupled with detailed field sampling is needed in the approach based on development by application of the principles of the method used. Ultimately, a key is not necessary as proficiency is gained. However, time and cost does not permit the use of the latter on a widespread basis for materials survey. Hence, the basic need is for the preparation of guide keys to permit efficient utilization of these four methods.

In areas where geologic, physiographic, soil-survey, and in some instances, topographic maps are available, prospecting for materials is relatively simple if the engineer or soils surveyor can translate the terminology and mapping units into engineering test data from similar situations obtained elsewhere. In some instances, the mapping units representing potential material are all inclusive and refer to a soil type belonging to a particular agricultural catena or to water-deposited materials of a certain geologic age. A true surface-material picture is not comprehended because of unfamiliarity with literature and maps of this type. Confusion exists in the minds of those unable to translate the literature used by the soil scientist, agronomist, geologist, or others talented in the fields of natural earth sciences. It is difficult to ascribe the proper engineering significance.

Those who conduct detailed study of agricultural, geological, and topographic maps and accompanying literature and who can translate the data to engineering materials and their related problems will be able to accomplish a good job of materials prospecting. This can only be accomplished if literature about an area is available and if the engineer or surveyor has had experience with the maps in the field. There is considerable literature concerning the use of various types of nonengineering maps for soil and material surveys. Most of the literature, however, is in the nature of progress reports or reports of an investigational nature and are not the manual type or the how-to-do-it type. Because of the confusion due to the many names of soils and rocks keys have not been representative and the user must conduct his own research to correlate the soils, as named, or rocks, as named, with engineering soils. In addition, reports discussing the principles of the various mapping methods have not been prepared which would assist the materials prospector in comprehending the system before he attempts to ascribe an engineering significance to the data.

Literature Study for Material Surveys

No matter which tool is used to prepare material-survey data there is a certain amount of study required on the literature of the area to be surveyed. The literature which will be significant in assisting the survey is that written concerning pedology, physiography, geomorphology, geography, agriculture, and climate. The purpose of reviewing such literature is to gain a perspective concerning the area. This perspective includes knowledge of the landforms expected with general information as to the surface and subsurface conditions related to each landform. In general, this perspective formulates in the mind of the surveyor a picture of what to expect in an area.

It is anticipated that the perspective will enable the surveyor to obtain more significant data from each of the tools he may wish to use (airphotos, agricultural soils maps, geological surveys, and topographic surveys). On the basis of the arrangement of landform units and topographic position within each landform unit, the materials are determined from details available in connection with the specific tool used. Map symbols are prepared to represent landforms, and in turn, landform units are subdivided with appropriate map symbols, based on topographic position. The symbols concerning topographic position are based upon the general class of materials, such as silt, sand, or gravel, to be found in a particular topographic position.

Purpose of This Report

The purpose of this report is to set forth a few principles of the methods of analyses, mapping, and presentation of

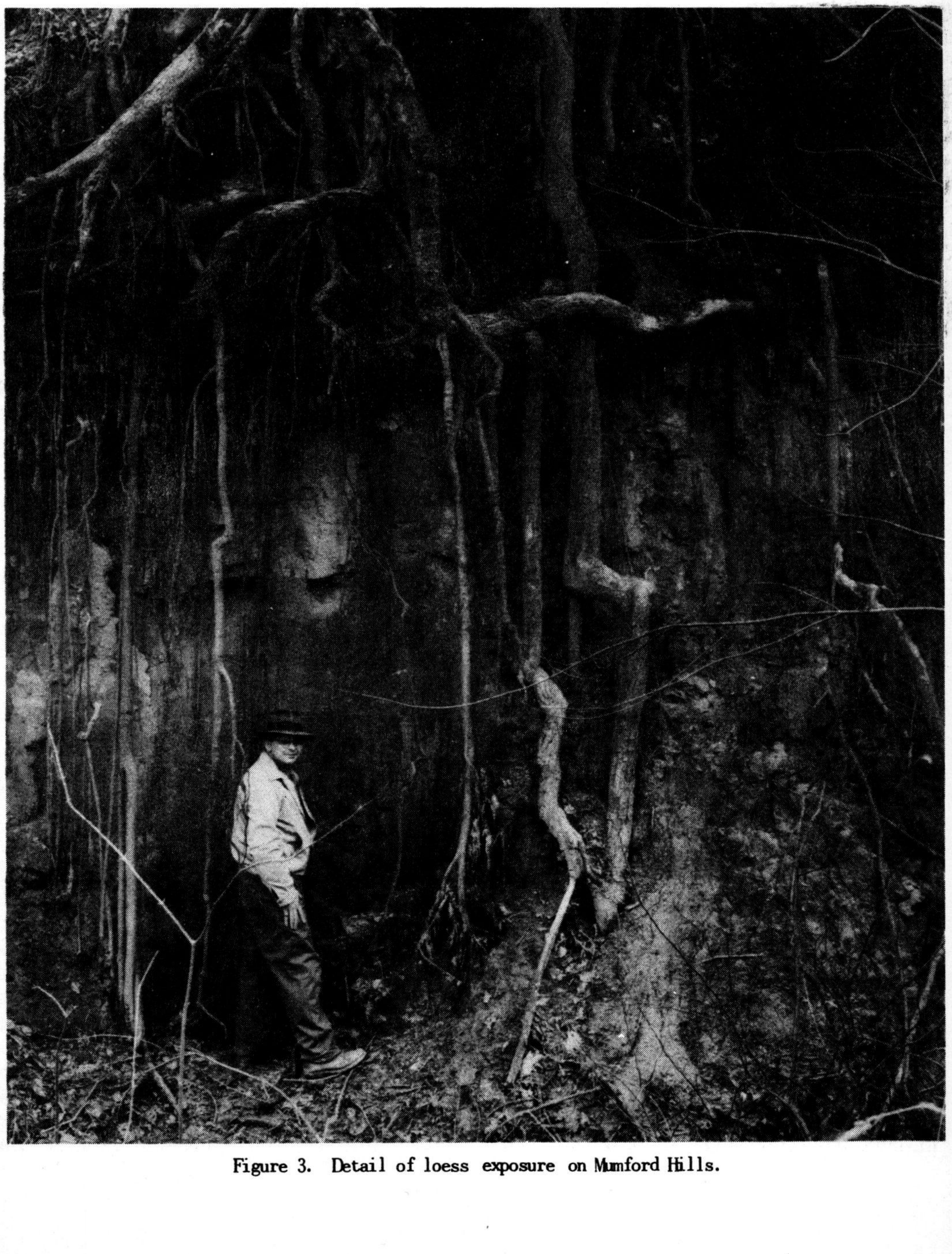

Figure 3. Detail of loess exposure on Mumford Hills.

soil and materials data from aerial photographs, agricultural maps (soil survey), geologic maps, and topographic maps and to illustrate by example how to use aerial photographs, agricultural soils maps, geological maps, topographic maps, and combinations of these for conducting engineering-material surveys.

(see Fig. 1). Each area was surveyed with each of the four methods, and material maps were prepared. In order to illustrate the methods involved, the discussion of each tool is applied to a different area of the four selected. The last part of the report shows how all methods can be combined to obtain material information. The

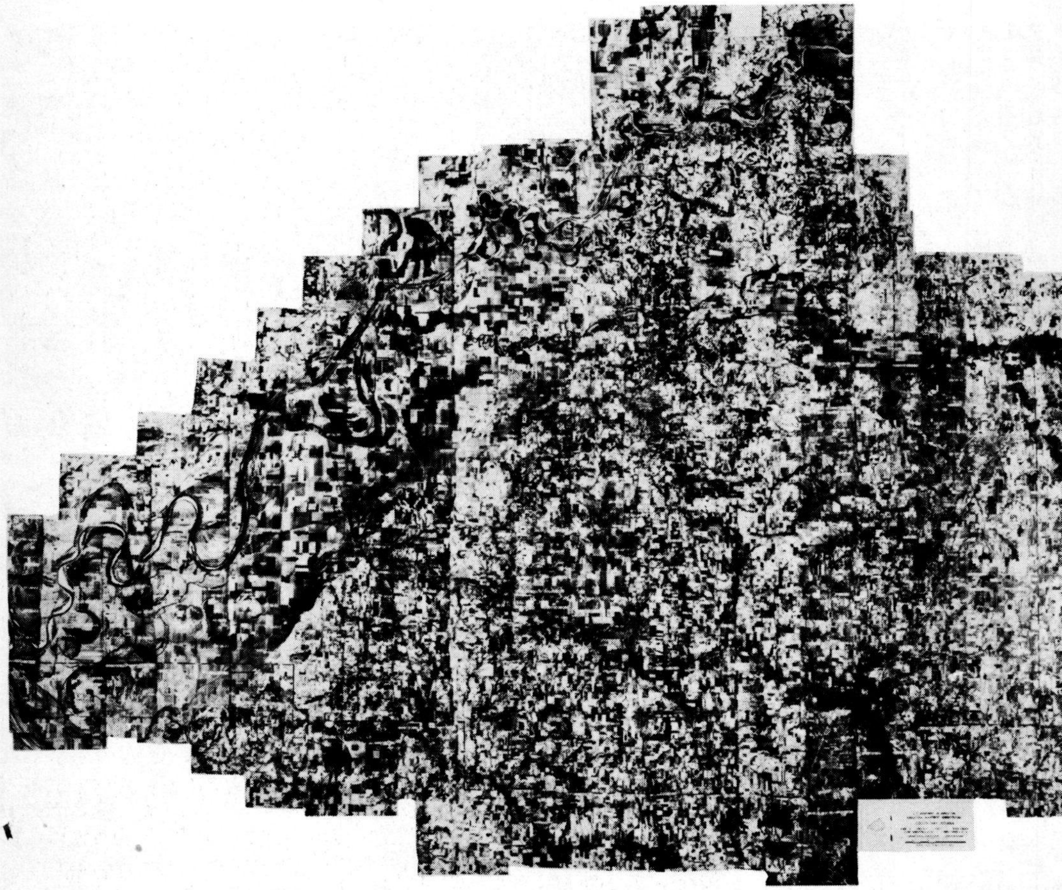

Figure 4. Airphoto mosaic of Gibson County.

Scope of This Report

This report presents qualitative information on the use of aerial photographs, agricultural soil maps, topographic maps, geological maps, and combinations of these media for making engineering-material surveys. The scope is limited to a short discussion of principles, techniques, keys, limitations, and examples for each of four major tools. Four areas in southern Indiana were selected for use in this study

discussion on principles in the section of airphotos is limited to airphoto-interpretation principles in general. The discussion of principles for the other three methods has been limited to the manner in which technical data are presented in the various surveys and the engineering significance of each tool is given as it is applied to a particular area. The discussion on techniques in each section is concerned with how to do it, or standard procedures to be followed in using the method. The section on keys presents a discussion on various keys in existence or those being developed currently. The limitations of applications of each method are discussed also. The scope is further limited to discussion of granular materials.

Visual Aids Used in This Report

This report is illustrated with aerial photographs, ground photographs, charts, tables, diagrams, and photographic copies of maps for the convenience of presentation of the data and methods of conducting material surveys. The high cost of color printing precludes the use of colored symbols on the geology and agricultural soil maps. Original map colors are named and the symbols are drafted reproductions.

MASTER KEY DEVELOPMENT FOR EXAMPLE AREAS

The first major section of the report is given to the development of a master key which would be used in a material survey in any location whether being conducted by these methods or not. The key is then made to fit the location of the example by adding local details in discussions of each area.

Key

Regardless of the method of survey used, the materials prospector must group deposits in some fashion. The landform (topographic position arrangement) has proven a useful means of grouping materials. There are three major topographic situations in which granular materials may occur in this particular area. The three divisions are referenced to the base level of erosion. These are lowlands, terraces, and uplands. Each of these may vary from a few hundred yards to several miles in extent. Within any one of the three groups there are many minor or local topographic situations. Lowlands can be divided into low lowlands and high lowlands, which divisions might correspond to first and second bottoms of a flood plain. Within these two major positions can occur depressions, rises, and intermediate level areas. In the same manner, terraces can be divided into low terraces and high terraces with each further subdivided into depressions, rises, and intermediate areas. Uplands, for the sake of simplicity, are divided into depressions, rises, steep slopes, and intermediate areas.

A diagrammatic sketch showing this arrangement has been prepared (see Fig. 23). The letter L indicates lowlands, T indicates terraces, and U indicates uplands. The relative position for subdivisions appear as H (high) and L (low) before the letter of major landform position. Local topographic situations are indicated numerically following the letter of major position as 0 (depression), 1 (intermediate), 2 (rise), and 3 (steep slope). Thus, the symbol HL0 is a depression on an elevated lowland.

The concept of this arrangement is important: it has considerable engineering significance. The formation of soil profiles is influenced strongly by topographic position. The occurrence of certain types of granular-material deposits can be understood more easily by comprehension of the landform-topographic-position arrangement. Such items as occurrence of ground water and surface water depend to a large extent on the topographic position with respect to the base level of erosion. Usually the thickest overburden of undesirable materials occurs in depressed topographic situations in either lowland, terrace, or upland deposits.

Figure 23 becomes a master key because it contains descriptive data which can be used to correlate the various mapping units with the above landform-topographic arrangement. Provision has been made for short description of supplementary data on the diagram pertaining to airphotos, agricultural soil series, geological name, physiographic type, topography, and engineering materials. The key now becomes applicable only to the locale of the examples because the mapping units would be different in other areas.

In the discussion under each method this key will be referred to since all mapping has been reduced to the key units and subdivisions. It is to be used in connection with the particular key developed for a particular method.

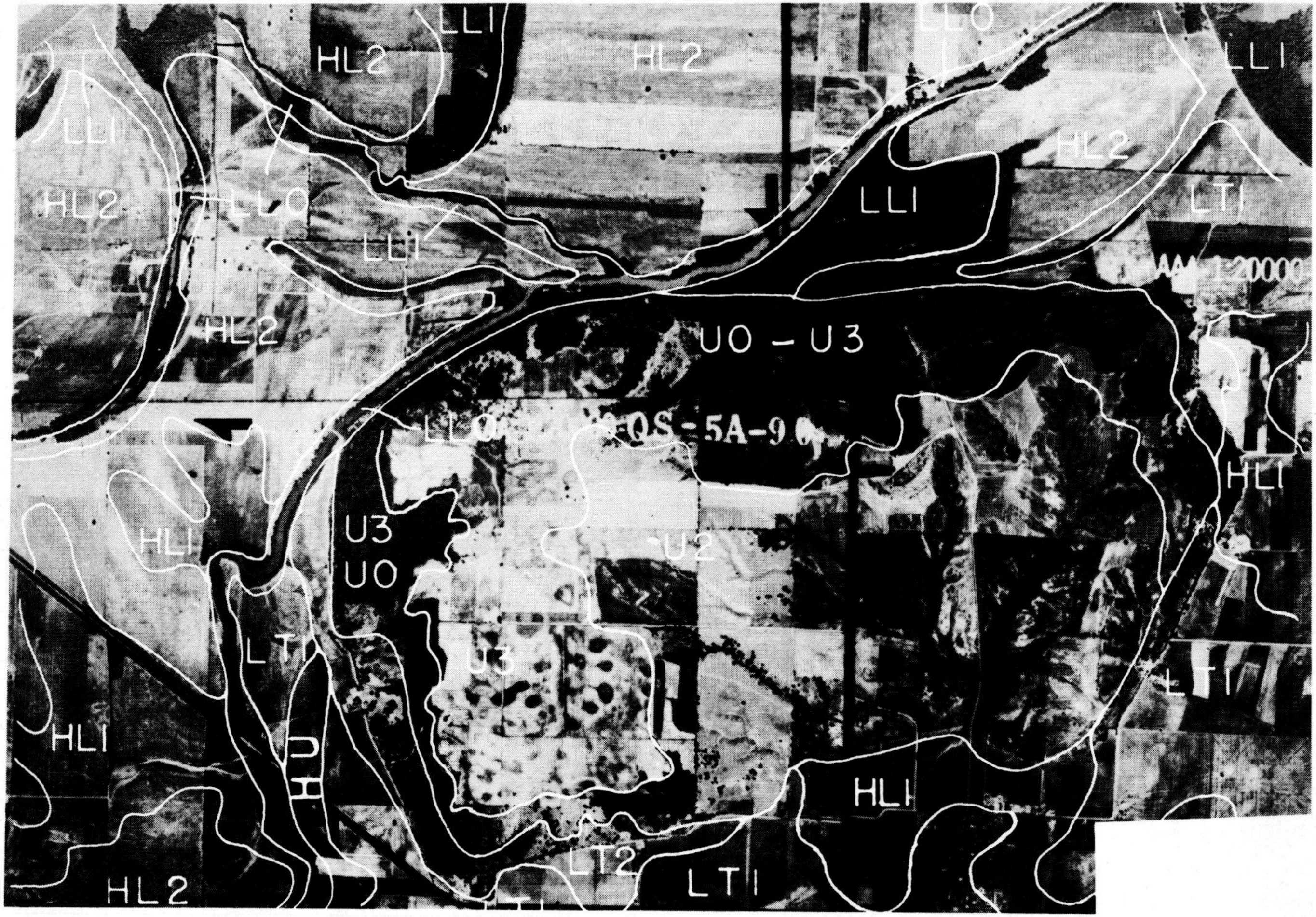

Figure 5. Airphoto of the Mumford Hills area.

AIRPHOTO METHOD OF MATERIAL SURVEY

An aerial photograph is a pictorial representation of both the natural and man-made features of the earth's surface. It pictures the sum and total of natural and physical environment. It pictures a pattern which is created by the forces of nature and modified by the forces of man. In cultivated regions one gains the impression that the pattern consists of a checkerboard field pattern and other man-made features. In a heavily forested area one gains the impression that the region is carpeted with vegetation, perhaps dense enough to obliterate surface detail. In an arid or desert region one is likely to gain the impression of a complete absence of any recognizable feature other than "oceans of sand." However, regardless of climate, vegetation, location, or man's influence, to the trained observer who gives the airphotos careful study there is another pattern distinct from the superficial vegetative pattern: the natural pattern. Through detailed study and proper evaluation of this natural-pattern mapping of soil and bedrock is accomplished.

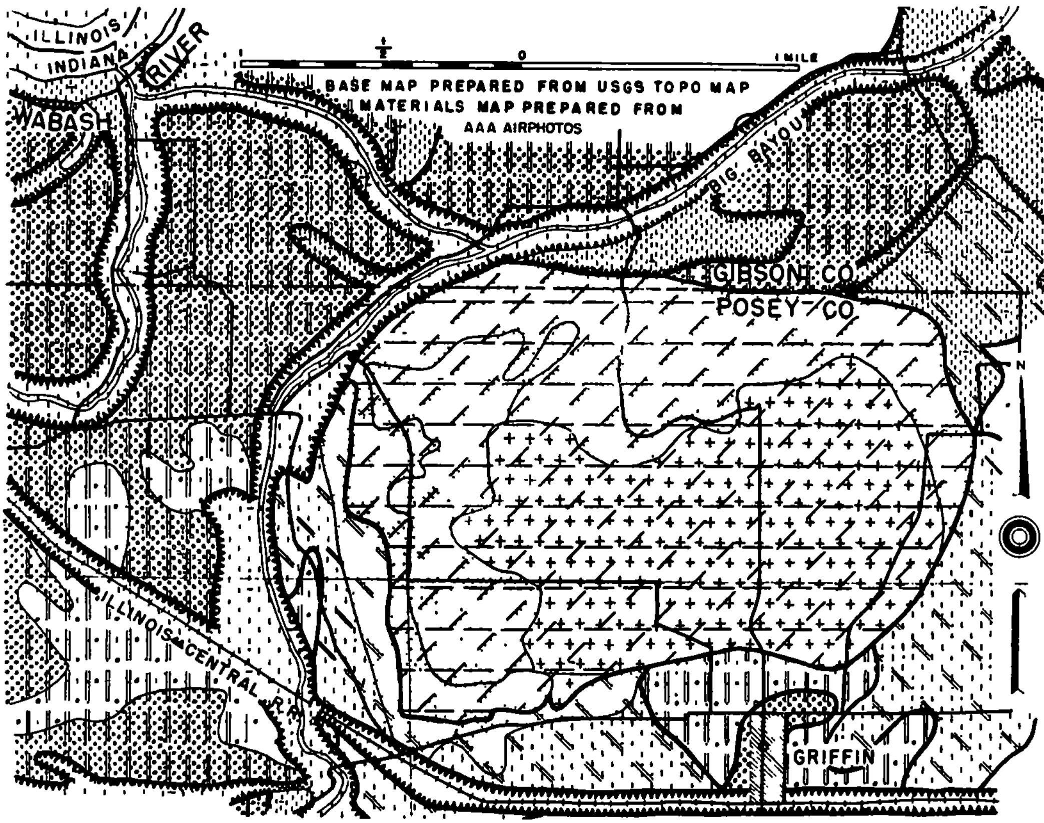

Figure 6. Engineering-materials map of Area F, Mumford Hills, Gibson County, Indiana.

Much has been written on this subject and only a brief review will be presented for the purpose of this paper. The reader is referred to reference material in the bibliography.

Principles of Soil Evaluation from Airphotos

The analysis of an aerial photograph is based on determining the origin of a deposit and tracing the erosional history which was responsible for its present-day landscape. The pattern of a deposit, or of an area, is an accumulation of surface features which reflect the subsurface.

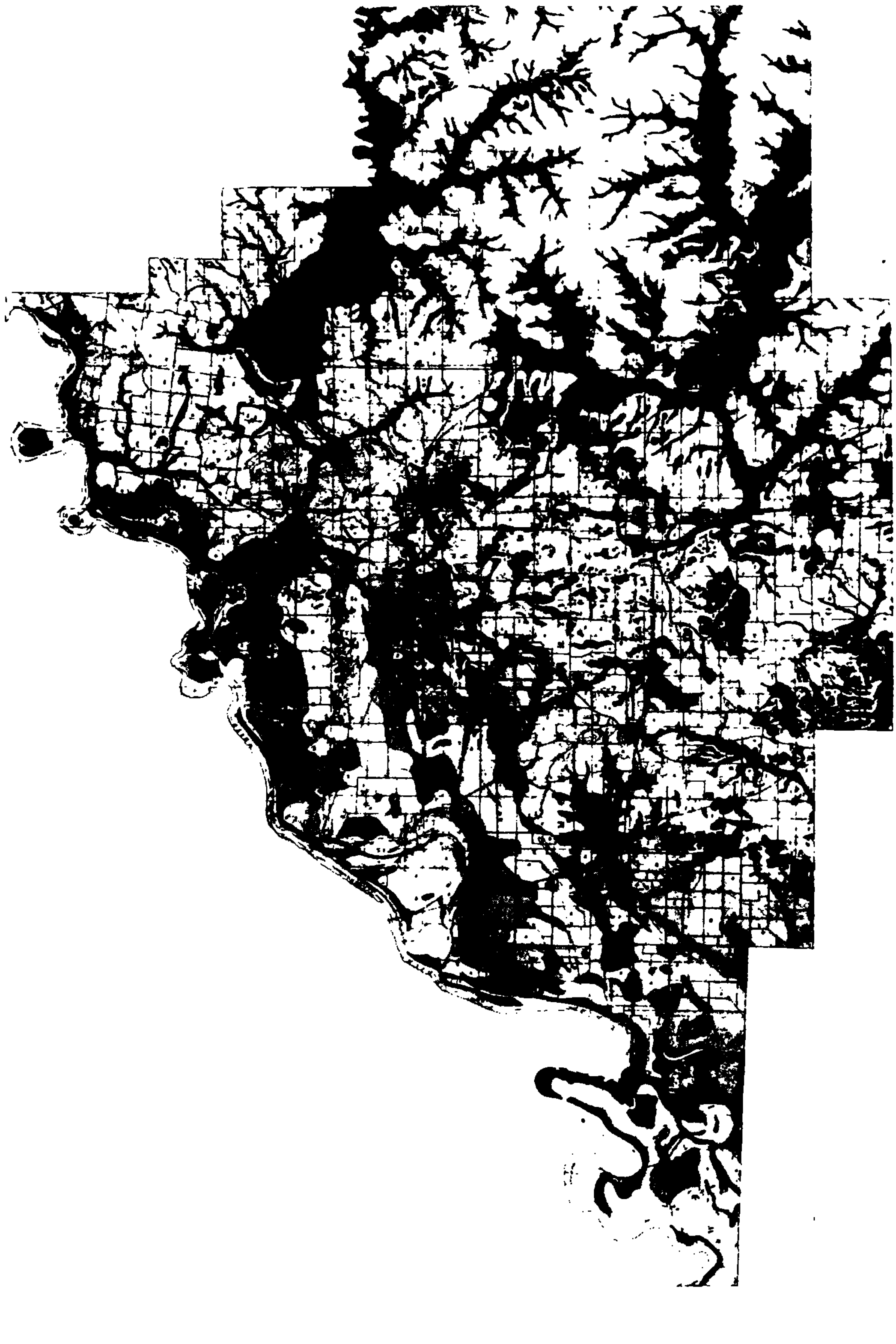

Figure 7. Gibson County Agricultural Soils Map.

Soil deposits, soil-parent materials, or soil-rock groups are areal in extent and are closely associated with the major geologic and physiographic divisions or regions; hence, the earth materials create a variety of patterns all of which are recognizable in aerial photographs because of certain contrasts between them.

A soil pattern is composed of certain physical features which can be grouped into elements of a pattern, all of which are recognizable on airphotos. Without a specific key it is necessary that the interpreter group the physical features into some classification system which lends itself readily to use and to easy analysis. The natural elements of the pattern are landform, areal-drainage pattern, gully systems, soil color tones, vegetation, special elements and man-made features.

Landform reflects geology and physiography, since it is closely associated with origin and subsequent erosional history. Landform refers to the landscape, the arrangement of the physical features.

The areal-drainage pattern also reflects geology and physiography. In addition, it reflects the general porosity of a soil-parent-material area. Six major types of patterns include dendritic, trellis, annular, radial, parallel, and rectangular.

Gully systems and gully characteristics reflect soil textural properties, and profile development. Changes in gully characteristics reflect changes in soil properties. In general, granular soils exhibit short, stubby, V-shaped gullies; plastic, nongranular soils exhibit broad, softly rounded gullies with a long shallow gradient; loessial silts and sand clays reflect box-section U-shaped gullies which erode at the headward end.

Color tones (photo-gray-scale values) reflect the product of soil moisture, topographic position, vegetative cover, and actual soil color. When evaluated in light of climate and processing (film sensitivity, exposure, development, and printing) then color contrasts become quite significant in soil study from airphotos.

The element vegetation reflects the environmental conditions for plant growth. At times, vegetation can be used to indicate certain features about soils (type, texture, and moisture) but only if vegetation is evaluated in light of regional and local environment.

Special elements are those which are characteristic of a particular soil, rock, or soil-rock mixture. Among the more outstanding ones are "silt pinnacles" and "cat steps" which are common to wind-blown silts, sinkholes and solution valleys of limestone regions, columnar structure of basalt, polygons in the Arctic and sub-arctic, and "blow outs" on sand dunes.

Techniques of Soil Evaluation from Airphotos

The analysis of soil conditions from airphotos is made possible through application of the processes of logic and deductive reason to the detailed study and evaluation of the natural and man-made surface features. Interpretation is broad in scope; it includes recognition of natural and physical features which create a pattern; it includes gathering data and analysis of the data; and finally it includes interpreting the data in light of the end point — ascribing an engineering significance to the area. Interpretation includes analysis in light of its regional and local environment. The interpreter must be able to trace the natural sequence of events in an area from the time of original deposition to the present as presented on the photos by the arrangement of the physical features. Usually all of the information is contained in the photos of an area, and it remains for the trained interpreter to apply the principles and techniques to obtain the information which he is seeking.

When all information must be obtained from photos it is important that the interpreter has considerable areal coverage. Analysis made from a few photos is exceedingly risky and cannot be done with any assurance of accuracy. This is particularly true when an interpretation must be made of an unknown or an inaccessible area. In such instances coverage should be sufficient to enable the interpreter to establish the major features such as basic climate, physiography, and geology on a regional basis, since these can only be obtained from study of a large area. The amount of photographic coverage, of course, depends on the

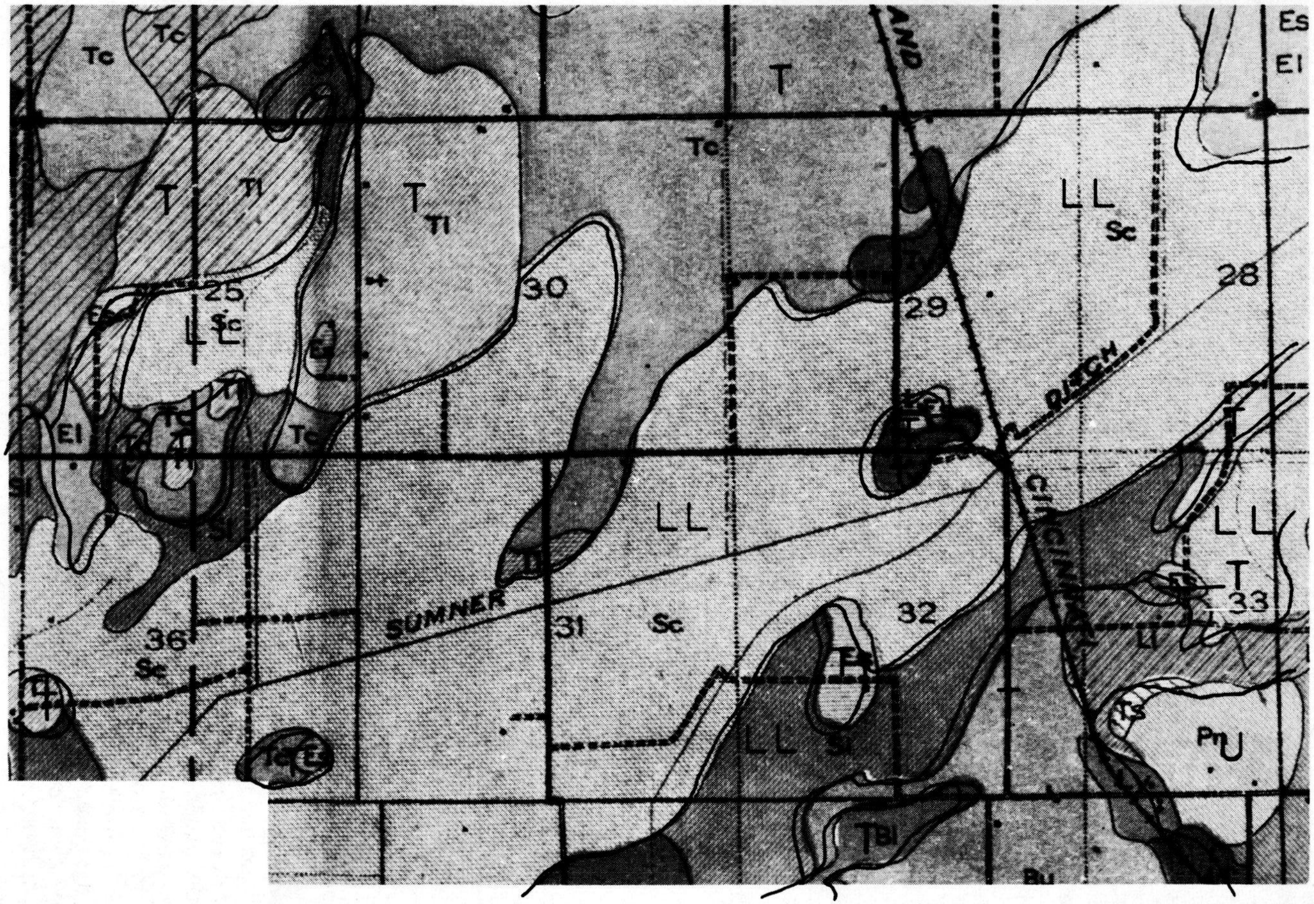

Figure 8. Agricultural-soils map of Sumner Ditch area.

relative size of the land units being studied as well as the physical setting. Once the basic features of the region have been established, the interpreter is able to identify and evaluate the local details. This is accomplished by detailed study of stereo-photographs.

In most cases advance information concerning the regional environment of an area is either known or, at least, available. There are very few areas in which such items as climate, physiography, and geology can not be located in the literature. With this material available the photo-interpreter's job is simplified. Smaller areal coverage will thus be needed and the interpreter can confine his efforts to observing, analyzing, and evaluating the local details from the airphotos.

In conducting a photographic analysis of an area the analyst should standardize the procedures he follows. His skill and proficiency is governed by constant use of airphotos not only in the office and in the field but also by constant correlation of predictions with literature, with actual field sample data, and with engineering performance data. The following suggested procedure is based on the assumption that the interpreter has an index sheet and complete vertical stereo-coverage of an area and that he is trained in the application of them.

Using the photo-index sheet as a guide, alternate prints are assembled into a mosaic form and stapled on to Celotex boards. The observer should study the entire area either as a unit or as a series of units if a definite grouping of features occurs. There will be certain items or markings or groupings which, by virtue of shape, magnitude, color, or configuration or markings, will form a group — a pattern which will stand out.

All borders and major features are studied in detail using a stereoscope and guided by a photographic guide sheet (see Fig. 24). Tentative predictions of soil type, depths, and profile development should be made from study of each element separately. If the predictions made do

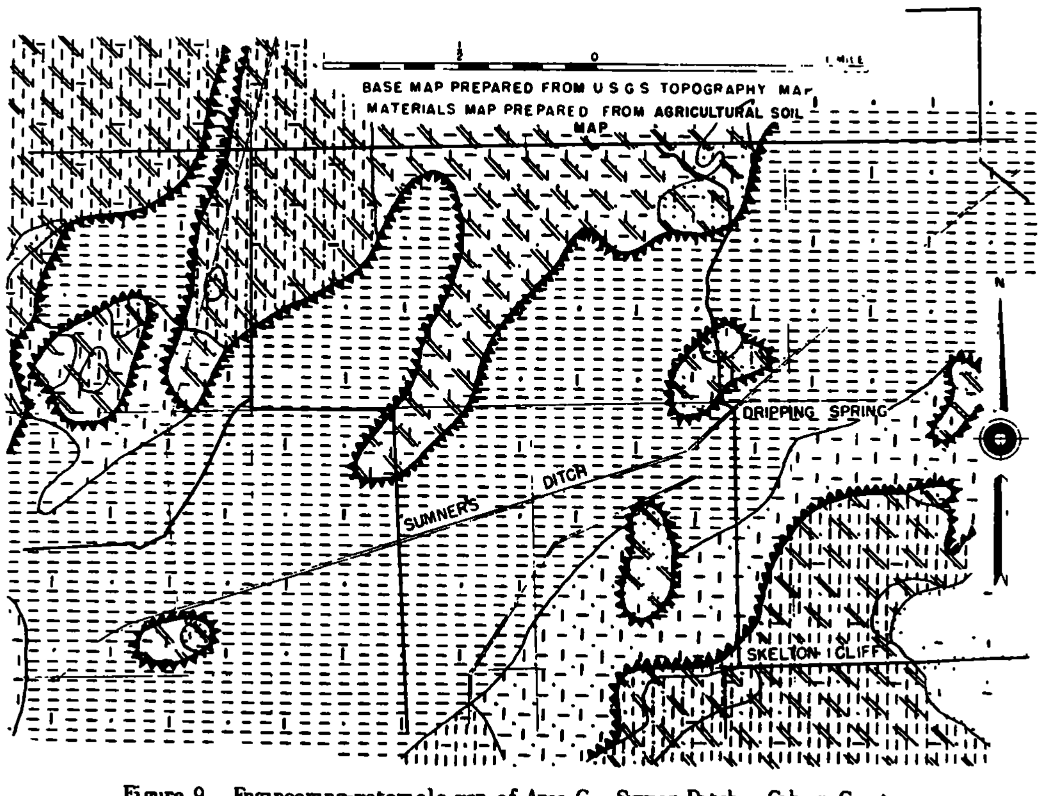

Figure 9. Engineering-materials map of Area C, Sumner Ditch, Gibson County, Indiana.

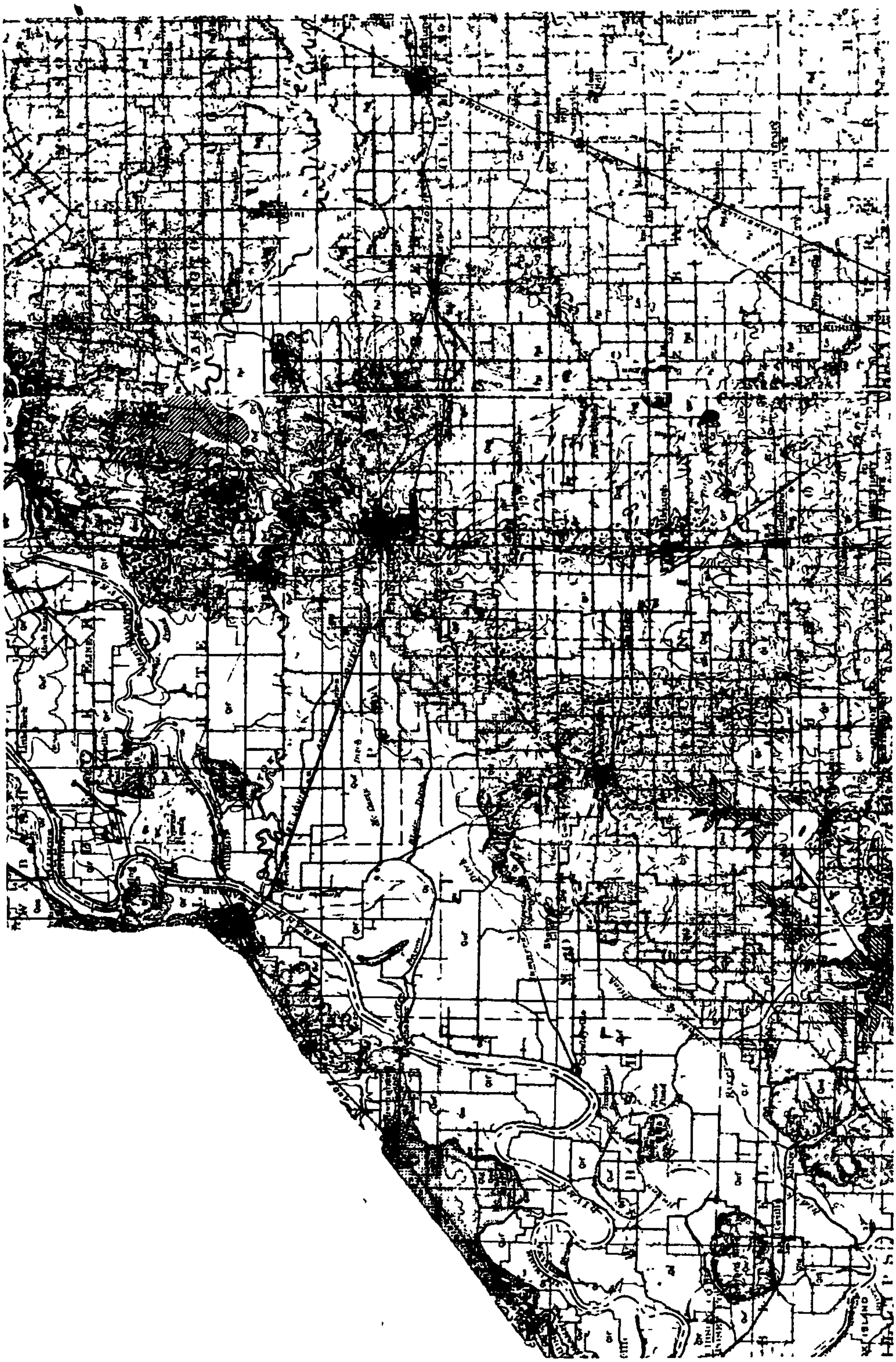

Figure 10. Geology map of Gibson County.

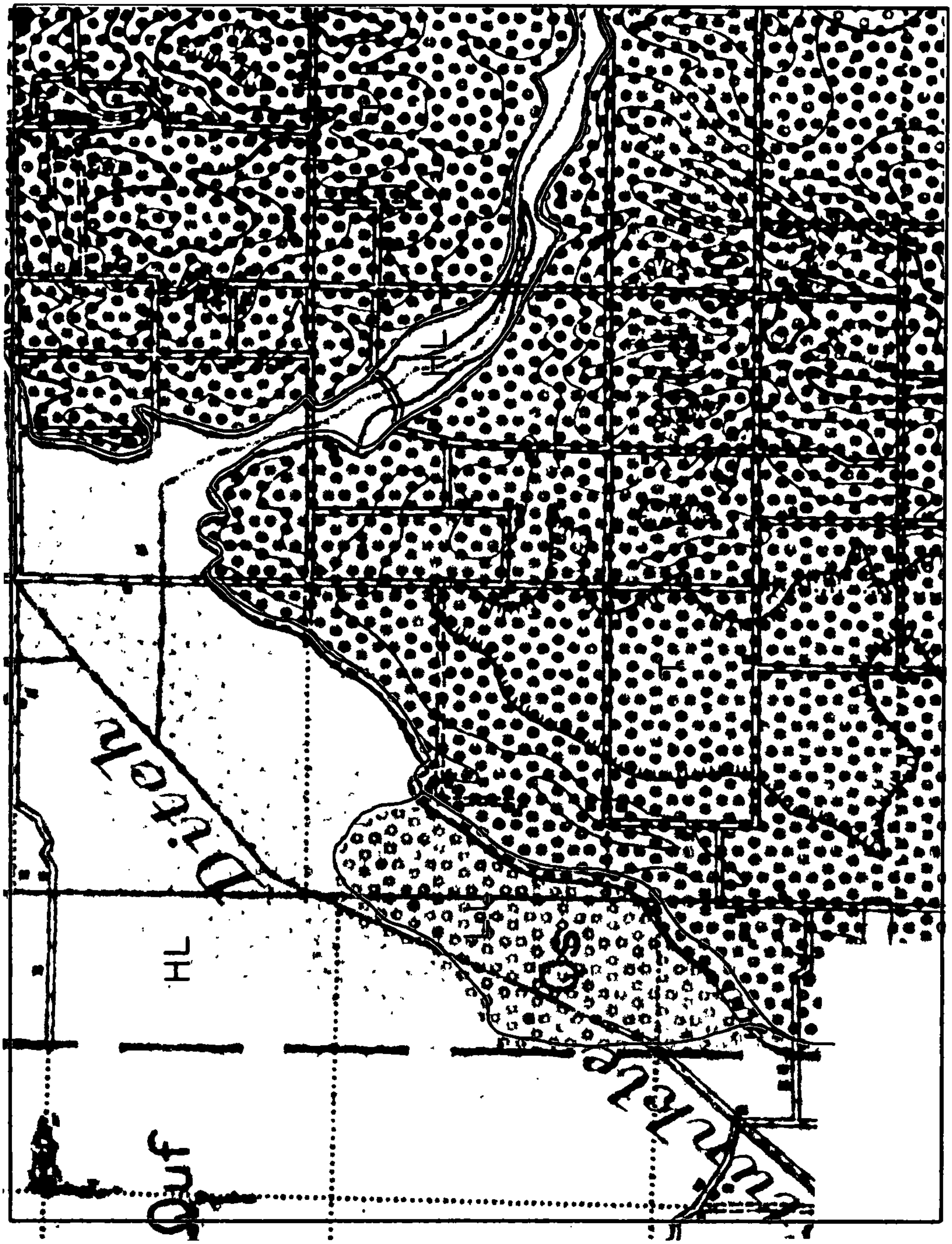

Figure 11. Geology map of Stunkle Ditch area.

not agree, then the interpreter should retrace his steps to locate any errors in judgment. During the preliminary study the observer should mark or locate areas for field checking. By making predictions in advance of any field checking the analyst will develop a high degree of reliability. It is to be remembered that the airphoto method can be used to identify and bound parent materials with a high degree of accuracy. However, estimates of profile depth, grain size, moisture contents and density are inferred from the photo analysis and should be field checked for positive assurance. After the interpreter has made his preliminary predictions based on airphotos, he should conduct a literature survey which should include the fields of pedology, geology, physiography, and agronomy available for the area in question.

Following the airphoto study and the literature study, the interpreter conducts a field study which should consist of a thorough ground check of previously made predictions in areas determined during photo analysis. Field checking should be accomplished with photos in hand and by on-the-spot stereo inspection. The engineering significance of soils and soil patterns may be gained if the interpreter observes and correlates the performance of highway pavements with soil types. Particular attention should be directed toward observing performance characteristics in areas requiring numerous cut and fill sections. The interpreter should obtain ground and aerial oblique photos which will characterize certain pattern features and which may illustrate pavement performance correlated with soil patterns. These photos will be of great help in evaluation of similar soil situations which may be extended to other areas. Of particular importance is keeping a catalog of photos illustrating the many materials sources. As a final analysis the interpreter should reanalyze all data and revise earlier predictions to suit actual field conditions. In this way the interpreter can concentrate on points where errors of judgment have been made and thus produce a more reliable materials survey.

Keys for Soil Evaluation from Airphotos

There are many types of keys which the interpreter may use in proceeding to identify, analyze, and interpret soils and materials of an area. The purpose of any key or series of keys is to point out or call attention to objects or features of a pattern which will serve as guide in a soils determination. Keys are used to identify, not interpret. The keys become the photograph's legends.

Basically, there are two types of keys: positive keys and inference keys. Positive keys permit direct identification of objects by pointing out or comparing easily recognized objects, chiefly those with which the analyst is already familiar and which lend themselves well to picturing, illustration, and description. Keys based on inference are those requiring the use of logic, deductive reason, and detailed analysis of regional and local environment. Such keys describe situations, either natural or man made, occurring in one area assumed to be typical and suggest, often by association, that analogous situations exist where natural and physical environmental conditions are similar. The development and the use of such inference keys are based on interpretive procedures.

Both positive and inference keys point to identification of objects or situations. Analysis follows identification and the success of the analysis lies entirely within the province of the analyst. The analysis is dependent upon background or major field of interest of the analyst. The data gained by recognition, inference, or deductive reason, are arranged in such a manner as to convey the picture of what is contained in the area. Interpretation of the data is the final step and must follow both identification and analysis. Interpretation must be based on the end point, desired result or field in which the information is to be used. Quite necessarily it follows that interpretation of results will be done in some major field of use. Hence, the airphoto becomes a tool by which, in this instance, the engineer gathers information concerning the soils – whether he uses a direct key, an inference key, or follows interpretive procedures without the use of a key. He will analyze the soils data in light of his background and interest. His interpretation of what to do with those soils will be based on the job requirements and on his judgment.

Some keys are built around a series of diagrams, sketches, ground photographs or airphotos of easily recognizable physical features representing the component parts of a pattern. They are

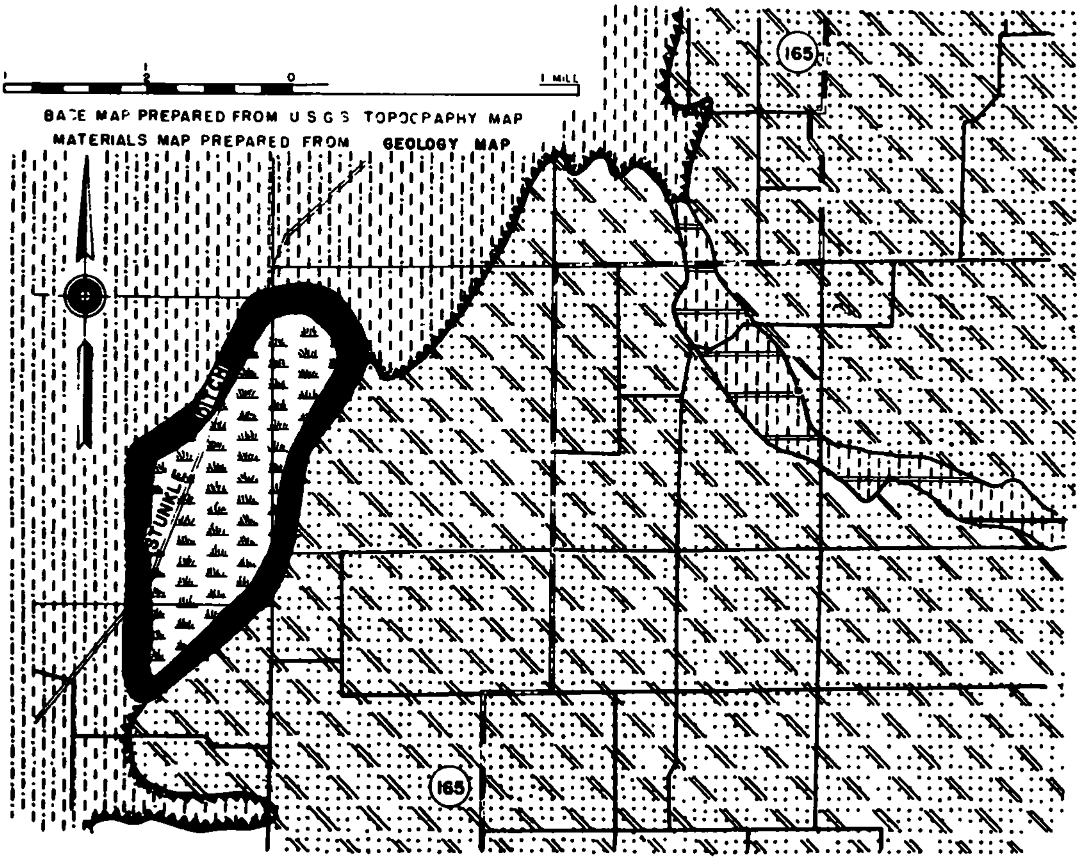

Figure 12. Engineering-materials map of Area D, Stunkle Ditch, Gibson County, Indiana.

usually ideal representations and must be outstanding in both their simplicity and their representation. In some situations a series of charts may suffice. The analyst, from a detailed stereographic study of photos of his area, proceeds to study the physical features and to look for objects which may be similar to those represented in the keys.

Another type of key may be built in the form of a catalog or encyclopedia. Many possibilities exist in this type. Many choices for first division exist; they should, however, be based on the final use. As an example they may be catalogued into natural features and man-made features at the level of the first major division. First subdivisions for man-made features may be industry, agriculture, or some other major field of endeavor. This may be further subdivided into types of industry such as manufacturing, processing, etc. Further subdivisions can occur based on the detail required in the collection. In a similar manner the natural objects can be subdivided into major earth-science fields such as physiographic forms, geologic forms, ecologic forms, geographic forms, etc. Subdivisions can occur such as construction and destructional forms under physiographic forms. Again, they may be further subdivided into agents of construction or destruction such as wind, water, ice, etc. It can be seen that the ramifications are many and such a key or catalogue can reach tremendous proportions if many off-shoots are pursued.

One type of key which may be devised and applied to photographic analysis is the question-and-answer type in which various questions are asked each having several possible answers but only one correct answer. Each answer, in turn, suggests certain questions, each of which has several possible answers but only one correct answer. This process continues until the analyst has arrived at the final and most-probably correct answer. In this type of key the various possibilities are referenced and are discussed elsewhere in the general collection of keys. The analyst continues from question and answer along a chain of connected events until he either has the answer or is forced to pursue another path. The first series of questions may refer to such major

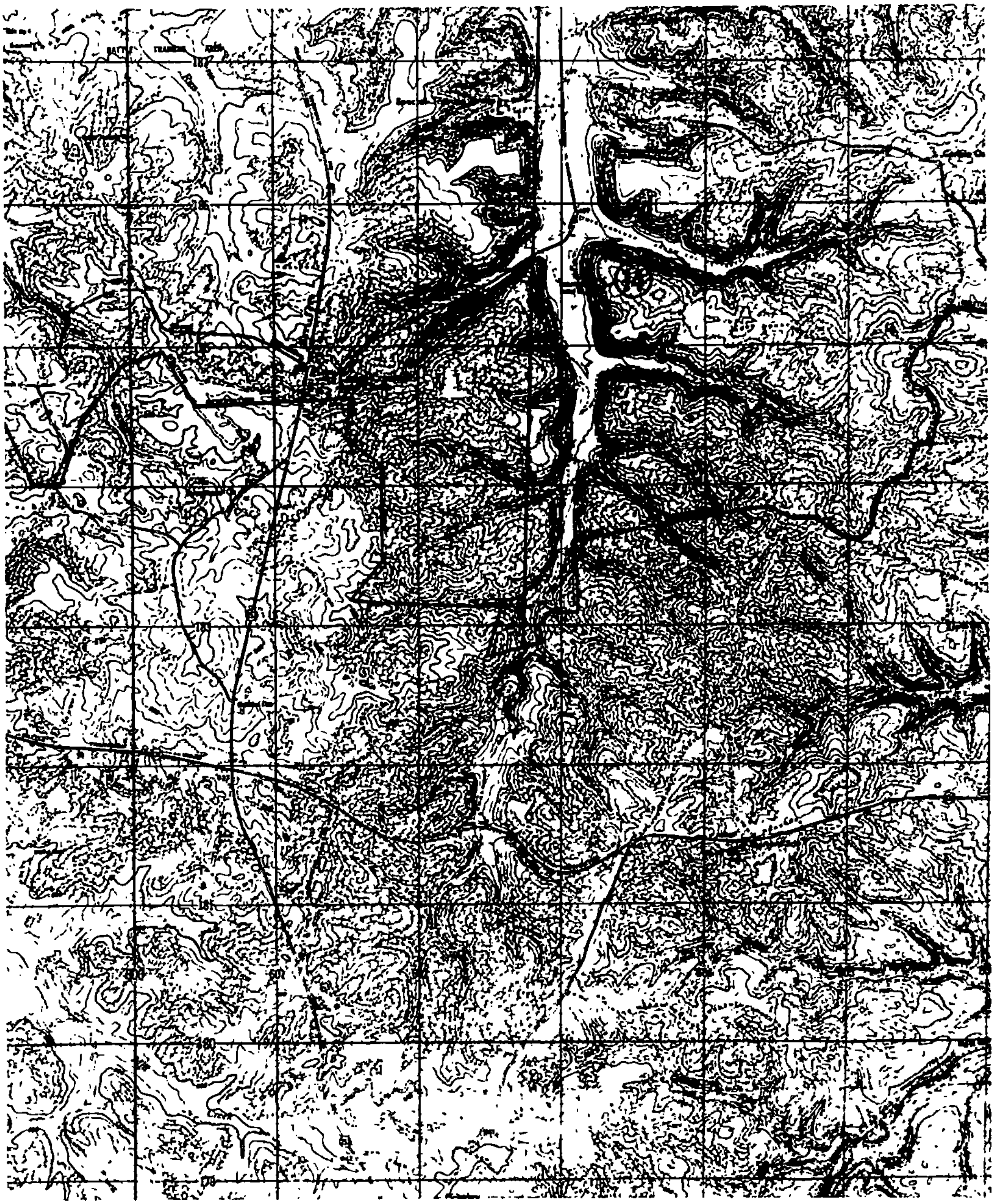

Figure 13. Topography Map of Cedar Creek, Kentucky, part of U.S.G.S. Topo Sheet, Colesburg, Kentucky, 1946.

items as climate, geology, physiography. Under climate there may be six possibilities as indicated in the vegetation-erosion features. Under geology there may be several leading questions intended to point out methods of origin, subsequent erosion, and deposition. The choice of answers and subsequent references will depend on the observation powers of the analyst — his impression of the features of the photo pattern. He must make the answers fit the case in question. Likewise, physiography may be called to the observer's attention setting forth the possibilities in question form. A second series or group of questions and possible answers are aimed at pointing out local details of the physiographic pattern. Questions and answers concerning such features as landform, erosion, drainage, color, vegetation, and others will carry the analyst to the final goal: soil identification. The above question-and-answer key must, through necessity, be all inclusive: all possibilities and all steps must be shown. A key of this type may also approach encyclopedia proportions.

Another key is that built up around the use of pattern elements as major key divisions of the landscape. At present, this is one of the more popular approaches to gathering data about the natural and man-made features which form a pattern. These were discussed previously (see Fig. 24). Analysis of the areas in Southern Indiana in connection with this report was performed following the guide sheet in Figure 24. The data in the first part under regional environment were known. Only the second portion, local environment, applies in the example areas.

Limitations of the Airphoto Method

It is of extreme importance that the interpreter be fully cognizant of the limitations imposed on the airphoto method of survey in order that he will learn to recognize conditions beyond which he cannot successfully evaluate. These limitations fall into three general categories, natural, photographic, and human.

The natural limitations are those which existed or which were reflected in the surface patterns at the time of photography. Usually they can be identified and interpreted entirely from the photographs by observing irregularities or deviations in the natural pattern. Natural limitations arise largely from the influence of environmental conditions, chiefly climate.

The climatic influence is suggested from the photographs by distribution and type of vegetation and by the presence or absence of vegetation. The vegetation limitation is of extreme importance in northern latitudes, where such items as elevation, exposure to sunlight, and protection from severe climatic conditions often govern the presence or absence of vegetation. Changes or contrasts in vegetation may reflect significant changes in soils if environment has been evaluated properly.

Another important natural influence which often imposes a serious limitation is the erosion pattern of an area. In general, gully cross section and gradient are indicators of soil texture; however, the interpreter must evaluate the climatic condition under which the gullies were formed. He must decide whether erosion has been of a geologic nature and has taken a long time to develop or whether erosion has been of a recent nature and has formed in a relatively short period of time. As an example, clay shales or clay soils normally occupy softly rounded slopes in the erosional features in humid regions; however, the flash-flood characteristics of arid and semiarid regions will carve clay shales or clay soils into fantastic shapes with unnatural vertical slopes. By knowing the general climatic conditions of an area the interpreter can establish the degree of reliability which can be assumed when studying gully characteristics.

The photographic limitations are largely a matter of recognizing the limitations associated with the various types of photography and scales. In general, there are three major types of photography which consist of trimetrogon, vertical coverage, and continuous strip. Trimetrogon photography is used chiefly in reconnaissance mapping of large areas and for this work it is usually obtained from high altitudes with the resulting scale quite small. As far as engineering soil survey is concerned, trimetrogon photography should be limited to reconnaissance use where

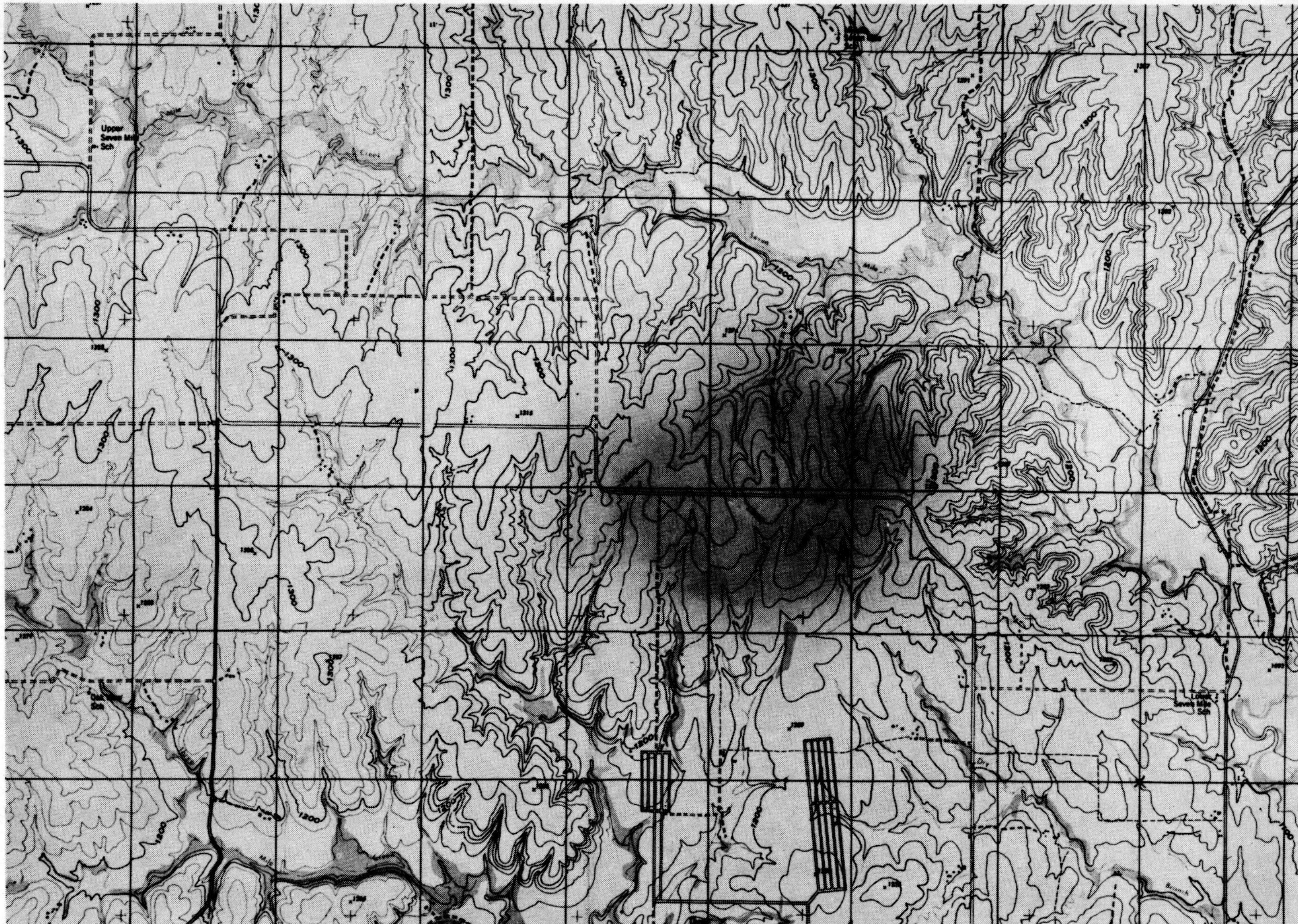

Figure 14. Topography map of Seven Mile Creek area, Kansas; from a tactical map of Fort Riley and vicinity, Corps of Engineers, 1946.

the interpreter can use it to establish the major soil-parent-material boundaries. Vertical coverage of mapping-type photography is the most common and is the most practical type for engineering surveys dealing with earth materials. Detailed preliminary soil surveys and engineering soil maps should be made from vertical-mapping-type photos. Continuous-strip photography for engineering use is best suited for making performance surveys of such structures as runways, railroads, or highways. This is important, because it is possible to correlate engineering performance with soil type, traffic, or any other variable which will show its influence. When such photos are taken periodically they provide a permanent record of progressive failure or of the condition of a particular installation.

As far as general engineering-soil survey is concerned a scale ranging between 1:15,000 and 1:22,000 is satisfactory. General soil-parent materials can be bounded with ease. Scales on the order of 1:5,000 provide an excellent scale for obtaining minute surface detail, but the photos do not include sufficient area per print to provide a practical means of mapping large areas. It is difficult to interpret such items as relief with the use of common instruments from large-scale stereophotos. When photos are taken with scales ranging from 1:30,000 to 1:40,000 the resulting images are too small to evaluate properly the engineering-soil conditions.

For engineering-soil survey, photos should be obtained in stereopairs or the area should be covered with sufficient overlap on individual photos that stereovision is possible in all parts. This usually results in two complete sets of airphotos of an area (composed of the alternate prints of the flight lines). It is important to stress that even though every other print in a flight line will provide complete physical coverage for a mosaic, it will not be possible to study the area stereoscopically; hence, it is important to obtain the total number of prints in any given flight strip. As far as soil survey and related studies are concerned, photographs should be obtained of as large an area as possible and they should be obtained in stereopairs. Photography of this type is readily available for most areas of the country and can be purchased from various government agencies at a relatively low cost per print.

The third major limitation lies within the province of the interpreter and is based on such items as his background or major interest, keen vision, and a good imagination. The interpreter must have a keen appreciation of the relationship between natural soil or soil-rock conditions and engineering problems. It is not necessary that the interpreter be especially trained to the extent that he becomes a specialist in the natural sciences dealing with the surface features of the earth. The interpreter should be aware of the sources of literature in any of the related fields, since this is of paramount importance in obtaining background material about any particular area.

Example of Airphoto Method of Material Surveys—Mumford Hills

In conducting the material survey of the Mumford Hills area from airphotos, several major steps were followed, which include: (1) assembly of airphoto mosaic; (2) study of the county index or mosaic; (3) study of the Mumford Hills portion of the mosaic; (4) detail stereostudy of the Mumford Hills area; and (5) grouping landform types and designating textures. The steps are discussed as follows:

Assembly of Mosaic. The aerial photography for Gibson County was flown in 1940. It bears the county symbol QS. Alternate prints were assembled into a mosaic form for a preliminary area study. Figure 4 is a copy of the Department of Agriculture Index Sheet covering the photography of Gibson County. This index sheet served as a guide for mosaic assembly.

Study of County Mosaic. From the preliminary study of the mosaic, Gibson County can be divided into two major features: a broad, gently rolling, dissected upland which contains several inland basins and a lowland which contains the channel and floodplains of a major river.

The basins in the upland provide the outstanding feature of the upland pattern in as much as they are dark in color

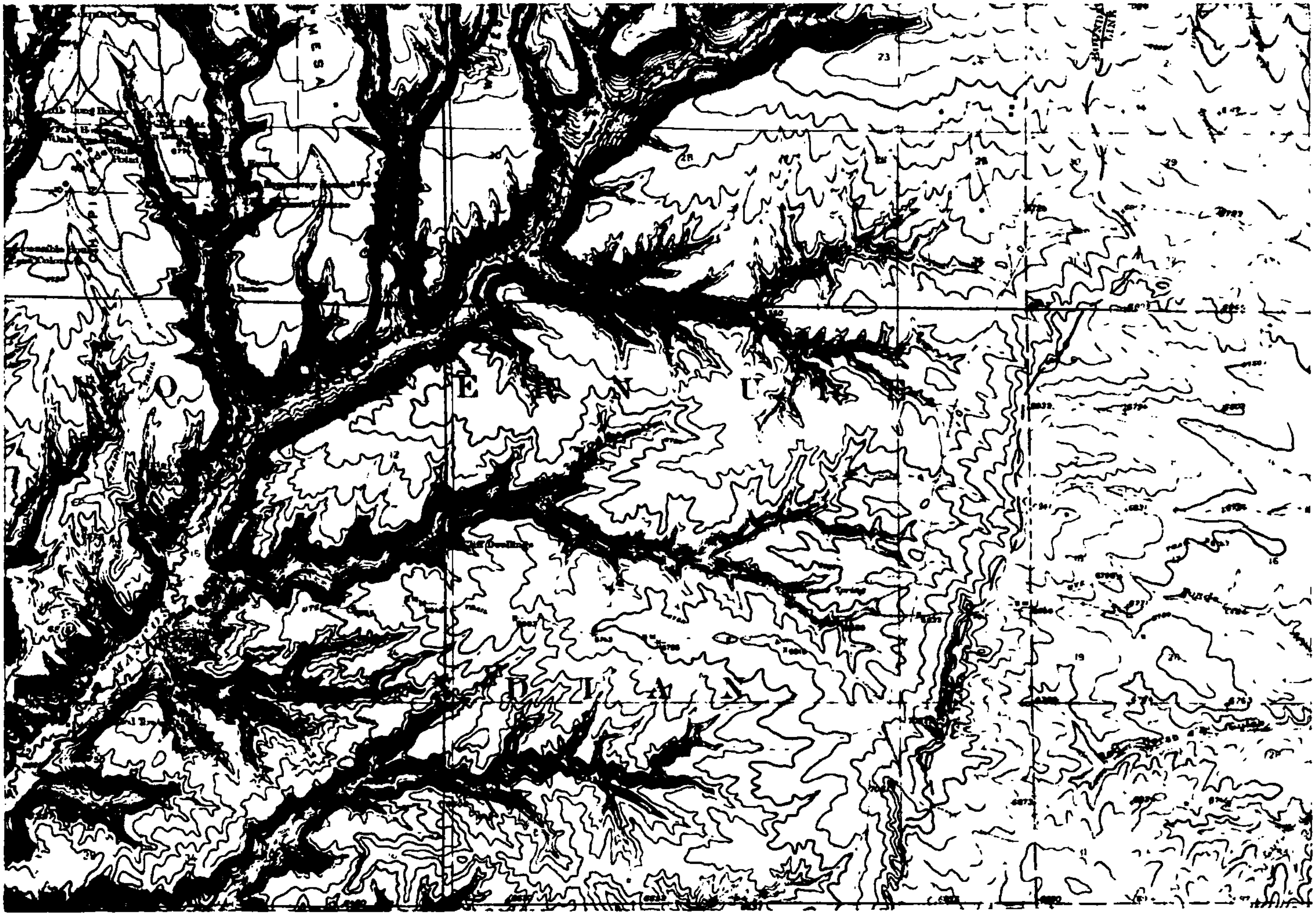

Figure 15. Topography map of Mancos Canyon area, Colorado, from part of the U.S.G.S. Topo Relief Map, Soda Canyon, Colorado, 1943.

(sharp contrast to the surroundings), they are quite broad, and they do not appear to contain a definite stream channel. The impression given is that each represents filling by sedimentation in the quiet waters of an inland lake. Inland from the major river valley the pattern is one of considerable dissection by long, broad, dark-centered gullies which extend back considerably into the upland. In the far eastern part of the county these gullies have light-colored fringes, which suggest that the parent materials might be Illinoian Drift. In the central portion of the county, fringes are absent and a sharp contrast exists between the dark center of the gully and the light tones of the adjacent uplands. This suggests that there may have been a modification of the surface by material of aeolian origin. Adjacent to the major flood plain there are considerable areas of light tones where gullying is not well-developed, suggesting that the soils might be well-drained internally. These may be sand dunes. In other areas of the upland adjacent to the major stream valley, the impression of moderately great relief is created by intense dissection. This consists of tree-filled gullies which do not extend great distances into the upland but instead are confined to small areas. Some of these gullies, which are outlined by timber cover, resemble those of windblown silts found elsewhere. Hence, it is believed that loessial silts may be deep in places along the valley wall. It is believed that the area is underlain by bedrocks, flat-lying or slightly tilted, because of the numerous sharp bends in many of the upland gullies and major upland basins. The mosaic can not be used, in this instance, to identify the rock type other than to suggest that it is possibly sedimentary and not limestone.

The major lowland, which contains the river valley, forms the western border of the county. The river appears to be in a mature stage of its development as indicated by the numerous meanders of the present stream and by the presence of abandoned meanders in the lowland, many of which are no longer connected in any way with the stream. Almost all parts of the lowland contain markings indicating current activity, all of which suggest that the soils of the lowland are chiefly alluvial in origin. There is some evidence that the stream is controlled to some extent by underlying bedrock because of the variation in the shape of some of the stream meanders. In the extreme southwest, part of the meanders form broad, free-swinging loops, while in the west-central part the stream follows a straight course for several miles to the point where it is joined by another major river. The straight portions of the stream occur downstream from a series of prominent islands, or monadnocks, which occur in the lowland and which may be responsible in some part for deflecting the stream. These islands are easily seen on the county index sheet or the mosaic by the sharp contrast in pattern of the islands with the surrounding lowlands. The islands contain dense timber on the steep slopes, which is inferred from the interrupted crescentic arrangement of the timber pattern. The timber pattern encloses a field pattern vastly different from that of the adjacent lowlands. In addition, well-developed gully systems are found on the larger of the islands. The Mumford Hills area is one of these islands, and it is believed that since it has remained in the flood plain of this mature river, it is rock and is a remnant of the strata which may underlie the remainder of the county.

From study of the index sheet it is believed that the texture of the materials in the flood plain varies considerably, as reflected by sharp contrasts in color tones from nearly black to almost white. The darkest tones appear to occupy abandoned stream meanders and in one major depression. This major depression, which occurs at the junction between the upland and the lowland, is perhaps a backwater area which may have been isolated by alluvial levee building in the central portion of the valley. Scattered throughout the lowlands are some isolated areas which are very light in color. Since they show some indication of having been swept by fast-moving water, it is believed that they are granular in nature. From this it would appear that the lowlands consist of a flood plain with at least two major stages or bottoms.

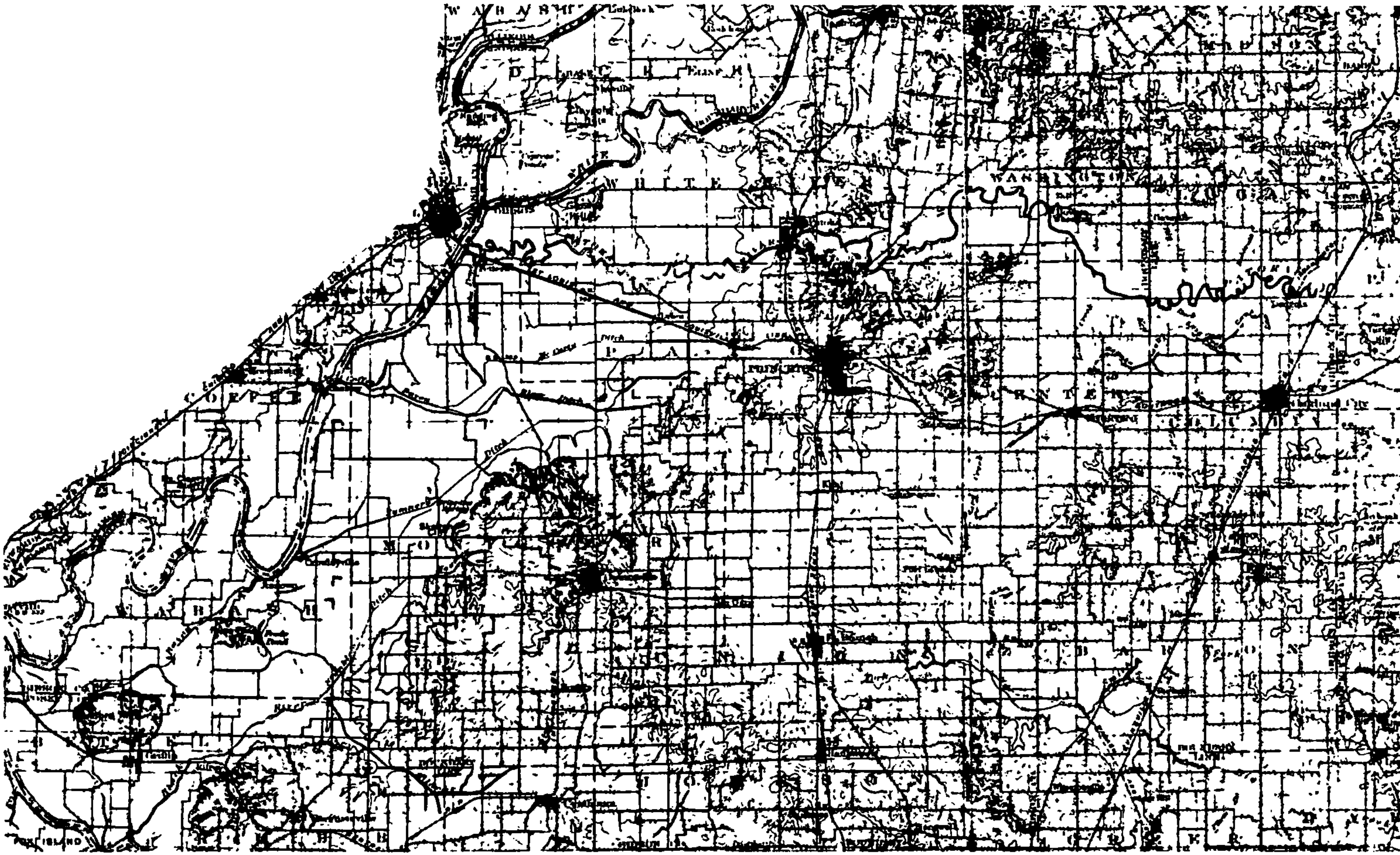

Figure 16. Topography map of Gibson County; from part of U.S.G.S. Topo Sheet (13).

Study of the mosaic can be summarized in the following manner: Gibson County contains two major physiographic situations, a dissected upland and a lowland occupied by a major river and its associated flood plains. The upland may consist of flat-lying sedimentary rocks covered to varying depths with glacial drift believed to be Illinoian in age. The drift appears to be mantled in places with aeolian deposits, sand, and silt. The lowland is composed of perhaps two stages or bottoms of the flood plains. A series of rock monadnocks appear as islands in the lowlands.

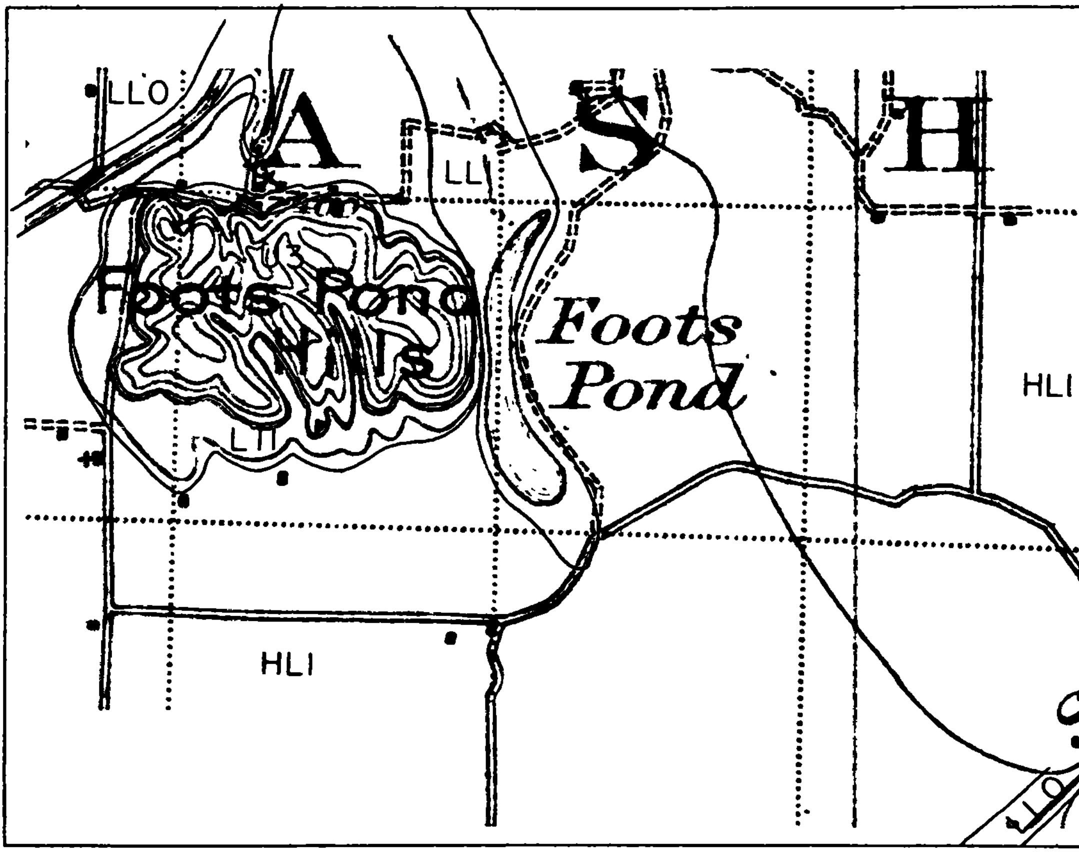

Figure 17. Topography map of Foots Pond Hills area, from U.S.G.S. Topo Sheet.

Detailed Stereostudy of Location of Survey. The next operation consists of conducting a detailed stereoscopic study of the photographs covering the Mumford Hills area. Figure 5 is a copy of photos of this area. In general, the observations made by study of the mosaic concerning the presence of monadnocks were verified. The Mumford Hills area is quite a pronounced knob lying in the lowlands surrounded entirely by alluvial deposits. There is considerable contrast in all pattern features between the lowland flood plain and the island. The most outstanding of these, in addition to the high topographic position of the knob, is a difference in drainage patterns between the two areas. The Mumford Hills area contains a well-developed drainage pattern on the south and east portion, no surface drainage on the far western part, and a well-developed system of gullies on the northern part. The surrounding lowlands do not contain any natural drainage pattern other than that associated with the series of meander scars.

From detailed study of the elements of the pattern of the Mumford Hills area it is believed that the island is composed largely of rock. Even though it may have been originally formed by the cutting action of the river, it is not streamlined in shape. It is irregular in plan and is asymmetric in cross-section along the north-south axis. Steep, timber-covered bluffs occur along the north and far west slopes. A long backslope characterizes the southern portion. The eastern and southeastern part is believed to contain a mantle of windblown silt of varying depths as indicated by pinnate gullies (loessial silt). The western part contains numerous basins which are, to a large extent, surrounded by sharply rounded hills, some of which are crescent shaped. This, together with the light color tones and absence of surface drainage, suggests the presence of shallow sand on silt.

Detailed stereoscopic study of the lowland reveals a series of level surfaces or stages which are at different topographic locations. These are terraces and first and second bottoms of the flood plains. The parent materials in the flood plain are derived entirely from water-deposited materials. In some of the abandoned stream meanders there are indications that organic accumulations exist.

Grouping Landform Types and Designating Textures. Following a detailed study of all the pattern elements, the area was divided on a basis to topographic position. Figure 25 has been arranged to show as nearly as possible the correlation existing between the air-photo pattern, the map symbols, the landform division, and the materials expected.

The upland is divided into intermediate level areas marked U1 which contain some basins marked U0 (the combination is shown as U0-U1); rolling and mod-

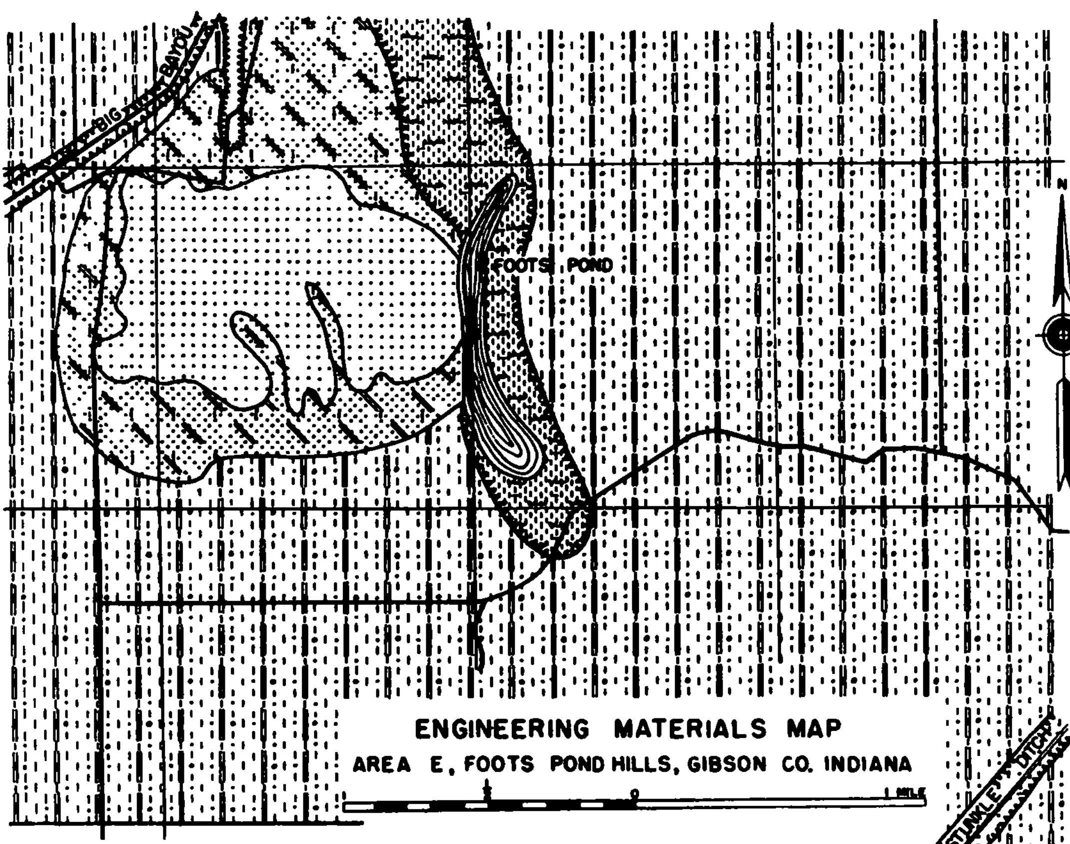

Figure 18. Engineering materials map of Area E, Foots Pond Hills, Gibson County, Indiana.

erately dissected areas marked U2, which cover the major portion of the area; and sharply rolling topography of the dunes marked U3; and steep slopes of the outward face of the knob marked U3. The uplands carry the basic parent material symbols for sandstone, symbol 10; shale, symbol 12; loessial silt, symbol 41; and windblown sand, symbol 39. These basic parent materials are obtained from the chart in Figure 31.

The lowland consists primarily of two major divisions, high bottoms marked HL and low bottoms marked LL. The appropriate parent material symbols 30 and 34 are indicated. In the low lowlands the lowest topographic situations appear as basins, usually of the abandoned stream-meander type, and these have been designated as LL0. The level areas of the first bottom are designated LL1. The basis for designation of this area, in addition to its flat topography, is the complete uniformity of color tones – an absence of scours or ridges associated with current activity. Rolling areas of the lowland are designated LL2, since they are marked with ridges which provide some local topographic differences. The second bottoms (HL) contain only two divisions – HL1 and HL2. The areas marked HL1 are level and unmarked with the usual indicators of current activity. The areas marked HL2 are marked with slight ridges left by fast-moving water which have added some local relief. The only terraces in the area are a series of dissected benches which adjoin the island proper. These are low terraces and, for the most part, fall into the LT1 class, since they are level and unmarked by current activity. Two minor terraces with rolling topography (LT2) occur on the southwestern and western portion of the island.

The appropriate soil-texture symbols are superimposed on the parent materials symbols. The symbols are obtained from the Purdue Soil Texture Chart (Fig. 31).

The results of the material survey has been incorporated into a materials map (Fig. 6). This, together with the air-photo of the Mumford Hills area and its landform overlay, presents the data on patterns, parent material, landform, topographic situation, and approximate texture ranges.

AGRICULTURAL SOIL MAP METHOD

The soils-mapping program of the U. S. Department of Agriculture in cooperation with agricultural experiment stations of the state universities provides the engineer with a very important source of information about the surface materials.

This soil-survey program provides basic data for various land-use programs of the counties. The soil-survey reports contain information pertaining to soils, crops, and general agriculture of areas being surveyed. As stated in one of the recent reports, St. Joseph County, Indiana, June 1950 (21), the soil surveys and maps present data designed to meet the needs of three groups of users: (1) farmers and others interested in specific parts of the area; (2) those interested in the area as a whole; and (3) students and teachers of soil science and related agricultural subjects. For those users in the first group valuable information is available concerning the soils and their estimated yields, productivity rating, and management. For the second group of users the soil-survey bulletin contains considerable information of a general nature which is applicable to many fields, since it discusses such factors as geography, physiography, relief, drainage, climate, water supply, vegetation, population, industry, transportation, markets, and cultural development and improvement. For those interested primarily in soil sciences and allied subjects information is available on morphology and genesis of soils.

Many years ago the engineer realized the importance of agricultural soils information for assisting in making soils and materials surveys. Michigan was the first highway department to use agricultural soil information for design purposes. A field manual containing engineering information about Michigan soils as mapped on the county agricultural maps was prepared and published in 1946 (17). Since that time many states have been developing information which should help translate the agricultural and pedologic terminology into engineering terminology. In general, the approach has been one of arranging or grouping agricultural soils into some logical classification based on one of the following:

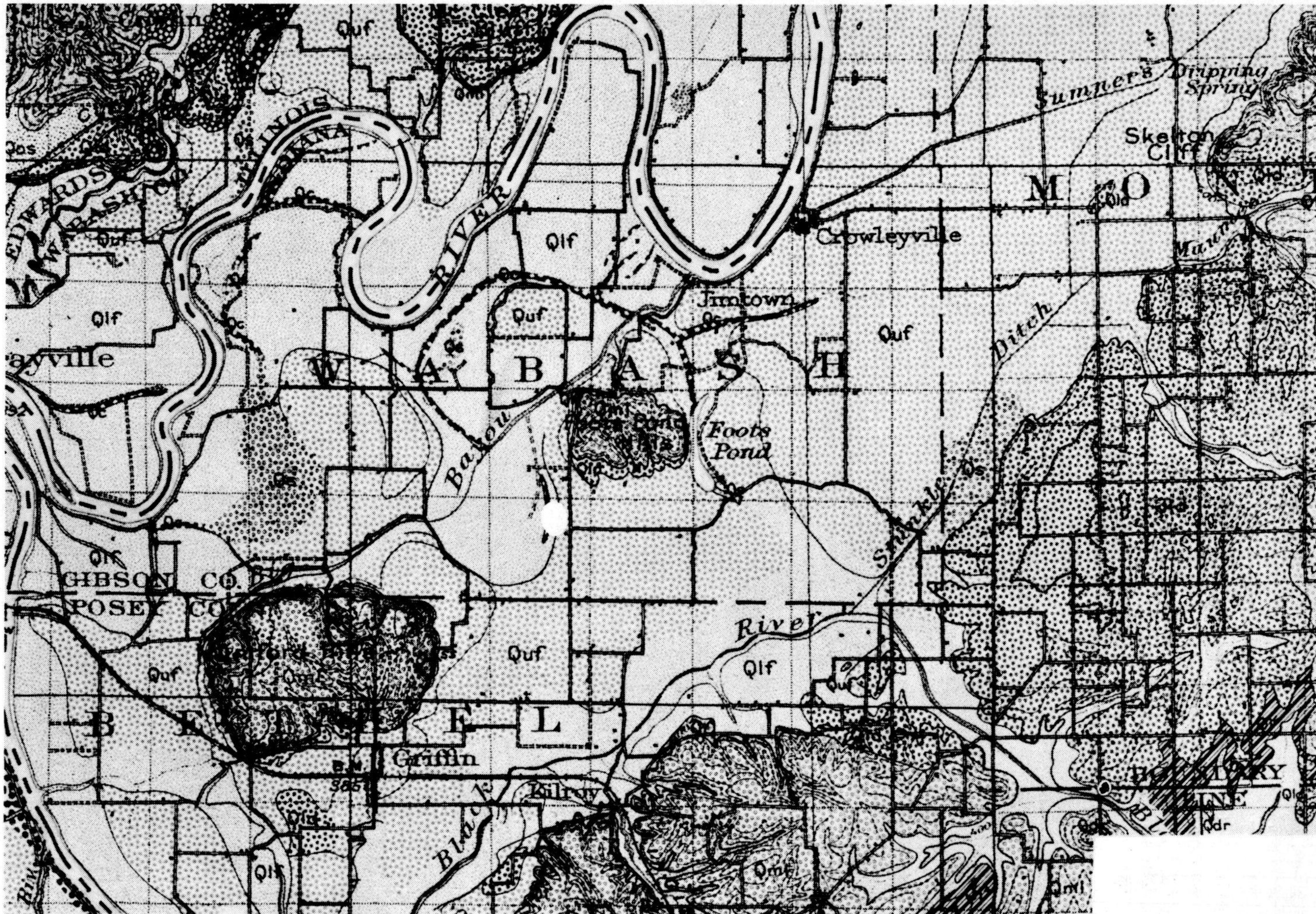

Figure 19. Geology map of example area.

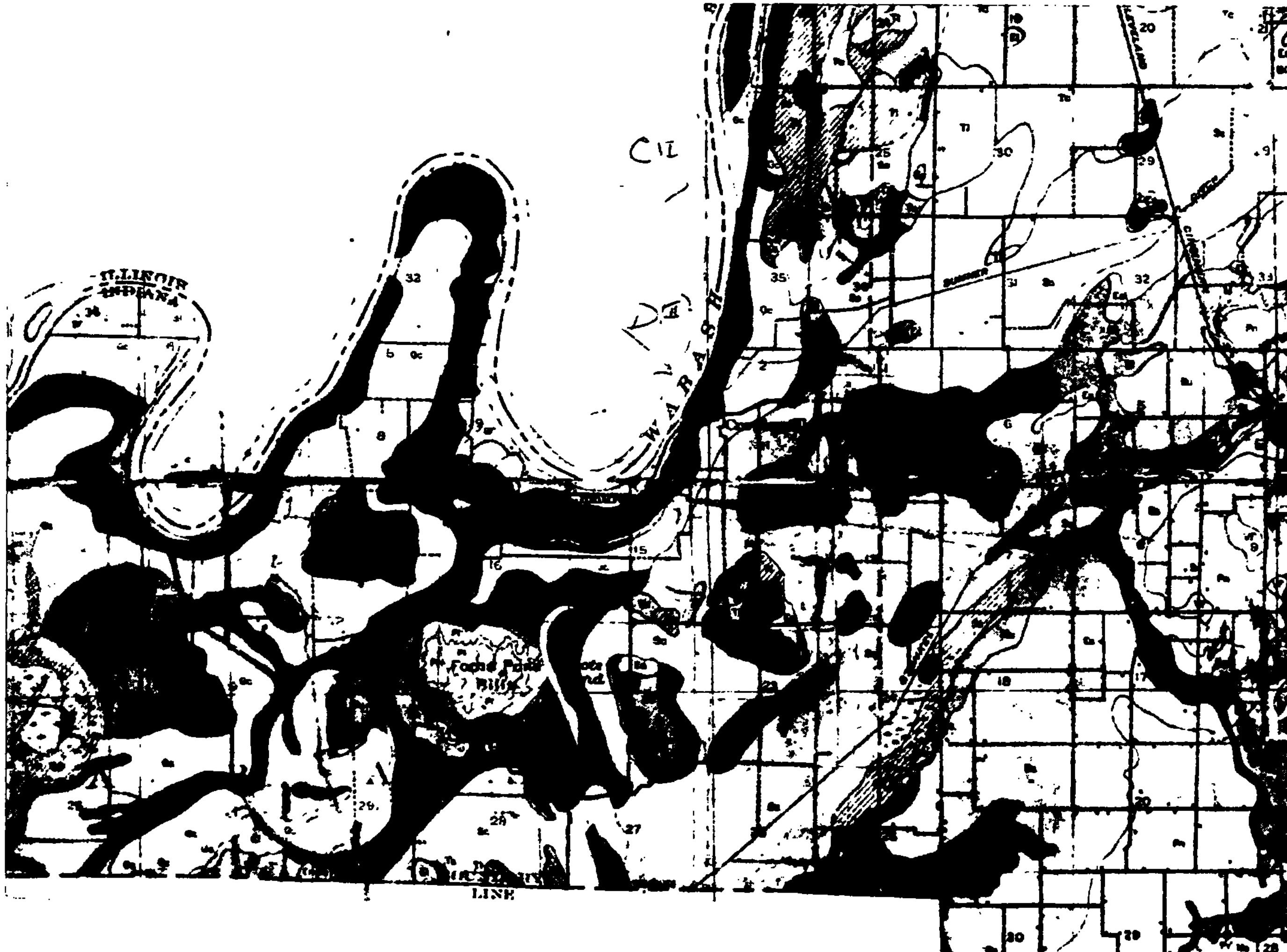

Figure 20. Agricultural-soils map of example areas.

parent material, drainage characteristics, landforms, or suitability for engineering use. The Committee on Surveying and Classifying Soils in Place for Engineering Purposes, under the direction of Frank Olmstead, chairman, prepared a bulletin for the Highway Research Board (8) which presented information concerning the status of agricultural soil surveys in each of the states. The reader is referred to this bulletin for detailed assistance concerning the use of agricultural soil-survey maps.

Principles of Materials Survey from Agricultural Maps

An understanding of the county agricultural soil map and text is necessary before the most efficient use can be achieved by the engineer for material surveys. In general, all bulletins are accompanied by a soil-survey map which is a graphic representation of the location and areal extent of surface soils—those responsible for the support of plant life. The amount of detail shown on the maps varies considerably. This variation in detail can perhaps be attributed largely to age of the report. The most recent surveys are quite detailed, since mapping procedures are not performed more efficiently today than in earlier times. In addition, more soils are recognized now than during the earlier part of the mapping program. In a similar manner, the amount of detail presented in the text varies both with the area and with the locale of the report. Use of the agricultural soil-survey literature and accompanying maps is contingent on an understanding of how the various soils are named and on an understanding of how the data are presented in the various reports.

Agricultural Soils Names. Agricultural soils are named after localities where they were first recognized. Soils are commonly thought of as occurring in families, or catenas. A catena is a group of soils derived from the same parent material and having common characteristics. It is composed of series, type, and phase. In this arrangement a series is a group having the same genetic horizons which are similar in their important characteristics and profile arrangement and having the same parent material. The series carry the catena-soil names such as Miami. Within a series there may be several types which are defined on the basis of texture. To the series name is added a textural term such as silty-clay Miami. This refers only to the upper part of the soil profile in agricultural mapping. Variations within a type are referred to as phase. The phase usually refers to unusual or outstanding features usually about slope, texture, erosion, or some topographic situation. An example might be silty-clay Miami, rolling phase.

To illustrate the above, an important Wisconsin Drift catena is Miami-Crosby-Brookston. These three are derived from Wisconsin till upland soils. They differ in profile characteristics and in topographic position. In general, Miami soils occur on steep slopes, are light in color, and have shallow profile development consisting of silty clay in the B horizon; Crosby soils occur on lesser slopes, are light in color, have a moderate profile development consisting of silty clay with some sand in the B horizon; and Brookston soils occur in the depressions, are dark in color, have an organic top soil, and a relatively thick B horizon of a plastic silty clay and clay.

Presentation of Soils Data. An understanding of the manner of presentation of agricultural-soils data in the various bulletins is important since methods change and the user must follow constantly the changes in order to obtain most efficient use of this method. A brief discussion of some of the methods of grouping soils in county soil-survey reports as presented by the Department of Agriculture follows.

In the soil-survey report on Bartholomew County, Indiana, of 1947, soils are grouped according to the major agricultural pursuit. The first major division is in two groups: (1) soils of the grain and livestock areas and (2) soils of the general farming areas. These are subdivided into soils of: (a) corn, wheat, and livestock, (b) special crops, (c) cash grain crops, (d) general farming, (e) hill farming, and (f) forestry. Under each of these latter subdivisions appear the actual soil names grouped according to whether they are well-drained, imperfectly drained, or poorly drained. This general approach is irrespective of parent material, texture, or topography.

Another type of soils grouping is that based on drainage as discussed in the Washington County, Indiana, soil bulletin of 1939. (23) In this instance, the soils are divided into "well-drained agricultural soils, imperfectly drained agricultural soils, and poorly drained agricultural soils" as primary groups. The individual soil names appear directly beneath these three headings. By such an arrangement it is possible for each group to contain soils of uplands, terraces, and flood plains. It is also possible to find one parent material contributing to each of the three groups.

The Vanderburg County, Indiana, soil-survey report of 1944 (22) groups soils on a landform-parent-material basis as the primary grouping. In this report major soil groups are: (1) deep silty soils developed over sandstones, siltstone, and shale; (2) shallow soils over sandstone, siltstone and shale; (3) deep silty soils of the upland; (4) soils developed from silts of the lakes plains; (5) soils developed from slackwater clays; (6) soils of the Ohio River Terraces; and (7) alluvial soils. These major groups are subdivided into soil catenas in which the series, types, and phases are shown. In this report a table presents additional information, such as parent material, topographic position, drainage, slope, and profile description.

The soils grouping of the Morgan County, Indiana, survey report of 1950 (19) is based on parent materials as the primary arrangement. The parent-material groups include soils developed from: (1) calcareous late Wisconsin drift; (2) calcareous early Wisconsin drift; (3) calcareous Illinoian drift; (4) sandstone, siltstone, and shale; (5) limestone; (6) deposits of wind-blown sand and silt of Wisconsin glacial age; (7) calcareous glaciofluvial deposits of Wisconsin age; (8) calcareous limestone silt and clay of Wisconsin age; (9) noncalcareous clay, silt and sand of stream terraces; (10) noncalcareous outwash, sand, silt, and gravel of Illinoian glacial age; and (11) calcareous slackwater silt and clay. As can be seen in Group 9, the parent material is modified by the expression "stream terraces."

An additional primary grouping is also shown for alluvial soils which is based on alkalinity or acidity. The three groups shown are (1) neutral to slightly alkaline alluvial soils from the region of Wisconsin drift, (2) slightly to medium acid alluvial soils from the Borden formation, Illinoian glacial drift, and limestone, and (3) strongly acid soils from the Borden formation and Illinoian glacial drift. Both major groups are divided further into catenas. Details of the profile and other characteristics are discussed in the text (19).

Another of the most-recent survey bulletins, St. Joseph County, Indiana, published in 1950 (21) recognizes five major divisions which are based on a landform grouping as follows: (1) soils of the uplands, (2) soils of the glaciofluvial outwash plains and terraces, (3) soils of the glacial outwash and lake deposits, (4) mineral soils of the flood plains, and (5) organic soils. Group 5 is a departure from the landform arrangement. The soil series within the landform groups are shown in tabular form in such an arrangement as to show major drainage, parent material, and position with respect to the great soil groups of the world (which in this instance are gray-brown podzolic and prairie soils, semiplanosols, Wiesenboden and half-bog soils, and bog soils). This is a convenient arrangement and easily used in development of an engineering key.

In some of the earlier reports a general soils description prefaced the detailed descriptions of the soil series. There was no attempt to grouping such as in the Porter County, Indiana, report of 1918. In this report (20) it is stated that: "The soils of the county have been identified as members of 23 series differing from each other in source of material and character and composition of the soil and subsoil." Such items as parent material, geology, and topography, are covered very generally in connection with individual series descriptions.

The text of all soil-survey manuals, particularly those published in the last 20 years, contains a good description on the various soils as to color, texture, drainage condition, and profile development. However, since the agricultural surveys are concerned primarily with that portion of the soil supporting plant growth, detailed

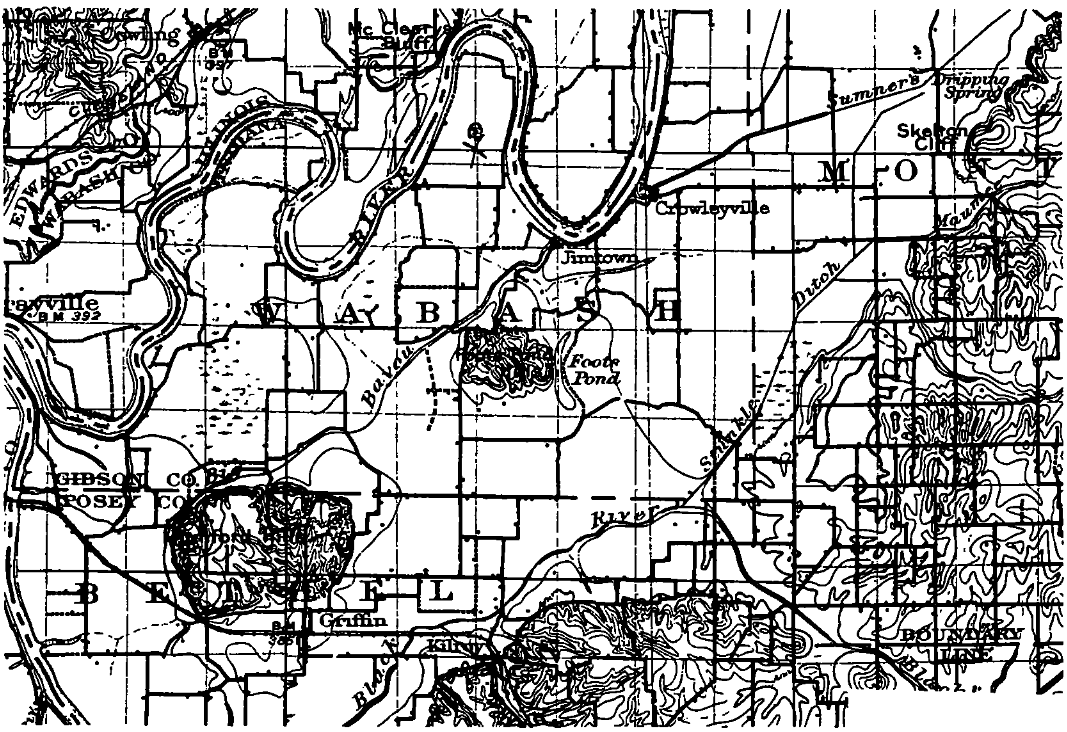

Figure 21. Topography map of example areas.

information is presented for the upper 3 to 4 ft., which is usually the portion encountered in the A and B horizons. Some description is given, in most instances, of the parent material. Some reports present mechanical analysis of samples.

Summary. In summary, the principles of materials evaluation from agricultural soil-survey maps are based on four major points which are basic and five minor points which are general and of an applied nature. The four basic points which the engineer must possess for optimum use are: (1) a working knowledge of the various agricultural systems of grouping soils for presentation both in text and map form; (2) an understanding of the pedologic concept of soil formation; (3) the ability to translate agricultural terminology into engineering terminology; and (4) an understanding of the engineering significance of the areal soils which is based on the catena arrangement.

The minor points which are of an applied nature include: (1) continuous field-sampling program for correlation of test data with agricultural-soil series; (2) correlation of pavement-preformance data with agricultural-soil series; (3) constant review of literature concerning agricultural soils; (4) constant use of the agricultural-soil maps in the field; and (5) recognition of the series names which are known to contain materials.

Techniques of Material Survey from Literature and Maps

The techniques to be followed in conducting a materials survey from agricultural literature and maps are based on the availability and amount of detail of engineering data about agricultural soils and on the background of the user. Access to a comprehensive key, which correlates agricultural soils names with engineering test data and other important features, is very useful. In such cases locating materials becomes a matter of recognizing the names of the agricultural soils which are known material sources and outlining them on an agricultural-soils map of the area under consideration. These areas should be field sampled, either by an examination of the soils in existing road cuts or by obtaining profile samples using a soil auger. Representative samples should be taken in several areas covered by the same soil symbol. It should be remembered, however, that there may be more variations in a soil series shown in an agricultural map due to slope, erosion, or textural differences than will be practical to recognize in connection with the engineering survey. If the key does not contain test data covering these variations or does not point out the engineering significance, then it will be necessary for the user to study the variations as described in the soil-survey bulletin before attempting a field sampling program.

Areas Already Mapped. In areas where agricultural-soils maps are available the procedure is shortened considerably. Material survey may be accomplished by grouping the soils types and phases of a series known to be predominantly granular. The areal extent is easily determined following such a grouping. Locations for field sampling can be accomplished in advance of field operations by studying the soil areas as indicated by such a grouping on the agricultural-soils map. In most soil surveys, the maps are of sufficient accuracy to eliminate most of the field work. Final delineation of soil boundaries may be located in many instances directly on the agricultural-soils map. Field data, when analyzed in the laboratory, will provide engineering characteristics and suitability for use in connection with highway or airports. The data from the laboratory can then be plotted and an engineering-materials map drawn.

Areas Unmapped. In areas where agricultural surveys are unavailable, information can be extrapolated from areas of known conditions where known conditions are similar, providing the user has cognizance of the pedologic concept of soils. It is necessary that the user make a field reconnaissance to establish parent materials and the topographic arrangement and to determine the landforms represented. In a rapid reconnaissance an examination of road cuts and landforms will provide information necessary to establish parent materials. This type survey will provide information for the preparation of preliminary material maps. Borders can be established on the landform basis for preliminary work. Following the preliminary map preparation a detailed sampling program should be initiated to provide qualitative and quantitative data about the material boundaries. Revision of borders can be accomplished by detailed sampling along the transition between landforms. Sampling in such an instance should be of the profile type in which samples for testing are taken of the various soil horizons and of the underlying parent material.

Keys for Use with Material Surveys Using Agricultural Soils Maps

There are several possible methods of developing keys for using agricultural-soil-survey information in connection with materials survey for engineering use. Basically, all keys are of a guide nature and are designed to assist in obtaining information. They may be elaborate and contain extreme detail, or they may be simple and merely serve as reference material.

Perhaps the easiest key and that easiest used by those not familiar with the pedologic concept is one which lists agricultural-soils names alphabetically. Accompanying each soils name is a technical description of the soil which includes physical test data of the horizons comprising the profile, drainage characteristics, and structure, as well as information concerning the parent material, topography, slope, cover, and any miscellaneous features which may be significant. Such a key becomes a legend or glossary for an agricultural soils map. The arrangement of the soils alphabetically is of no major concern, since the soil names are obtained from the map and the descriptions are obtained from the legend-glossary. The system developed by Michigan (17) is of this type. The series are listed alphabetically and accompanying information is tabulated. The table gives general information about characteristics, treatment, and resources. These groups are subdivided to permit presentation of information of greater detail. The key or soils table is accompanied by a series of detailed profile descriptions. In this series the profile of each soil is shown graphically and described in an accompanying text. Another important key, but somewhat more complicated, is that developed by North Carolina and illustrated in Bulletin 22 of the Highway Research Board (8). This key is so designed that it can be used in areas which are unmapped by extending information to analogous areas. This requires a knowledge of the pedologic concept and some knowledge of the basic geology of the area. The key is most effectively used in conjunction with a geologic map in areas not mapped by soil survey. The key is a diagrammatic presentation which correlates physiography, parent materials, drainage, profile development, and agricultural-soil-series names.

The key developed at Purdue is a diagrammatic presentation of the correlation between parent material, topographic arrangement and the agricultural soil series names. The key is supplemented by a detailed description of soils profiles listed alphabetically. This key is discussed in Purdue University Bulletin 87 (6). A copy of this correlation chart is included as Figure 26. A brief description of this key follows.

Soils derived from the same parent material form the major groups. Subdivisions are on the basis of landform and slope. Agricultural soil names appear in the proper slope position in the diagram. The catenas, consisting of the various series, extend horizontally across the table. There are four slope arrangements which are 16 to 55 percent, 4 to 16 percent, 4 to 0 percent and depressions. The fifth column is for alluvial and special types.

Limitations of the Use of Agricultural Soil Survey Data

This survey method is an excellent one for obtaining preliminary information in areas where detailed agricultural soils information is available. It is limited to those areas possessing good maps. As pointed out previously, many of the early soil surveys were not accomplished in sufficient detail to warrant use in detailed engineering surveys. This limitation results because earlier soil names included many variations which, even though not recognized at that time, are important today. Another limiting factor is the ever-increasing number of soil names which are being added as the agricultural program recognizes and maps to greater detail than in the past. This requires more work on the part of the engineer in conducting a sampling and testing program and in translating the agricultural information into engineering terminology. However, this added detail is to the benefit of the program if properly correlated. The method may be limited by the extent of the engineering testing program which has been conducted to provide test data for the various agricultural-series types and phases.

Survey procedures learned in one state or one area can be followed and adapted to other areas; however, a change in parent material and climate is accompanied by a change in the agricultural name. This necessitates the development of new keys. This becomes a limiting factor for surveys which cross state lines.

Example of Material Survey from Agricultural Soil Survey

The soil survey of Gibson County was published in 1926 (18). Figure 7 shows the county soil map. In the report the soils of Gibson County are arranged in several different methods. One grouping is on the basis of profile development, one grouping is on the basis of physiographic arrangement, and another is on the basis of parent materials. These various major arrangements assisted materially in the preparation of the Agricultural Soils Map Key (Fig. 27). From all soil-survey reports studied, detailed descriptions were obtained of each type, phase, and series and are presented here as a key. These proved very helpful in designating the proper topographic position and the proper materials symbols to be used on the materials map (Fig. 9). A landform-soils-series guide as used in the Purdue studies (6) was also helpful in developing the key (Fig. 26).

Soil Groups in the Agricultural Text. The soils arranged on the basis of profile

Figure 22. Aerial photographs of example areas.

development are subdivided into three groups (18). Group 1 includes soils with normal soil-profile development and which are well-drained, such as Bainbridge, Buckner, Elk, Princeton, Ownesville, Haubstadt, Gibson, Tilsit. Group 1 also includes soils situated on flat areas but having abnormal profiles and still retaining good drainage characteristics. These are Vigo, Lickdale, McGary, Robertsville, Robertson, and Calhoun. Group 2 soils are those poorly drained soils having a poorly developed profile. Included in this group are Tyler, Montgomery, and Lyles. Group 3 soils contain the recent alluvial deposits and include Lintonia, Genessee, Huntington, Holly, Waverly, and Sharkey.

The soils of the county are also arranged according to their proper physiographic headings of upland, terrace, and bottom. This grouping is as follows: Upland — Princeton, Owensville, Gibson, Vigo, and Lickdale. Terrace — Buckner, Elk, Bainbridge, Lintonia, Robertsville, Haubstadt, Robinson, McGary, Calhoun, Tyler, Montgomery, and Lyles. Bottoms — Genessee, Huntington, Holly, Waverly, and Sharkey.

The parent material grouping of soils is described on page 1173 of the soil survey. This arrangement is as follows: Residual — Tilsit and Lickdale; Glacial — Gibson and Vigo; Loessial — Princeton and Owensville; and Waterlaid — Bainbridge, Buckner, Elk, McGary, Robertsville, Haubstadt, Calhoun, Tyler, Montgomery, Lyle, Lintonia, Huntington, Genessee, Holly, Waverly, and Sharkey.

Soils Grouped for Materials Use. The key which has been prepared for use in this portion of the survey is Figure 27. It is an arrangement of soils into upland, terrace, and flood plain. The flood plain has been subdivided into high lowland (HL) and low lowland (LL). It is to be noted that the names Miami and Yazoo appear on the key. These names were taken from the soil survey of Posey County, since part of the area under study falls within that county. Since these names are not shown on the Gibson County map they are not discussed here.

In addition to showing the soil-series names in their proper arrangement physiographically the map shows appropriate parent material. Map symbols for the engineering-soil-texture-landform-parent-material arrangement are taken from Figure 31.

The results of the engineering evaluation of Sumner Ditch area are shown in Figure 9. This, together with the agricultural soils map (Fig. 8) of the Sumner Ditch area contain all of the data obtained for survey of the materials accumulated.

GEOLOGY-MAP METHOD

The mapping program undertaken by the U.S. Department of Interior through its Geological Survey and the mapping programs undertaken by the various state geological surveys provide the engineer with a valuable source of information which can be utilized in material surveys. The purpose of these surveys is to make available to the public information about the lands so that the natural resources that should be profitably exploited could be guided by a body of facts assembled by a competent and impartial agency (16).

In addition to literature prepared by state and federal mapping agencies, the engineer can often obtain detailed geologic data published in technical journals which are reports of research or exploration. Among these are Journal of Geology, American Journal of Science (14), Journal of Geomorphology, Geographical Review, and bulletins of the Geological Society of America (15).

Principles of Soil Evaluation from Geology Maps

The interpretation of geology maps to establish general areal soils data is dependent upon two factors: first, the knowledge and experience of the interpreter, and second, the quantitative and qualitative detail of the original map. Within certain limitations the engineering interpreter with a good knowledge of historical geology and a concept of physiography can make an excellent and reliable survey with a given set of areal geology maps. Furthermore, with a given set of geological maps of both stratigraphic and surface geology the interpreter can make a materials map which will be as accurate as the literature and map data employed.

Preliminary Survey. There are two principal steps to be taken in order to make a materials survey from a geological map and geological literature. The first of these is to assemble and study the literature and maps available concerning the area to be surveyed. These data enable the engineering interpreter to formulate a perspective as to the physiography and general materials to be expected in the vicinity. The types of literature that should be studied include geological atlas, geologic folios, quadrangles, bulletins, papers, survey reports, and professional papers. Usually a topographic map is available of every area that has a surficial geology map. This type map is also helpful as a supplement to the geology map. Water-supply papers and ground-water data published by the U. S. Geological Survey furnish excellent sources of data to use in preparing the material survey. The Lexicon of Geologic Terms and a hard-rock-and-surface-geology dictionary of some type should be handy when studying these data.

It is important that the user of such data understand the manner in which the data are presented in the various types of publications. Some discussion of this topic is covered more thoroughly elsewhere (12). A geology map is one which represents, by means of symbols and an appropriate legend, the distribution of soil and rock masses of the surface of the land and the stratigraphy underlying the surface of the land. On recent maps the amount of detail shown on a map depends upon the map scale. The surface geology map shows the surface forms. The forms that are included in the make up of the earth's surface are the valleys, uplands, terraces, beaches, and mountains. The areal geology map records these features along with the general materials that constitute the forms. The legend that accompanies an areal geology map usually represents both the landform and the materials contained therein. There are other types of geology maps which may be of use in any material survey. Among these are the economic geology map and the structure-section sheet. The former represents the distribution of minerals and rocks, showing their relation to the topographic features and to geologic formations. The structure-section map shows the arrangement of rocks in the earth's structure. The stratigraphy is represented in the form of groups of rocks according to the geologic time table. The distribution of the rocks according to the age in which the sediments were correlated are indicated. The legend on these types of maps represents the age and type of material found below the earth's surface conformably or unconformably resting layer upon layer. Each group of rocks is described briefly in the legend usually found in an appendix accompanying the map or folio.

Techniques of Material Surveys from Geology Maps

Literature and Map Survey. All of the data which can be located concerning an area should be assembled and studied before use of maps is made. The more detailed this survey is made the more reliable the resulting materials survey will be. There is a wealth of geological data available in the folios for some areas in the United States. Gibson County, Indiana, has been surveyed by various geological survey parties. The best source of geological data has been found in the geological atlas or folio. The Patoka (13) and Ditney folios (7), each cover portions of Gibson County. The western section of the county has been surveyed and the areal geology reported in the Patoka Folio. The Indiana Handbook of Geology provides good information also (11).

In order to obtain the required data from the geology maps available a perspective should be formulated. The perspective consists of a concept of the general physiography and the surface materials to be expected. This study determines if the location can be classed as mountains, plateaus, upland, or lowland. Once the physiography is known local landforms can then be determined. This includes determining whether the locality is terrace, flood plain, upland, or lake-bed. The next step is to determine how these forms occurred. One should determine that the area either has been glaciated, modified by aeolian or alluvial deposits, vial, or surface deposits are derived from sedimentary, metamorphic, or igneous residual materials. When the physiography, landform, origin, and parent material are known, then the perspective of the area is enhanced and the survey is simplified to a large extent. The next step is to study available details of the various landforms.

Geology-Map Interpretation. The best map to use in the materials survey is an up-to-date, areal-geology map of a scale of 1:125,000 or larger. This map shows the distribution of the older subaqueous deposits as well as the younger more recent deposits. The map legend usually indicates the forms and layering system of all deposits within the area. The older forms will be on the bottom of the legend column and the most recent deposits appear at the top. In general, four major material-landform patterns exist, namely: residual, aeolian, glacial, and alluvial. To determine from the map the landform of a locality with a distribution of residual materials is difficult. This study is always supplemented with a study of the literature.

Some landforms, such as a few of the aeolian, glacial, and alluvial forms, usually are indicated in the legend. Primarily these latter types are of more recent origin and, in many cases, cover residual types. In such cases the residual type is usually modified. Details of modification may not be apparent from the legend; hence, further study of the literature may be necessary.

Once the landform origin has been determined, the materials listed within these types should be classified. This classification is best defined on a landform basis. The various landforms that may be local within a river valley area are flood plain, lake plain, terrace, or upland. Within a glaciated region there may be outwash plains, flood plains, lacustrine plains, terraces, eskers, kames, till plains, uplands, and others. Within an aeolian region there may be any of the above but covered over by wind-blown deposits. Within residual landform types there may be all of the above listed types and mountains or plateaus may even be underlying the types indicated. The materials within each landform class are then listed. These are interpreted directly from the legend.

Preliminary Materials Map. A preliminary materials map can be made based on the landform-materials classification system outlined in the previous paragraph. With the new legend a base map of the given area is prepared. Each landform is delineated according to types designated, then these boundaries are subdivided on a general material basis.

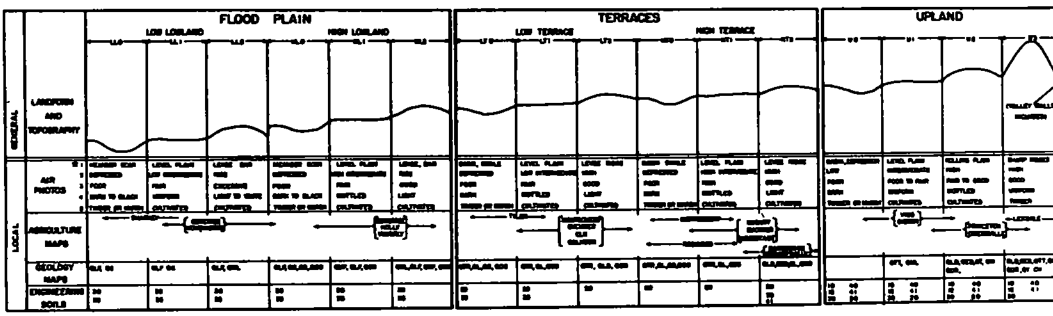

Figure 23. Master key for material survey.

The preliminary map is taken to the field for checking. Each landform type is inspected. Highway cuts and cut-banks along rivers are observed to simplify field work. Holes are augered and samples procured for laboratory analysis. The depth to which samples should be taken is determined by the use to which the materials are to be put and by the thickness of profile development.

The preliminary map eliminates a considerable amount of field work. The field investigation may then be confined to confirming the existence of the predetermined gravel or rock deposits. Once the field check and the soil laboratory analysis has been made a final materials map may be prepared. This map will show the correct delineation of materials boundaries that may be encountered in any given area within each landform.

Keys for Use with Material Surveys

In general, the key that should be employed with geological literature is one which tends to classify and determine the boundary conditions of given data. The key for use in this paper is one based upon the landform, topographic expression, or relief within the given landform, and the general materials that accompany the landform. This key (Fig. 28) is made up from the data acquired from the literature and map survey. The key is a supplement to the map legend in Figure 31. Quite often map space for scale used is insufficient. Also, too much detail on a given map tends to destroy its usefulness. Therefore, the key is a necessary adjunct to the understanding of the materials map. In general, the key is a qualitative-analysis chart. An application of the use of this key is given in the example.

Limitations of the Method

Availability of and Amount of Detail on Maps. The availability of geologic maps is a limitation to the use of this method. For example, there are areas in the United States which have not been surveyed. Obviously one could not use the method without maps or data for a given area. Some maps are very general, particularly earlier ones, and do not show sufficient detail to establish the surface materials of an area. For example, the map of the structural geology of Indiana shows only the hard-rock stratigraphy. Much of Indiana is overlain by glacial deposits which have changed the original surface features. Here is a limitation to the use of stratigraphic or structural geology maps. Likewise, many geological maps are of reconnaissance nature and very general. The detail required for survey of specific areas can be accomplished only with supplementary data to the reconnaissance.

Accuracy of Qualitative Information. The qualitative data that can be obtained from geologic maps and geologic literature is usually excellent. It is necessarily of a descriptive nature and must be supplemented by field data. However, the areal extent of surface deposits can be determined and evaluated from these data. Many spot checks can be made in the field to evaluate the depths of the deposits of representative areas. These data then can be extended to geologically similar areas.

Example of Geology-Map Method

Study of Data for an Overall Perspective. The example given in this section is known as Area D, Stunkle Ditch. Physiographically, it is located in Gibson County, Indiana, in a river valley which is within the Wabash lowland of the Till Plains Section of the Central Lowland Province of the Interior Plains Physiographic Division of the United States (9, 10). Figure 10 is a copy of the geology map of Gibson County (13). The area is in a glaciated region and within the specific area surveyed the flood plain is that associated with a mature stream valley which is believed to have been the result of glacial meltwaters occurring during the Wisconsin Age. The valley-fill material is reported to consist of sand and gravel overlain by sand or silt. Some features of the Illinoian Drift Age appear in this valley and in some cases dominate the surface pattern. In locations where the Illinoian Drift is deep and is encountered as the surface material (in the southwestern section of Gibson County) the surface imparted by the ice is flat and the major stream channels are dendritic in pattern form.

There are loessial features to be encountered in this area; they are reported overlying many parts of the valley. The present flood plain is the result of seasonal floods and lateral erosion with abandoned channels filled to the present established level. There are also some terrace remnants reported to have been formed by the old Maumee River. These border the uplands on the eastern border of the flood plain. Underlying the features of the flood plain, loess, and terrace remnants are glacial drift deposits of Illinoian Age and bedrock features related to sandstone, shale, and limestone of the upper Pennsylvanian Age. Outcrops have been correlated in various parts of the Wabash Lowland. These bedrock features do not outcrop except in the Mumford Hills (see Area F of this survey).

It is seen then that the perspective gives the picture of a landscape associated with a wide river valley consisting of upland islands of bedrock, overlain by loessial deposits; an alluvial flood plain marked by silt-filled, abandoned-stream channels, and oxbows, and bordered by old terrace remnants also overlain by loessial deposits. Hence, in general, the materials that can be expected in this part of Gibson County are silt, sand, and gravel. The section that follows is written in order that the reader may obtain a procedure for determining details of how to find materials using an areal geology map.

Geology-Map-Interpretation Procedures. The geological map (see Figs. 10 and 11) was studied and analyzed with the landform perspective in mind. It was found that the Stunkel Ditch Area on the geology map consisted of three general landform classes, namely: upland, terrace, and flood plain. The flood plain was subdivided into high lowland and low lowland, principally on basis of seasonal flood conditions. It is believed the high lowland is less subject to seasonal flooding than the low lowland. The materials as classified on the geology map are on basis of origin and formation. Some of the data listed on the map is self-explanatory. However, the description of the Wabash Formation had to be supplemented with data obtained in the Lexicon of Geologic Names of the United States (29). With the three landform classes in mind, all the materials of the area were classified in their respective landform position. A topographic map was overprinted on the geology map. This step assisted in organizing the arrangement of classes of materials into their landform positions. The landform classes were in turn subdivided into topographic (relative relief) position. The description in the legend also assisted the classification of the available materials.

The following grouping of geologic classes of symbols forms a simple arrangement of the materials available for engineering construction. Grouping by landform and topographic position simplifies the field work of an engineer and enables him to determine what materials he has available and within what topographic position these materials occur. The upland-landform arrangement of materials has several types of materials. The Stunkle Ditch Area used to illustrate the method does not have an upland form. However, there are two landforms, namely: terrace and flood plain. The flood plain has both high and low lowland situations. The terrace landform has been mapped as coarse sands over all the area. The later dune sand is applied to material of aeolian origin in part but consisting of particle sizes larger than that which can be transported by wind. The high-lowland landform has been mapped on the basis of the upper flood plain class of materials and the swamp deposit class. This upper flood plain refers to materials deposited during the Quaternary Age. It consists of silts and sands in a stratified system. In places, silt overburden is thick. The swamp deposits term applies to materials found in depressed situations. It usually consists of muck and peat and on geologic maps is referred to as vegetable mold. The low lowland of the flood plain has only one topographic situation. According to the geologic map the lower flood-plain sediments refer to materials of Quaternary origin. These sediments are found in flat areas subject to seasonal floods and are silts and sands.

In the upland the topographic situations U-1 and U-2 are shown as Qtt and Qt respectively. According to the lexicon, Illinoian Drift is applied to the third drift of Labrado and Patrician parts of Laurentian ice sheet. It consists of thick and thin deposits of till consisting of a heterogeneous mixture of silt, sand, and gravel with clay. If the Illinoian drift is surface material, silt is the dominant grain size in the upper layers, whereas silty clay predominates in the subsoil, and a mixture of sand, gravel, silt, and clay in the lower layers (29). The topographic position U-3 is designated as marl-loess by the geology map (13). According to the lexicon the marl-loess term is applied to material of aeolian origin, calcareous in character and uniform in grain size. It is the formation that overlies much of the Wabash Lowland in dune or ridge forms. The grain size is most generally silt. However, it ranges from clay-like to fine-sand materials. The Wabash Formation, where it occurred, was designated as U0 on the geologic map; thick Illinoian drift was delineated as U-2; thin Illinoian drift was delineated as U2; and loess where it was encountered was delineated as U-3. The latter was usually the highest in topographic position and the former the lower member of the formation since outcrops of it were found in gullies and lower slopes only. The symbol U0 is shown as Wabash formation, and designated as CW by the geologist (13). It consists of thick sandstones within thin shales, limestones (Pennsylvanian Age), and coal beds in the lower half with the upper half containing alternating sandstones and shales to a thickness of 180 feet (29). According to the lexicon, the formation is overlain by Tertiary Age alluvial deposits.

In the terrace three separate and distinct topographic positions were found. These were delineated as depressions, flat areas, and ridge areas. The depression form is delineated as LT0; the flat-topographic situation as LT1; and the ridge class of materials as LT2. The topographic position LT0 is designated as swamp deposits by the geologist (13). According to the Lexicon swamp deposits are depressed situations, poorly drained and having muck and peat or vegetable organic materials (29). The topographic position LT1 is designated as marl-loess by the geologist. It consists of stratified silts and fine sands in a flat topographic situation. The topographic position LT2 is designated as later dune sands by the geologist. The materials are delineated in this topographic situation as coarse sands (see Figs. 11 and 28).

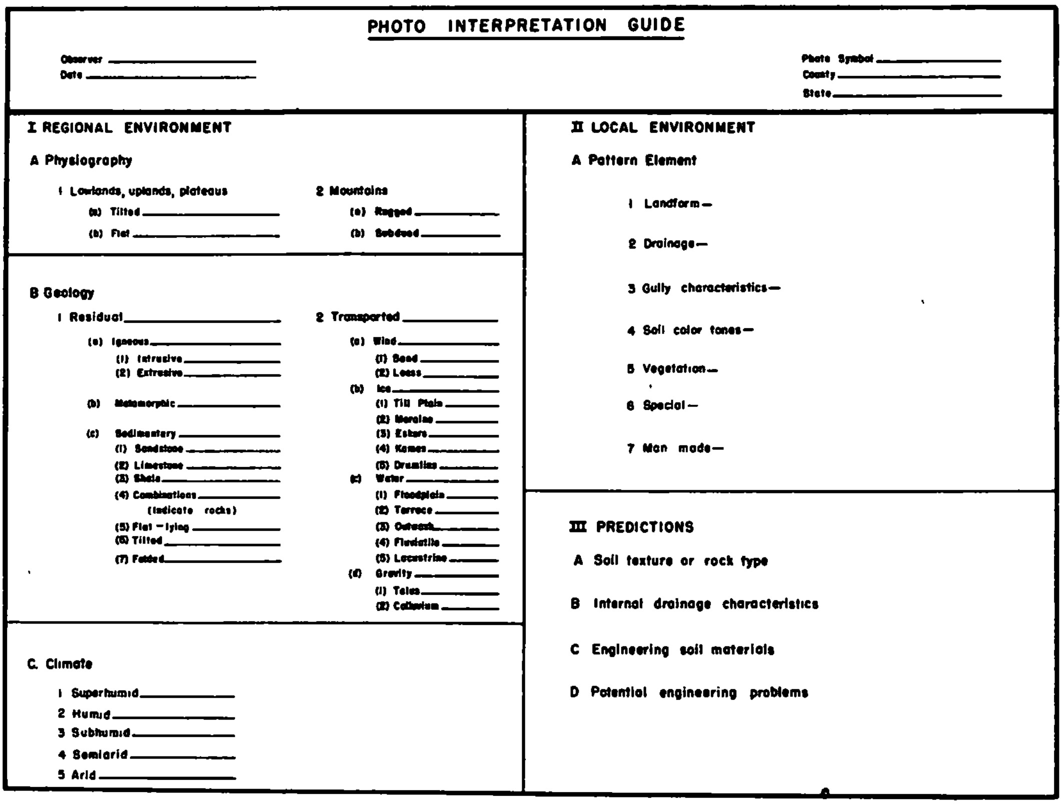
PHOTO INTERPRETATION GUIDE

Observer ____
Date ____

Photo Symbol ____
County ____
State ____

I REGIONAL ENVIRONMENT

A Physiography

1 Lowlands, uplands, plateaus
(a) Tilted ____
(b) Flat ____

2 Mountains
(a) Rugged ____
(b) Subdued ____

B Geology

1 Residual ____
(a) Igneous ____
(1) Intrusive ____
(2) Extrusive ____
(b) Metamorphic ____
(c) Sedimentary ____
(1) Sandstone ____
(2) Limestone ____
(3) Shale ____
(4) Combinations ____ (indicate rocks)
(5) Flat-lying ____
(6) Tilted ____
(7) Folded ____

2 Transported ____
(a) Wind ____
(1) Sand ____
(2) Loess ____
(b) Ice ____
(1) Till Plain ____
(2) Moraine ____
(3) Eskers ____
(4) Kames ____
(5) Drumlins ____
(c) Water ____
(1) Floodplain ____
(2) Terrace ____
(3) Outwash ____
(4) Fluviatile ____
(5) Lacustrine ____
(d) Gravity ____
(1) Talus ____
(2) Colluvium ____

C. Climate

1 Superhumid ____
2 Humid ____
3 Subhumid ____
4 Semiarid ____
5 Arid ____

II LOCAL ENVIRONMENT

A Pattern Element

1 Landform—
2 Drainage—
3 Gully characteristics—
4 Soil color tones—
5 Vegetation—
6 Special—
7 Man made—

III PREDICTIONS

A Soil texture or rock type
B Internal drainage characteristics
C Engineering soil materials
D Potential engineering problems

Figure 24. Airphoto-interpretation guide.

The flood plain is divided into high lowland and low lowland areas. The high lowland of the flood plain consists of several geological divisions of materials. The upper-flood-plain deposits shown as Quf are mapped as HL2. These sediments consist of silts and sands in a high topographic position. The area is rarely overflowed by seasonal flooding. The abandoned channel deposits (Qc), are mapped as HL1. The materials found in this flat topographic position are mapped as fine silts and clay with organic matter by the geologist (13). The low-land position of the flood plain has similar materials to those found in the high lowland according to the geology map. These are mapped as lower flood plain, Qef, and abandoned channel, Qc. Some places swamp deposits have been indicated; these have been described already (13). The geologist indicates lower-flood-plain sediments as materials having been deposited during Quaternary Age. They consist of silts and sands in flat and depressed areas. Where found in a depression the silt overburden is thick and highly organic.

Abandoned channels are sediments of filled-in old oxbows, cut-offs, or depressions formed by the river current at former water stages. The materials found in these situations are usually fine silts and clays. Where the topographic position is low, they may be highly organic. Under high lowland of the flood plain are found such geologic classes as upper flood plain, abandoned channel, and swamp deposits. These are designated as HL2, HL1, and HL0 respectively according to where the symbol occurs topographically. The low lowland classes of the flood plain include the geology symbols for lower flood plain, abandoned channel, and swamp deposits. Each of these in turn is designated as LL2, LL1, and LL0 according to its topographic position.

Summary of Materials Based on Landform. In the Stunkel Ditch Area, a study of the areal geology map and the lexicon of geological terms revealed that the landforms and their origin are flood plain and dune or terrace deposits of silt and sands, and coarse sands respectively. Some swamp deposits were noted but were classed as insignificant sources of useful materials. The engineering-materials map has been prepared on basis of landform and topographic position as well as materials within these topographic or relief situations. Each class of surface materials was delineated within U, T, and L map units based on grain-size distribution as indicated in Figure 31.

TOPOGRAPHIC-MAP METHOD

Topographic maps are among the oldest of engineering maps. They are prepared in a variety of ways: Topography can be obtained by merely sketching, by detailed field survey procedures with instruments, or by the use of photogrammetric methods from airphotos. They can be extremely accurate and rigidly controlled or they can be poorly done with little or no control. A topography map may convey differences of elevation and nothing else. An excellent topographic map conveys more than topography. It pictures the "expression of the surface" by the arrangement of contours representative of the earth's surface. An accurately prepared topographic map reflects patterns which have elements. The patterns can be broken into elements which can be recognized easily. These collective features can be analyzed and the pattern interpreted for the purpose of preparing a material survey.

The primary sources of topographic

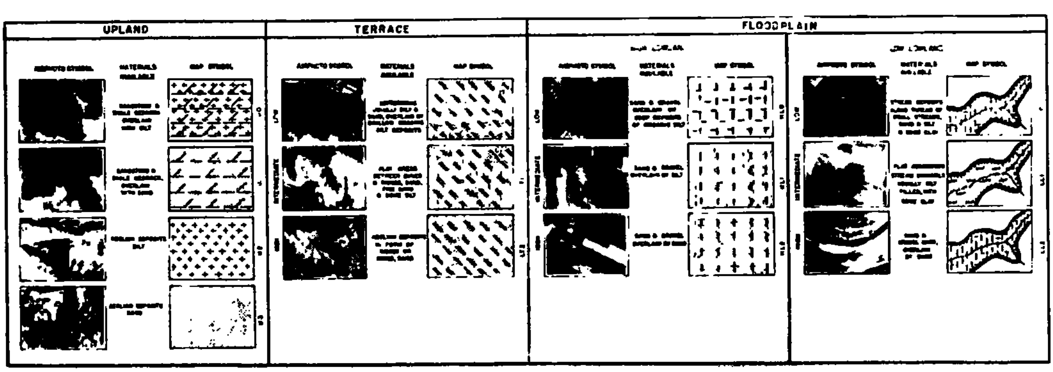

Figure 25. Airphoto-interpretation key.

— PEDOLOGICAL SOILS AND THEIR RELATIONSHIP TO PARENT MATERIALS AND TOPOGRAPHY

PARENT MATERIAL: AREA	PARENT MATERIAL: CLASS	NATURE OF PROFILE	SLOPE CLASSIFICATION: S (55%–16%)	L (16%–4%)	O (4%–0%)	P (DEPRESSIONS)	E (RECENT ALLUVIAL SOILS AND SPECIALS)
WISCONSIN DRIFT	I	SILTY—CLAYS	*MIAMI*, HENNEPIN	*MIAMI*, PARR, *RUSSELL*, CARRINGTON, GALENA, ST. CLAIR †	CORWIN, DANA, *CROSBY*, *CONOVER*, *FINCASTLE*, TORONTO, NAPPANEE †, BETHEL, ODELL, DELMAR, HELT	*BROOKSTON*, CLYDE, COPE, PAULDING †	*GENESEE*, EEL, WAYLAND; MUCKS, ETC: CARLISLE, EDWARDS, HOUGHTON, KERSTON, WALLKILL, PEAT, MARL
WISCONSIN DRIFT	II	POROUS SUBSTRATA (SANDS AND GRAVELS)	*BELLEFONTAINE*, RODMAN	*BELLEFONTAINE*	DELPHI, HARTMAN, WAUKESHA, MILL CREEK, WEA, *FOX*, *WARSAW*, DOOR, TRACY, HOMER, BRONSON	*ABINGTON*, BRADY, GILFORD, WESTLAND, *MAUMEE*	
WISCONSIN DRIFT	III	SANDS	*PLAINFIELD*, BRIDGEMAN	*PLAINFIELD*, COLOMA, HILLSDALE, METEA **, ALLENDALE **	*PLAINFIELD*, BUCKNER, METEA **, ALLENDALE **, CALUMET, OSHTEMO, AUBEENAUBEE **, BERRIEN	*NEWTON*, *MAUMEE*, DILLON, DE MOTTE	GRIFFIN
WISCONSIN DRIFT	IV	SHALLOW SOILS ON BEDROCK	FARMINGTON, LORDSTOWN	FARMINGTON, LORDSTOWN, MILTON	MILTON, HARTMAN, RANDOLPH	MILLSDALE	
LACUSTRINE	V	DERIVED FROM WISCONSIN DRIFT		LUCAS	LUCAS, *FULTON*	*TOLEDO*, BONO	
LACUSTRINE	VI	DERIVED FROM ILLINOIAN DRIFT (SILT AND SILTY-CLAY)	BAINBRIDGE	BAINBRIDGE, OTWELL, WHEELING	HAUBSTADT, ELKINSVILLE, WHEELING, MARKLAND, ELK, BUCKNER **, PEKIN, SCIOTOVILLE, MCGARY, TYLER, BARTLE, WEINBACH, ROBERTSVILLE, CALHOUN, DUBOIS, ROBINSON, PEOGA, GINAT	HARBISON, LYLES, ZIPP, MONTGOMERY, SHARKEY, VINCENNES	HUNTINGTON, LINDSIDE, POPE, PHILO, ATKINS, STENDAL
ILLINOIAN TILL	VII	SILTS AND SILTY—CLAYS	PARKE *	*CINCINNATI*, GIBSON, PARKE *	*GIBSON*, ROSSMOYNE, PARKE *, ROSSMOYNE, AVONBURG, *VIGO*, CORY, AVONBURG, *CLERMONT*, LOY	BLANCHESTER	GENESEE, EEL
ILLINOIAN TILL	VIII	SHALLOW SOILS ON BEDROCK		*GRAYFORD*, *JENNINGS*	CANA, WHITCOMB		
WINDBLOWN AND LOESS-LIKE	IX	SANDS		*PRINCETON*, OAKTOWN	ELKINSVILLE		STASER, INGLEFIELD, MCCUTCHAN
WINDBLOWN AND LOESS-LIKE	X	SILTS	PIKE	PIKE, *PRINCETON*, ALFORD, HOSMER	PIKE, IONA, MUREN, KASSON, OWENSVILLE, AYRSHIRE, IVA, COE		
RESIDUAL	XI	LIMESTONES	CORYDON	*ORLEANS*, *FREDERICK*, HAGERSTOWN, BLOOMINGTON	*BEDFORD*, LAWRENCE, GUTHRIE	BURGIN	HUNTINGTON
RESIDUAL	XII	STRATIFIED LIMESTONES AND SHALES	*FAIRMOUNT*	*SWITZERLAND*	ALLENSVILLE, LAWRENCE, GUTHRIE		
RESIDUAL	XIII	SANDSTONES AND SHALES	*MUSKINGUM*	*ZANESVILLE*, WELLSTON	TILSIT, LICKDALE		STENDAL

† LESS GRANULAR PARENT MATERIAL THAN OTHER SOILS IN BOX ** SHALLOW SAND ON SILTY-CLAY *** SAND * SAND SUBSTRATUM *IMPORTANT SOILS*

NOTE—SEE INDIVIDUAL PLATES FOR DETAILED SOIL PROFILES

Figure 26. Landform-soil series guide.

maps are the reports of the U. S. Geological Survey, the various state geological surveys and mapping agencies, and the Corps of Engineers. Several of these agencies prepared maps which were used in this survey (7, 13).

Principles of Material Surveys from Topographic Maps

There are three principles, namely: (1) the topography map records man's impression of the surface configurations of the earth, since these surface features are the results of natural processes in the development of surface materials; (2) the earth's surface materials can be grouped together to form a pattern which is composed of recognizable features; (3) the surface- and subsurface-material patterns and their representative topographic contour patterns are repetitive in nature.

An evaluation of the earth's surface materials from a topography map is based upon the principles that the topography, as recorded on the map, is representative of the natural and physical environment influenced by certain geomorphic processes. Such processes as orogeny, diastrophism, and earthquakes have distorted the surface to form the major features and wind, water and ice have moved, transported, or deposited materials on the earth's surface to alter these major features. The distortions and deposits are recorded by man in a topography map which features a certain arrangement of contours. Once an engineer recognizes patterns as significant of a particular landform, he analyzes step by step the contour picture of the characteristics of the particular landform studied. From these maps he may be able to determine the surface materials to be expected within reasonable limits.

In order to recognize that patterns are repetitive in nature, an examination of three materials (sandstone, limestone, shale) combined in a pattern in three physiographic regions of the United States will prove helpful (see Fig. 13, 14, and 15).

At Fort Knox, Kentucky, the pattern is located in the interior low plateau of the central lowland (see Fig. 13). The area covered is one of a tributary stream known as Cedar Creek. It is located near the eastern boundary of the military reservation. The gorge created by Cedar Creek is a solution valley in a limestone plain. Cliffs rise sharply east and west of this straight, north flowing stream. Smaller streams flow into the creek from short gullies each having an entrant angle almost perpendicular to the Cedar Creek. The floor of the valley is flat and rather wide, as indicated by a wide spacing of the contour lines. The contour lines along the valley wall are regularly spaced but close together. There are no terraces. On top of the plain there is the impression of a flat plateau-like rock pediment. Thus a pattern is formed by the drawing of contour lines which represent these surface configurations.

The second topography pattern is located near Fort Riley, Kansas, in the Osage Plains of the central lowland and is shown in Figure 14. The pattern is one very similar to that described above. There is a different cover type due to the fact that the rainfall is less than in the previously described area. Again, the long, straight tributaries exist, with short stubby gullies entering almost at right angles. The valleys are flat and wide. The geological structure of the underlying rock is similar to that in the Fort Knox area. The ages of the two rocks are not too different. Hence, it can be expected that these examples and the pattern elements are comparative to a great extent.

The third topographic pattern is in the vicinity of Soda Canyon, Colorado, and is shown in Figure 15. The region is located in the southwest part of the state in the Canyon Section of the Colorado Plateaus Physiographic Division of the United States (10). It is also a pattern of limestones and sandstones with shale. From an analysis of this region it can be determined that the stream valleys are flat with short, steep gradient forming canyon-like gullies. The valley walls rise sharply from the floor of the valley. It can be seen that these patterns are related to each other. The type of materials represented in all of these examples is a cherty limestone.

From the above discussion it can be seen that the arrangement of contours form a pattern, and that the pattern represents surface and subsurface (structural) features of a region. The above, when coupled with information and other data gathered from literature, may be used to predict the type of engineering problems to expect from a typical contour pattern. The literature survey mentioned previously will be helpful in ascribing significance to topographic expression represented by the contours. The literature survey, including geology and physiography, will be helpful to determine expected relationships between earth forms and earth materials as described and pictured on a topography map.

Techniques of Material Surveys from Topographic Maps

In order to use contour maps for material surveys there are a few steps that need be followed. Having a given geographical region in which to locate materials, a set of contour maps of the given region are spread out for inspection. These contour maps should be to the scale of 1: 125,000, or smaller, in order to establish the pattern. Next, the observer should record the impressions gained from this examination in an orderly fashion. In this regard he should determine the landform, drainage pattern, gully characteristics, ratio of number of contour lines to a unit distance, erosional features, vegetation, and land use, if indicated on the map. These features are known as elements and will establish the pattern which can be analyzed. Once they have been listed, the next step is to determine pin-pcint locations for field checking. Field checks are usually made on basis of landform divisions and topographic changes within landforms. Uniform slopes, flats, breaks in slopes, valleys, depressions, ridges, and other changes can be noted in the detailed analysis and set aside as representative of changes in materials. These landform changes and significant topographic positions within landforms are drafted on a tentative material overlay map. With the tentative material map prepared then pertinent locations in the field, representative of typical areas, are sampled. The performance of engineering structures is observed. Generally highway pavements will reflect the type of performance that the underlying materials support. Upon completion of this field check and performance survey, the material map is revised, if necessary, and prepared in final form. It is obvious that the material survey from a topographic map will be of the order of a reconnaissance survey. However, this procedure if followed will enable the prospector to determine the maximum amount of data from the existing maps in a minimum of time and field work. Quite often field work is conducted first; then maps are studied. However, in the steps noted above, the field work is not nearly so extensive, nor expensive, if the procedure enumerated

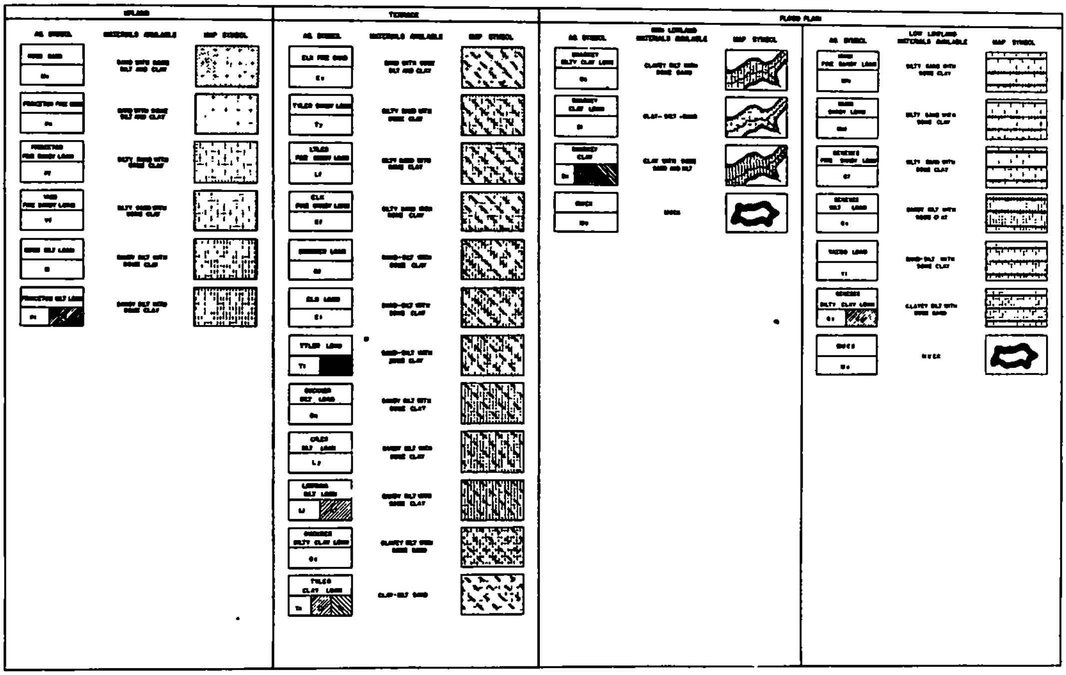

Figure 27. Agricultural-soils map key.

is followed prior to the field survey.

Keys for Use With Topographic-Map Data

Keys for studying material types are quite helpful. They should consist of an overall pattern with illustrations of all aspects of the pattern. Each element of a pattern, as listed above, should be indicated by both description and illustration, either by diagram or ground photo. Once the overall pattern is understood and the elements have given the prospector a concept of the make-up of what the pattern represents, then it is a simple analysis to delineate the materials represented by the key.

A key is based upon landform as the primary class. Each different landform is represented by its particular set of contour lines arranged in natural order. Flat plains, whether upland, terraces, or flood plains, are represented by contours spaced far apart per unit of distance. The junction or transition zone between a flood plain and an upland plain is represented by contour lines spaced close together per unit or horizontal distance. Depressions are represented by particular hachure-type of contour lines. It is to be noted that a series of contour lines to be representative of a pattern must be considered first on an overall basis. The pattern is then a significant indication of ground conditions. Each break in spacing of contour lines denotes a change in slope, which may be accompanied by a change in materials. A change in spacing per unit of linear distance is significant when there is change of slope on the ground.

Limitations of Topographic-Map Method

The contour map is limited. The map does not always cover an area sufficiently to be representative. If the scale is too large it may misrepresent the landforms. Likewise if the contour interval is too great the true arrangement, particularly slopes, may be misrepresented.

In areas where contours are spaced far apart per unit of horizontal distance (extremely flat areas), the contour map is unsatisfactory for material-survey use. In such areas, landform perspective may be lost. In areas where the slopes are so steep that contour lines will be spaced too close for accurate visual study of maps, the use is extremely limited. The techniques followed by the original draftsman in his interpretation and contour-representation of field data may become a limiting factor. As an example, it is important to know whether the brow of a hill or rise is softly rounded, sharply rounded, or angular, since such features reflect the texture of materials. If the original draftsman shows all alike in his interpretation and representation of field data, this limits the detail obtainable. Usually the technique of the draftsman, his artistic sense of proportion, and the reliability of data can be determined by detailed inspection of the minute features as described above.

In summary, the contour map, alone at best, should be confined to reconnaissance use only, since it merely groups areas into their probable landform arrangements and rarely provides detailed information about many of the surface features needed for materials study. However, when coupled with other information, the efficiency of use for material surveys is increased considerably.

Example of the Topographic-Map Method

The example selected is in Southwest Indiana in Gibson County. The general topography of the Area E, Foots Pond Hills, is flat with an upland island, or isolated hill of Pennsylvanian rocks and the alluviated flood plain of sand and gravel of the lower Wabash Valley surrounding the island. Foots Pond appears to be an abandoned cut off channel of a former position of the Wabash River. Figure 16 shows the Gibson County topography Map. Figure 17 is a copy of the Foots Pond Hills area as seen in original topography map (13).

Topography Map Interpretation Procedure. The interpretation guide (Fig. 30) is utilized to determine the materials available. There are three landform features to be analyzed: flood plain (HL and LL), low terrace (Lt), and the upland (U). Each is considered and discussed as follows.

In the flood plain there are certain

topographic features that stand out. Generally, flood plains are quite flat. Their topographic positions are difficult to outline, particularly with contour of large vertical interval. However, an examination of the overall picture (Fig. 16) gives flood-plain data concerning the site area. It can be seen from this perspective that the site area should be divided into low lowland (LL) and high lowland (HL), principally because of the position of site area intermediate between the upland to the east and the Wabash River to the west. The low-lowland (LL0) portion of flood plain was designated as such because of the .two channels which cross the northwest and southeast corners of area (Fig. 16). These two channels are not significant for location of materials; their significance lies in their location in the area — that of occupying the lowest position. The low-lowland area is subject to flooding and filling in with silt during periods of high water. The high-lowland area is designated as the part intermediate between the low lowland and the low terrace. In this particular area this part of the flood plain may contain the most significant materials. According to Fidlar, the flood plain is one formed by the filled-in materials during some glacial age. These filled-in materials may be sands and gravels. The ponds located in the flood plain have the appearance of abandoned channels.

The low terrace has the smallest areal extent LT1. It is that portion between the high lowland and the upland. It does not have very steep slopes nor is it flat. The area considered as low terrace is confined to a rim of materials deposited near the base of the upland island and overlying the flood plain adjacent to the rim of the upland. The contour line between the steep slope and the flat plain is irregular and spaced far enough from the more regularly spaced lines of higher elevation that it appears to define a bench-like form. The materials available within this area defined as LT1 are most likely to be similar to the materials in the upland. Generally, colluvial slopes develop from the materials sloughing down the slope and being deposited along the lower rim of an upland by water. In this area the lower terrace materials may be sand and silt, heterogeneously mixed, with perhaps rock fragments in the gullies. The gullies are indicated by the irregularity of the top contour lines. Sharp angles, bends, and turns in the top contour line indicate evidence of erosion along the colluvial slopes. Erosional features such as these indicate less-consolidated materials.

The area confined to the upland has a more rugged appearance (U3). The contour lines are spaced closer together indicating steep easily eroded slopes. The area higher than 400 ft. has been designated as upland (U3) and there are several types of contour lines represented. These types are closely spaced and are closed. The close spacing indicate an area which may be the underlying rock exposures; the closure indicates tops of small hills. The latter are similar to those found along the uplands which are used to indicate windblown sand ridges. According to the physiographic literature survey there are sand ridges in the area, hence, these may be the ones expected.

In the floodplain of the flat area, not confined to abandoned channels or oxbows, it is anticipated that sand and gravel with a silt overburden will be found in the low terrace. There may be colluvial materials of silt and sand. Finally it is expected that the upland may have uniform sand ridges underlain by rock. The materials as represented by a map are shown in Figure 18.

COMBINED USE OF LITERATURE, GEOLOGY MAPS, AGRICULTURAL-SOILS MAPS, TOPOGRAPHIC MAPS, AND AIRPHOTOS

This section of the report is concerned with the combined use of literature, various nonengineering maps, and airphotos for evaluating earth surface materials making material survey. It seems only logical for those interested in conducting a materials survey to attempt to gain as much information in advance of field inspection as possible. In most areas this is not a difficult task, since both published and unpublished information is usually available. Reports covering the findings of the agricultural-soil survey are on file in libraries of many colleges and universities, in county agents' offices, and

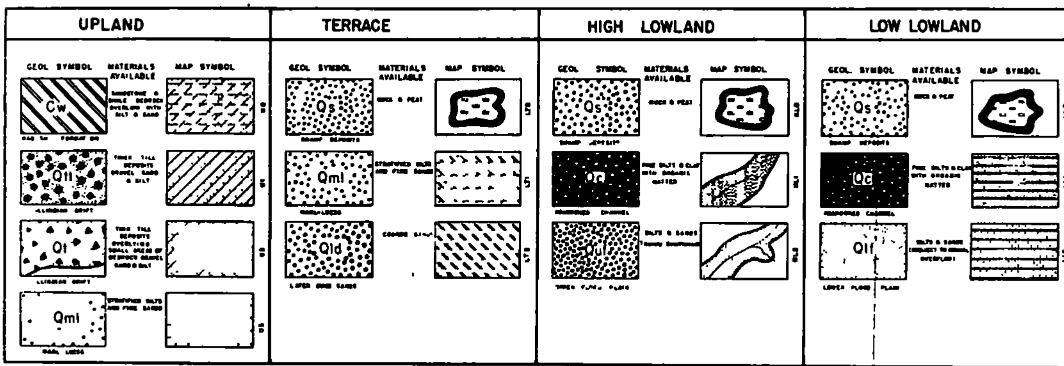

Figure 28. Geology map key.

in some public libraries. A listing of libraries is presented in Bulletin 22 of the Highway Research Board (8). Geological reports are available in libraries of many colleges and universities, as well as in the files of state geological surveys and of the U.S. Geological Survey. Many reports are available for purchase from the Superintendent of Documents, U. S. Government Printing Office, in Washington. For unmapped areas the materials prospector will find the state geological surveys, the U. S. Geological Survey, and the state agricultural experiment stations very helpful in obtaining materials data within certain areas.

Aerial photographs can be purchased from any government sources for a large portion of the United States. Maps are published by the Geological Survey showing status of photography by the various agencies. The largest source of aerial photographs is that of the Department of Agriculture. Status maps showing availability of photography and year flown are available for each state. Files of some aerial photographs are kept at some universities. in county agents' offices, in various geological survey offices, both federal and state, and in many highway departments.

Significance of the Combined Method

There are many advantages of studying literature available in several fields, such as the studies made available by the soil engineer, physiographer, the geologist, the soil scientist, the topographer, and the photoanalyst. The chief advantage lies in the fact that the materials prospector can screen the data and determine the high points of each source of information — those points which are the most significant to an understanding of the area under study.

From study of physiographic literature the type of land surface is determined such as, plain, plateau, mountain, or basin. The relationship of the area with respect to the surrounding physiographic provinces is determined. The agents responsible for the development of the landscape will be set forth.

The study of geologic literature reveals the history of an area — its origin and the development processes contributing to its present form. Such items as relative age and type of materials in the major land units are determined. From the geology map and accompanying literature, the major parent materials, whether in place or transported by wind, water, ice, or gravity, will be determined and can be located accurately. In one sense, geology is the basis for all material surveys.

From the topography map the magnitude of the landscape is determined. The various landforms are represented together with their respective positions relative to the base level of erosion. The magnitude of the landforms is represented clearly. The topography map provides a record of the earth sculpturing which has taken place.

For a grouping of surface soils into parent materials the maps and the literature provided by the soil scientists are used. Since the pedologic concept is followed in reports of this type, advance information concerning expected soil-profile types and characteristics may be obtained. The literature of this source presents information concerning not only the soil catenas of family groups but information concerning the variations, such as types and phases. Detailed description is concentrated on the development profile — that which supports plant life.

The aerial photograph records the sum and total of all surface features. It is a pictorial representation of the area recording the major as well as the minor details. In addition to picturing the distribution and density of the natural cover and cultural features such items as macro-relief are clearly shown. These minute details are often grouped in an all-inclusive symbol on other maps since expense precludes their being included in the representation of the area. The areal photograph provides a basis of comparison — it is an impartial representation — not prepared through the eyes of another. Its successful use is limited to the trained interpreter alone. The airphoto can supplement where macro-detail is needed; it can supplant where no information is available.

Combined Method Applied to the Example Areas

The following discussion has been prepared irrespective of the preceeding discussion. This discussion is divided into source data for survey, physiography, geology agricultural soil survey, and aerial photographs.

Physiography. This area is located in the Wabash River Valley which is a river valley of a glaciated region of the Till Plains Section of the Central Lowland Province of the Interior Plains Physiographic Division of the United States (9, 11). The valley consists of flood plains of a mature stream valley filled in with materials which are believed to have been deposited as the result of the flow of glacial melt waters occurring during the Wisconsin Age. The locale used in this study is located in the flood plain of this filled-in valley. The local landscape consists of flood plains, terraces, and uplands. There are generally two levels in the flood plains, one at or near the water level and one 10 to 30 ft. higher. The valley, or flood plain contains a series of island hills isolated as monadnocks.

Geology. This area is underlain with rocks of Pennsylvanian Age — Coal Measures (13). The rocks of the Central Lowland dip gently along the Cincinnati Anticline which underlies this area. Rock knobs, also Pennsylvania, protrude through the flood plain surface. The area has been glaciated as deposits of drift of Illinoian Age dominate the landscape in many places in the uplands. The results of the later Wisconsin Glacial Age are found in the vast alluvial filling of the Wabash Valley.

The present landscape reflects the glacial activity and considerable modification through the recent agents wind and

Age			Formation Names and Symbols	
Recent Epoch			Natural levees	Qn^{1}
Recent Epoch			Abandoned channel deposits	Qc
Recent Epoch			Swamp deposits	Qs
Recent Epoch			Lower flood-plain deposits	Qlf
Recent Epoch	Trans		Later dune sands	Qld
Pleistocene Epoch	Trans		Upper flood-plain deposits	Quf
Pleistocene Epoch	Wisc Stage		Earlier dune sands	Qed
Pleistocene Epoch	Wisc Stage		Terrace deposits	Qtr
Pleistocene Epoch	Iowan Stage		Older stream silts	Qos
Pleistocene Epoch	Iowan Stage		Loess	
Pleistocene Epoch	Iowan Stage		Marl-loess	Qml
Pleistocene Epoch	Illinoian Stage	Retreat	Lake deposits of third halt	Ql^{4}
Pleistocene Epoch	Illinoian Stage	Retreat	Lake deposits of second halt	Ql^{3}
Pleistocene Epoch	Illinoian Stage	Retreat	Lake deposits of first halt	Ql^{3}
Pleistocene Epoch	Illinoian Stage	Retreat	Lake deposits of maximum advance	Ql^{1}
Pleistocene Epoch	Illinoian Stage	Occupation	Outwash gravel plains	Qog
Pleistocene Epoch	Illinoian Stage	Occupation	Drift ridges	Qdr
Pleistocene Epoch	Illinoian Stage	Occupation	Thick till and drift plains	Qtt
Pleistocene Epoch	Illinoian Stage	Occupation	Thin till sheet	Qt
System			**Names and Symbols**	
Tertiary			River deposits (Eocene ?)	Tr
Carboniferous (Pennsylvanian)			Wabash formation	Cw
Carboniferous (Pennsylvanian)			Inglefield formation	Ci
Carboniferous (Pennsylvanian)			Ditney formation	Cd
Carboniferous (Pennsylvanian)			Somerville formation	Cs
Carboniferous (Pennsylvanian)			Millersburg formation	Cm

Figure 29.

water. According to Fidlar, the present flood plain is the result of seasonal flood and lateral erosion with abandoned channels filled into the present established level. The old Maumee River (pre-Wisconsin) formed what is now called terrace remnants. These are evident near the bordering uplands. The low gradient of the flood plain in this area causes wide meanders of the stream channel. Frequent flooding has resulted which has been responsible for forming bayous, oxbow lakes, bars, and abandoned channels. The Wabash Channel has cut through a projecting upland spur in places. Many marsh areas occur in the flood plains in the swales. Other features of the flood plain which are a direct result of alluvial activity are natural levees consisting of long ridges of a sand and gravel overwash. Both levels of the flood plain contain oxbows, meander cut-offs, swales, bars, levees, and channel scars.

The upland areas are covered with loess in various spots throughout the lower region of the Wabash Valley. There are deposits up to 50 ft. thick in places. Thornbury (24), in 1940, reported that this loess belongs to the Peorian Loess (Wisconsin Age) of Illinois. The slopes are unusually steep for unconsolidated deposits. Steep slopes are features typical of loess. Erosion of the soft, calcareous loess has produced smooth slopes along vertical-walled gullies. According to Fidlar, the loess also covers the island hills in this region — those in the flood plain of the valley. Other aeolian deposits, such as sand dunes, are scattered throughout the area. Some deposits are resting on the Maumee and Shelbyville terrace remnants and on the isolated residual remnants which protrude above the base level of the flood plain. It is said that upland dunes may have originated any time after the maximum Illinoian ice invasion. Typical dune topography marks the crest of such areas as Foots Pond Hills and Mumford Hills.

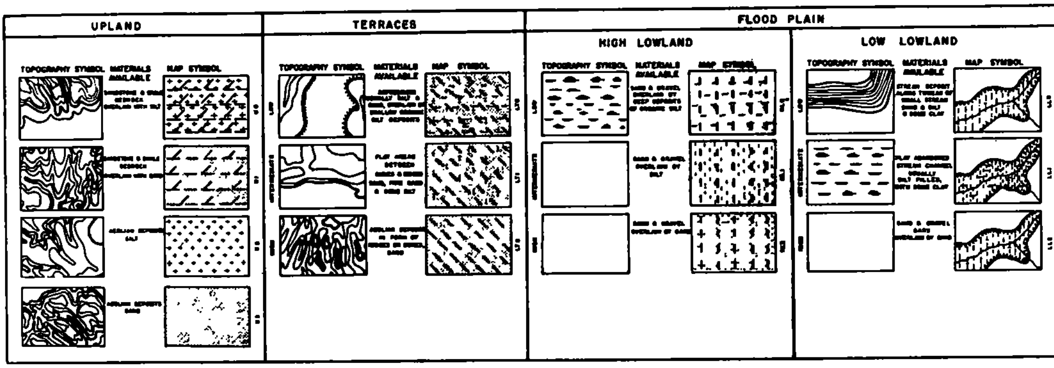

Figure 30. Topography-map key.

Agricultural-Soil Survey. The agricultural-soil survey provides detailed information about distribution of parent materials and the soil profiles of the various series, types, and phases. The soils are grouped into three groupings based on profile development, topography, and parent material. All three are important to a material survey.

The grouping under parent materials lists the soil series associated with residual, glacial, loessial, and alluvial. Such information provides a starting point for the development of correlations between the soil-series name and the geological designation, which is obtained from geological maps and literature. By studying the grouping of soils on a topographic basis, it is learned which of the soil series occur on uplands, terraces, or lowlands. This is irrespective of parent materials. The grouping provides a correlation between soil series, topography, and local physiography. It clarifies the concept of magnitude of various landforms comprising the landscape by pointing out areal extent of the soil series on a given landform from the agricultural-soil map and relative elevation position from the topographic map. The picture now assumes three dimensions. From the description given on soil groups accorded certain profile types, information concerning drainage and profile development is obtained. It is learned which soils are old in their development and which are young. This fact is important since porosity and profile development are closely related. Detailed information of series and phase is obtained from the pedological discussion of the profiles.

As an illustration of this, information concerning the Gibson Series is given here. The Gibson soils are developed from Illinoian till, and occur as an upland soil as stated in the survey report (18):

"The Gibson series is characterized by a light brown or yellowish-brown surface soil and a heavier yellow subsoil, underlain by a noncalcareous Illinoian till, mottled with yellow and gray. This till extends to a depth of about 10 ft."

The Gibson series occur in the Group I profile soils since it has a normally developed profile. They have been developed under forest conditions. Three distinct A, B, C, horizons exist in the profile. The description given in the survey report for soils of Group I is:

"A top layer (A) which, under virgin conditions, has a surface veneer of organic matter, contains some organic matter in the upper part and less in the lower part, and is thoroughly oxidized and leached; (2) a middle-layer (B) which is well oxidized and heavier in texture than the surface layer; and (3) a bottom layer (C) consisting of the parent material."

Details of the type and phase are obtained from the profile discussion and are not repeated here. In a manner similar to that discussed above information concerning the various soils pertinent to the example areas can be obtained for use in the materials survey and maps representative of the ground condition may be prepared.

Aerial Photographs. In the particular area chosen for the examples the literature was considered to be ample to furnish material necessary for conducting a materials survey. Little can be added from a study of the airphotos regarding the location, distribution, and type of materials when used in conjunction with the other methods of this particular area. The soil series as mapped and as described have provided the necessary data. It is, however, to be pointed out that in the case of the alluvial soils the airphoto more clearly separates the well-drained and more-granular ridges (levees) left by current activity from the intermediate and basin areas which are not as granular. On some types of maps these have not been separated. From a soils standpoint the airphoto provides the only method, where it may be desirable to obtain information pertaining to relative amounts of ridge - intermediate - basin areas.

Of importance in the survey is the use of the airphoto for determining the density and distribution of timber cover for purposes of consideration in land evaluation and clearing cost. This, of course, is not contained in detail on other maps. The up-to-date cultural pattern as well as access routes is more easily determined from study of airphotos.

Perspective. The foregoing discussion gives a perspective with which a study of the materials of an area can be accomplished in a more objective manner. From general literature, it is known what to expect in the various major landform units. From detailed literature, the perspective is enhanced, since actual information concerning the soils is obtained. The information from the airphotos completes a detailed concept of any terrain for locating materials surveys. One additional feature is worth nothing: Quarries may have been opened for source of granular materials and the supply of materials exhausted during same operation. These and other conditions pertinent to an area study are easily learned from a study of up-to-date photos whereas these data may not be abailable on older maps.

Four Example Areas Compared

The results of the entire study, in which four areas in southern Indiana were surveyed with four methods each, have been tabulated and appear as Figure 32. In-

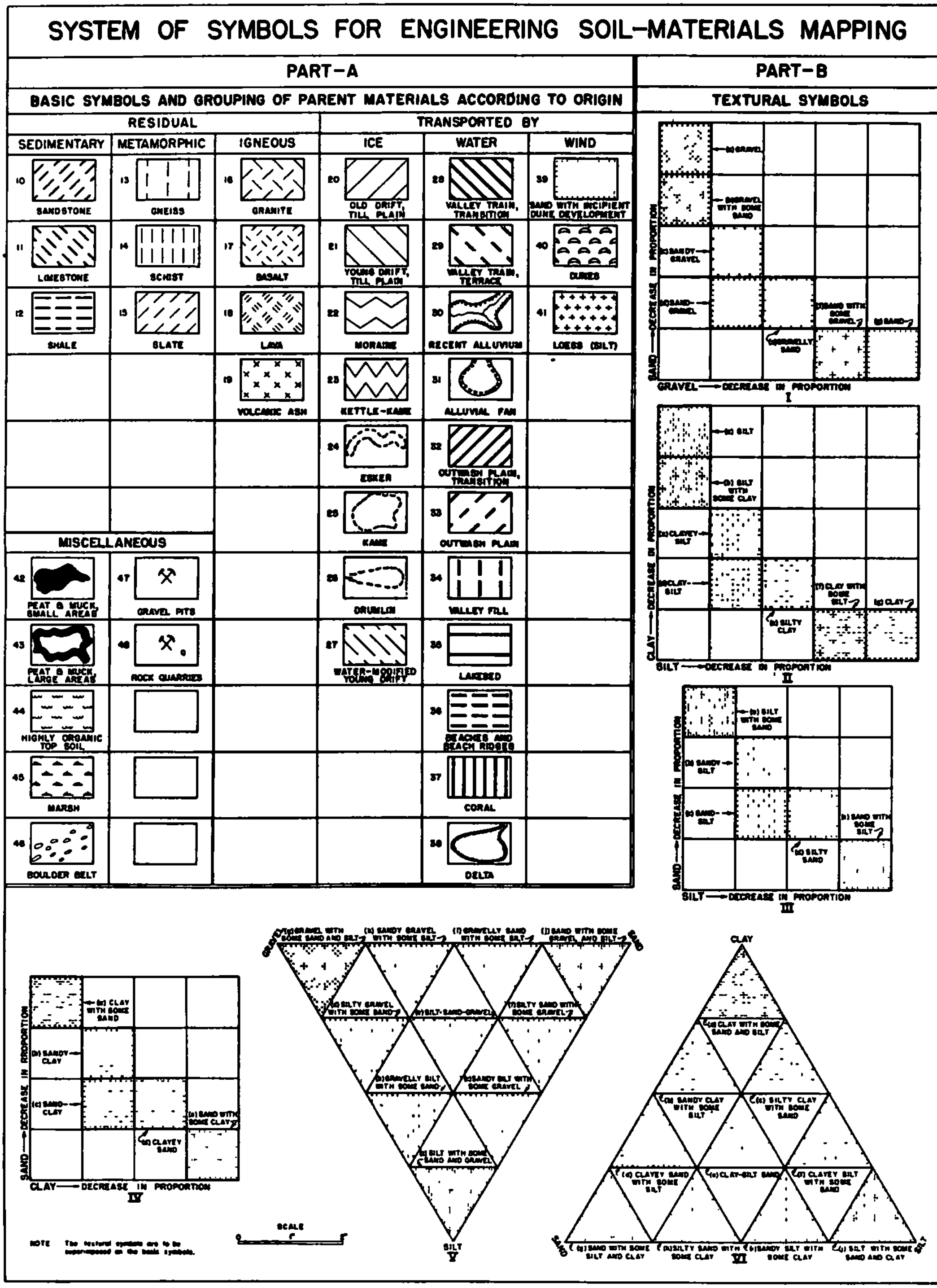

Figure 31. System of symbols for engineering soil-materials mapping.

dividual maps, airphotos, and copies of original maps have not been reproduced or discussed in this presentation. A portion of the Gibson airphoto-index sheet, agricultural soil map, geology map, and topography map which contains all four example areas, has been reproduced and is contained in Figures 19 to 22.

PURDUE ENGINEERING-SOILS-MAPPING SYMBOLS*

The accompanying chart represents the system of graphical symbols developed at Purdue University in connection with the Engineering Soils Mapping Project of the State of Indiana from airphotos. Although this system was designed primarily with the Indiana soils in mind, it possesses enough flexibility to enable its use in other areas, since all possible origins of soil materials are included and since the system admits expansion in accordance with specific needs.

The soil physical properties of foremost importance are: type of parent material, texture, and internal-drainage characteristics. An attempt has been made in this system to portray such soil properties as truly as possible.

Briefly, the following are the outstanding features of the system:

1. As shown in Part A of the chart, the soil parent materials have been arranged according to origin in two major groups: residual, and transported. In the residual group, sedimentary, metamorphic, and igneous materials are included. The transported group is further subdivided according to the agent of transportation into ice-deposited, water-deposited, and wind-deposited. Under these subheadings the corresponding types of soil formations have been listed. Part A also contains a column for miscellaneous formations, which cannot be included in either of preceding groups.

2. The symbols in Part A have been designed as uncomplicated as possible, so that they may admit superimposition of one symbol on another without confusion. This is necessary to show thin drift on rock, for instance, or wind-blown sediments on some other materials and also to combine the textural symbols (Part B) with such basic symbols. The basic symbols, by themselves, indicate the origin of the parent material, as well as the type of formation; e. g., glacial moraine.

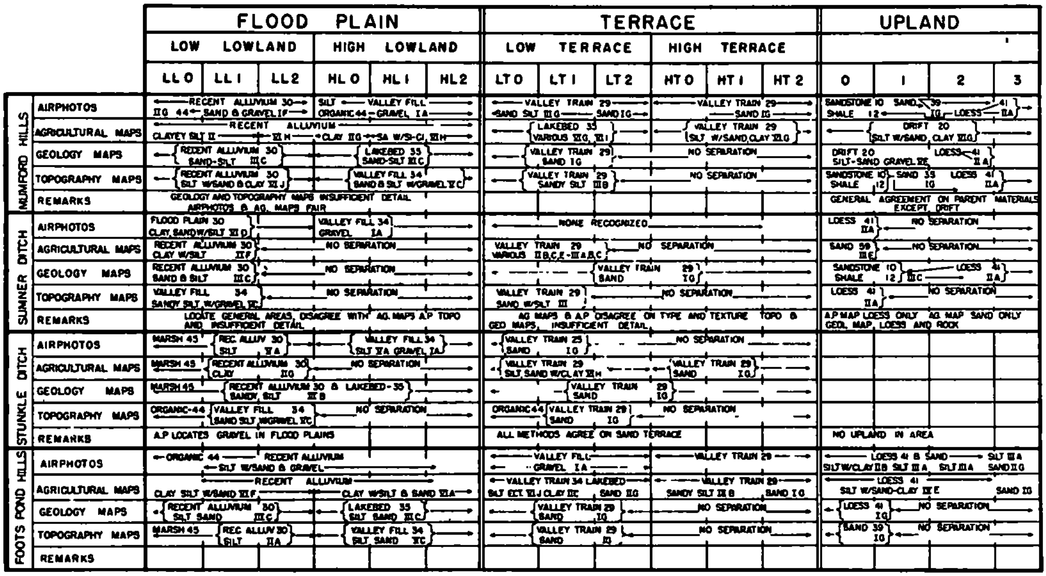

Figure 32. Correlation chart for example areas.

*Prepared by P. Montano

3. Four are the generally accepted grain size components in soils: clay, silt, sand, and gravel. A soil may be composed of one or a combination of two or more of these grain sizes. Some combinations occur in nature more frequently than others; and some almost never occur, such is the case of clay and gravel, and even silt and gravel. Discarding these unlikely combinations of two grain sizes, the first four groups of symbols shown in Part B were designed. Next, the most likely combinations of three grain sizes were chosen, as shown in the last two groups of symbols of Part B. For the sake of simplicity, and since only relative soil textures are intended to be portrayed by the textural symbols and not numerically accurate proportions of grain size components, combinations of all four generally recognized grain sizes were not included in this system. An example of relative soil texture for our purpose would be silty-sand, where the sand predominates and where the silt holds a secondary place in proportion. This however does not mean that such a combination may not contain a small proportion of gravel, for instance; however, this proportion would be so small as to be insignificant as far as the engineering properties are concerned.

All six groups of grain-size combinations shown in Part B contain some blank spaces. If symblos were to be devised for all the spaces of each group, either the proportions would be repeated or the relative textures would be so much alike that confusion would result. Symbols were devised, then, only for the most significant grain-size combinations. For our purpose, these symbols are called textural symbols.

4. Dashed horizontal lines and dashed vertical lines were chosen for the textural symbols for clay and silt, respectively; and the conventional dots and circles were adopted for sand and gravel, respectively. The horizontal arrangement was chosen for clay to denote its slow-draining properites. By similar reasoning the vertical dashed lines that represent silt, indicate better draining characteristics. The dots and circles carry the universal inference of good drainage. By noting the relative density or proportion of these conventional grain-size symbols on any combination, it is possible to acquire a reasonably good impression of the drainage characteristics of the soil represented by such a combination of symblos.

5. The textural symbols are superimposed on the basic symbols, to indicate texture and drainage characteristics of: (a) the parent materials in unconsolidated formations and (b) the derived soils in bedrock areas.

This system is especially suitable for engineering-soils mapping from aerial photographs, since by means of airphotos it is possible to tell the origin of the soil materials and the types of formations, as well as to predict the relative soil textures and drainage characteristics. The symbols should be used in full scale for best results.

It is hoped that the proposed system will constitute a common language for engineers engaged in soils mapping and will be regarded as a convenient method of grouping and graphical representation of engineering soil materials.

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