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NEW GLACIAL FEATURES IDENTIFIED BY AIRPHOTOS IN SOIL MAPPING PROGRAM

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SYNOPSIS

At the outset of the current soil mapping program, from aerial photographs, of the State of Indiana certain glacial airphoto patterns were found to be very complex and as a result an endeavor was made to trace the glacial features which have complicated the patterns.

The first part of the paper discusses the areal soil (regional soil) mapping program and how it is being done from aerial photographs. The common bedrock and glacial patterns are discussed and illustrated so that the reader may better understand the complex patterns. The remainder of the paper discusses many of the complex patterns and the glacial features which cause them to be developed. The complex patterns of these soils are being studied with the object of determining the lateral extent of such soils and their relation to highway engineering. The following are a few of the complex situations being studied: intermixed gravel and drift on glacial drift of an older period; recent terrace gravels on older drift deposits; sand clay and gravel clay deposits associated with older glacial drift; pre-glacial drainage; glacial drift borders; and resorted recent drift on older drift.

This study reveals that these patterns have definite elements which aid in their identification. Materials associated with these patterns are important in both highway and airport engineering. For example, sand-clay and gravel-clay materials find use in base course construction and in the surfacing of county roads in areas where other engineering soils are undesirable. The prediction of older drift is important because of its dense, indurated structure and low permeability.

The soil mapping program, which is being initiated, is comprehensive and a large amount of data are now being obtained. When the project is completed, maps will be available which will show the locations of potential sources of aggregates, base course materials, and materials for low cost roads for state and county use. Maps will be available for use in evaluating pavement performance; they can also be used in the design of pavements on an areal or regional basis from the standpoint of soils. The speed with which the program proceeds will depend, largely, upon the accuracy and refinement with which these complex glacial features can be evaluated from aerial photographs.

Purdue University and the State Highway Commission of Indiana are co-operatively undertaking a state-wide program for the purpose of preparing the following county maps: (1) a drainage map, showing major streams, creeks, large gullies, and small field gullies; and (2) an engineering soils map, showing the areal extent of soils, including the locations of granular deposits. These maps will be prepared from aerial photographs.

The method used in mapping drainage from air photos consists, in brief, of making a detailed stereoscopic study of drainage features on the photos, marking those features on the photos, and then transferring them to existing sectionalized base maps (*39*)[1]. Likewise, the procedure for mapping soils consists of a detailed stereoscopic study of photographs for the purpose of evaluating the airphoto "soil pattern" elements. The various soil areas are first outlined on the photographs and later transferred to county base maps.

The technique employed for interpretation of soils from aerial photographs for engineering purposes is based on the belief that each engineering soil material has its own characteristic airphoto soil pattern which, in turn, has its own set of identifying elements. Because the pattern is composed of elements, deductive interpretation permits the identification of soils, their physical characteristics, and their properties. There are several common elements of the soil pattern: land form, drainage pattern, gully systems (including cross-section and gradient), soil color tones, vegetative cover, and land use.

In order to interpret airphotos properly the interpreter must realize the limitations of each study. Perhaps the greatest limitation lies within the personal characteristics of the interpreter. That is, the amount and type of information which can be obtained from aerial photographs is in proportion to the interpreter's skill. Adeptness in airphoto mapping depends, to a large extent, upon a basic knowledge of some of the natural sciences; soil mapping experience, by the correlation of field data with airphoto pattern elements; knowledge of engineering problems as they relate to soil formation and topographic position; and the ability to observe, interpret, and evaluate the fine details of the airphoto pattern. One important limitation concerns the evaluation of climatic conditions, since they influence vegetative cover, soil color contrasts, erosion, and gullies. It should be realized that, within any soil area the physical properties of the soil will not remain strictly constant, but will vary with the somewhat erratic processes of deposition and soil formation. Generally speaking, however, the refinement obtained from an airphoto analysis is in keeping with limits of highway design, construction, and maintenance. When airphoto interpretation is properly used, literally a wealth of information can be obtained——particularly when airphoto and ground study are carried on concurrently.

[1] Italicized numbers in parentheses refer to the list of references at the end of the paper.

AREAL SOIL MAPPING

The engineering soil map must include the profile developments of soils and their areal extent. The modern demands of grade, alignment and width of right-of-way for highways, and a greatly expanded airport program have caused the highway and airport engineer to be concerned, not only with surface soils but parent soils as well. Concomitant with the importance placed on soil profiles or rock-soil combinations is the attention being focused recently on areal soil mapping. Field performance surveys correlated with areal soils have proved that each soil group is accompanied by a specific set of problems. The continuing trend toward regional design of highways based on regional soils and regional soil problems is therefore desirable from the standpoint of location, design, construction, and maintenance.

It has been said that 90 percent of the State of Indiana could be mapped in 10 percent of the time, and that the remaining 10 percent of the area would require 90 percent of the time for mapping. The basis for this thesis is that there are two major types of airphoto soil patterns, not only in Indiana but perhaps in other locations. The first is the pattern produced by a material which is of sufficient depth and areal proportions to blanket an area uniformly, thus showing similar airphoto pattern elements. These are the so-called "standard airphoto soil patterns." The second type pattern is one which depicts an area where several different soil materials are exposed at the surface. This may be due to geologic activity such as the earth's crustal disturbances; ice invasions and subsequent lacustrial, fluviatile, and aeolian activity; or by a combination of all these and others. In areas such as these, the airphoto pattern is very complex, for the reason that the standard pattern elements have been altered, often to the point where unrelated pattern elements are developed, thus forming what is called a "complex airphoto pattern."

Standard Patterns

There are about 12 standard airphoto patterns which are representative of the surface materials covering a large part of Indiana, or the "ninety percent of the area" previously mentioned. These patterns are directly related to bedrock geology and to glacial activity. The major surface material patterns are these: interbedded limestone and shale of Ordovician age; massive limestone of Mississippian age; various combinations of sandstone and shale of both Pennsylvanian and Mississippian age; windblown silts (loess) and sands; Wisconsin glacial till plains; Wisconsin glacial moraines; Wisconsin granular outwash; Illinoian glacial till plains; granular terraces; and lacustrine silts, clays, and mucks.

In bedrock areas, mapping is easy and depends upon the detail and accuracy required. Each major rock type has a characteristic pattern, and mapping is accomplished by merely separating the standard patterns. As an example, when limestone and sandstone occur in the same area or in adjacent areas, mapping consists of separating the soluble limestone plains from the "bold" sandstone uplands. Figure 1 is a composite photo showing a standard limestone pattern, a standard sandstone pattern, an area where both are present, and a soil map of the area containing both sandstone and limestone.

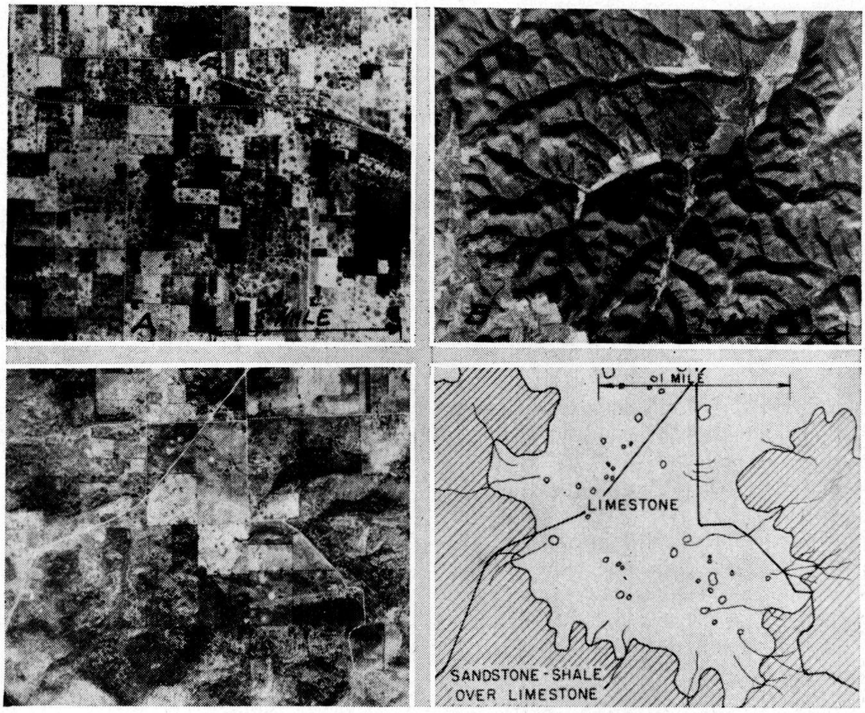

Figure 1. A Standard Airphoto pattern and Soil Map of a Limestone Area, a Sandstone-Shale Area, and a Sandstone-Shale on Limestone Area. The limestone pattern, A, is characterized by the presence of sinkholes; the sandstone-shale pattern, B, by dendritic drainage pattern, angularity, rugged topography, dense vegetation, deep V-shaped valleys and gullies, and sharply crested, V-shaped hills. Mapping is accomplished by separating the standard patterns wherever they occur in the same region.

The Wisconsin and Illinoian glacial drifts are shown in Figure 2. When glacial drift occurs on rock the pattern contains elements of both parent materials, as is clearly illustrated in the patterns depicting drift-on-limestone and drift-on-sandstone in Figure 3. The larger stream valleys containing granular terraces, likewise, are easily mapped because of contrasting patterns as shown in Figure 4.

Since the most complex airphoto patterns occur in glaciated regions, it is necessary to understand fully the many standard glacial patterns. Several soil-parent areas associated with glaciation are illustrated in Figures 5, 6, and 7. Four common moraine patterns are shown in Figure 5. Patterns associated with water-worked and wind-worked material are illustrated in Figure 6, and miscellaneous glacial patterns in Figure 7.

The foregoing patterns and a few others—such as loess, limestone and shale occur as surface materials over large areas and hence may be considered standard patterns. It is the presence of these large consistent soil areas which make it possible to map a large area in a short period.

Complex Patterns

The remainder of the state, roughly ten percent of the area, is complex because of erratic glacial activity and subsequent erosion. Successful airphoto mapping should be done in conjunction with occasional field checks, the number and locations of which will depend on the complexity of the area and its accompanying airphoto pattern. Standard pattern areas need occasional "spot checks" only; whereas, in transition zones and areas of overlapping parent materials, field checking should be frequent and correlated with the use of airphotos in the field. By mapping in this manner, the interpreter obtains a maximum amount of information from airphoto interpretation and an understanding of engineering soil materials in the field.

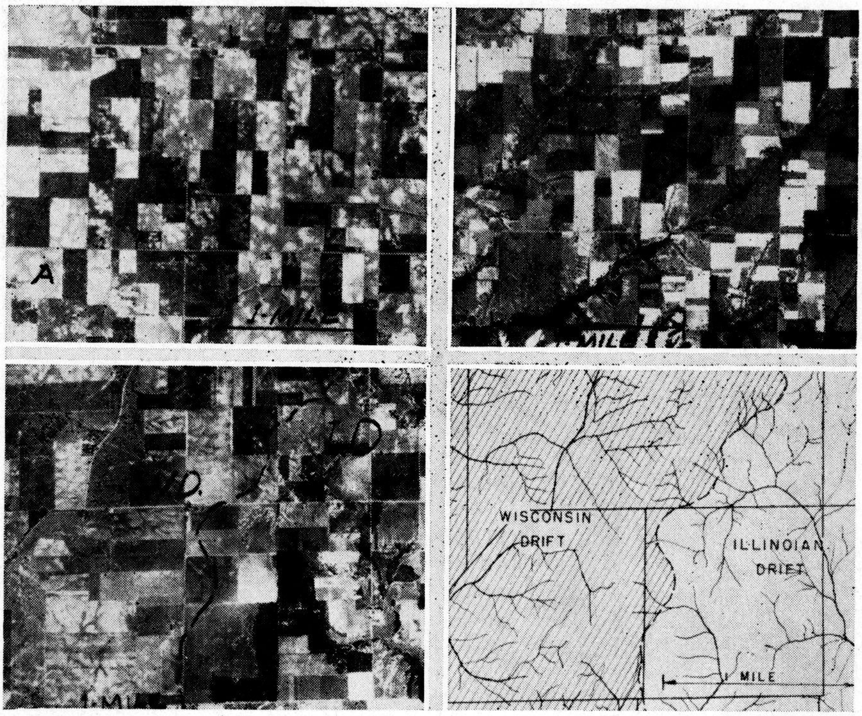

Figure 2. Contrasting glacial drift patterns can be mapped with ease by separating standard patterns. The till plain area, A, of the Wisconsin glacial drift is characterized by a mottled black and white soil color pattern in which the black areas are slight depressions containing organic topsoil on plastic clay; and the light areas are slight knolls, consisting of a silty topsoil on a shallow silty clay horizon. The Illinoian drift till plains are characterized by flat topography, light soil color tones, and white-fringed gullies.

COMPLEX GLACIAL FEATURES AND THEIR PATTERNS

The complexity of certain parts of Indiana's glaciated regions and their airphoto patterns is due to drifts from several glacial invasions. It has been generally accepted by geologists, glacialogists, pedologists, and engineers that the glacial soils of Indiana belong to either the Late Wisconsin, the Early Wisconsin, or the Illinoian glacial periods. However, some writers have discussed the possibility of an older drift—a fact which has long been known and accepted from the analyses of well-log data.

In connection with the airphoto mapping program, current field investigations have indicated the possible existence of large areas of pre-Illinoian glacial drift in Indiana. Also, in numerous localities within the Wisconsin drift areas, this drift frequently occurs only as a thin, superficial mantle overlying the Illinoian and, possibly in some instances, pre-Illinoian drift. These drifts, as a consequence of their partly or completely indurated conditions, have altered the airphoto pattern of the overlying Wisconsin drift, causing a new pattern containing identifiable elements. In some areas of Indiana the presence of complicated glacial features has altered the airphoto patterns to such an extent that changes in soil characteristics must be recognized. Many of these complex areas have been analyzed by airphoto and ground study.

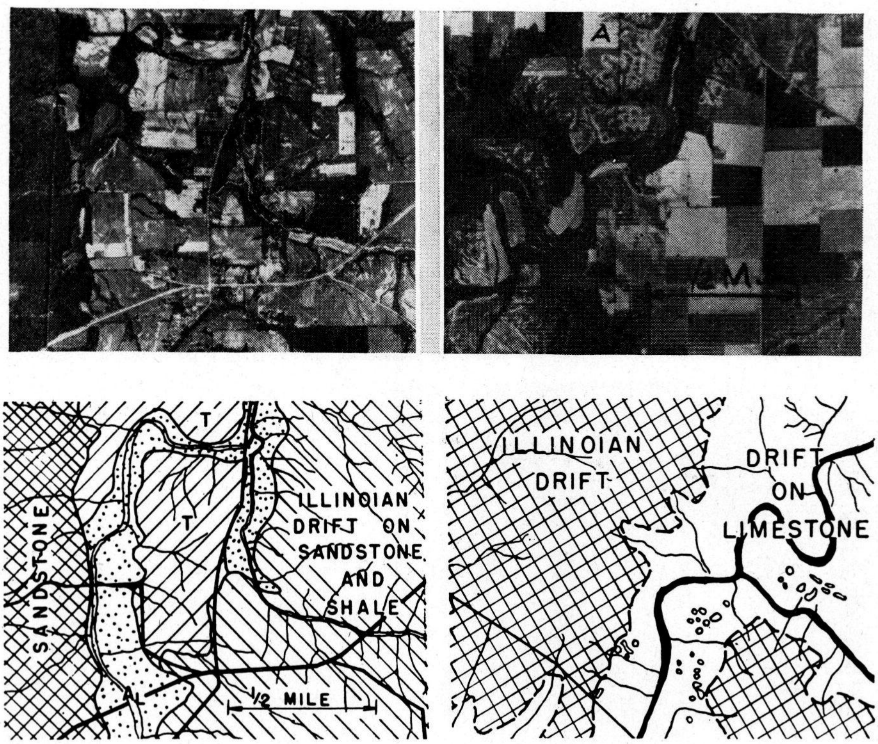

Figure 3. Illinoian Drift Soils on Rock. When glacial drift occurs on rock, the pattern contains elements of both parent materials. This is shown here as drift-on-limestone and drift-on-sandstone. The airphoto of part "A" denotes white-fringed gullies and sinkholes, characteristic of Illinoian drift on limestone. Illinoian drift on sandstone is typified by rough topography, a modified gully fringe, V-shaped gullies, and intense erosion.

Pre-Wisconsin Drift

The pre-Wisconsin materials in Indiana, which in some instances may be pre-Illinoian drift, have been seen in numerous exposures and everywhere show similar composition, structure, and induration. The upper part of the till is weathered to a rusty yellow, a deep red, or a brown color. The unchanged till consists of a very compact material, dark blue when damp but turning pale blue or These cracks and joints are frequently coated with a red oxide of iron. High natural densities and induration are associated with this old drift; in fact, the drift is so dense that a sharp pick, when thrust with full force, only penetrates the surface about one-half inch.

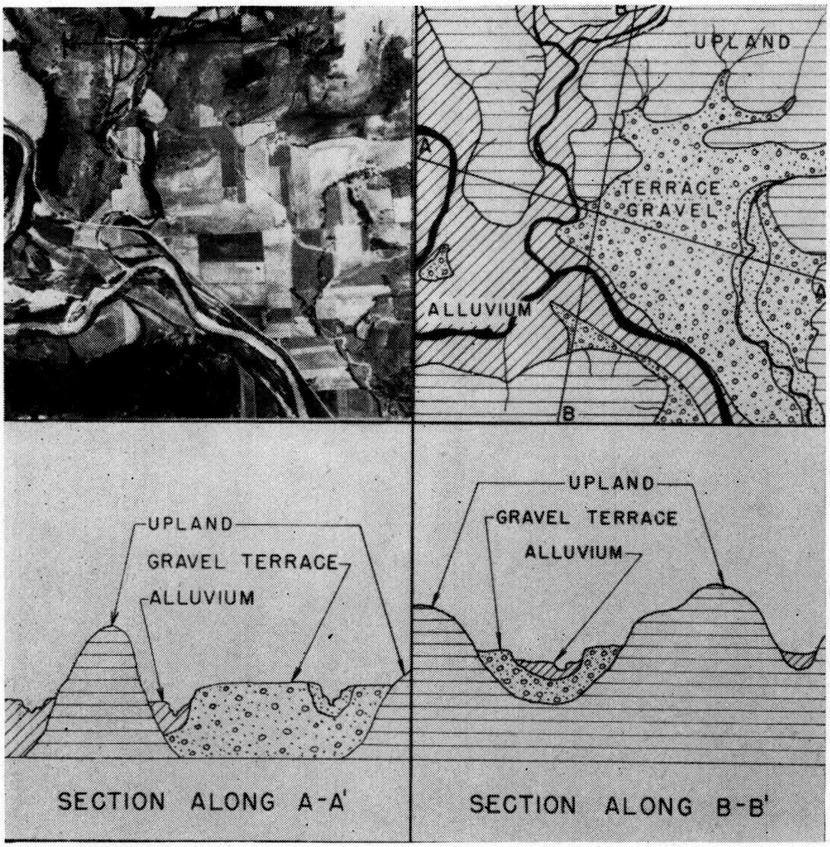

Figure 4. Mapping granular terraces in the larger stream valleys is easily done by separating contrasting patterns. The following materials and their important identifying elements are contained in this photo: Ordovician limestone and shale—rough, yet well-rounded topography, landslides, and long, straight convex gullies; gravel terrace—flat, elevated position between upland and alluvium, light soil colors, current scars, steep terrace faces, short, V-shaped gullies, and a light "speckled" mottling; alluvium—fresh sand streaks from recent currents, light gray to white color tones, and a low topographic position associated with the frist bottoms.

light gray upon drying. The structure of the drift is one of the main identifying elements. In addition to long, straight, frequently diagonal cracks or fissures there are numerous joint planes intersecting at such angles as to give the till a characteristic fracture, resulting in angular fragments a quarter to three quarters of an inch across.

The till is composed of a clay matrix with numerous sand grains and small pebbles. The matrix is a finely ground rock-flour, gritty from the presence of sand grains, but somewhat plastic when wet. Both the oxidized and unoxidized phases are strongly calcareous and contain a preponderance of blue and gray limestone pebbles. Other dominant pebbles are greenstones, quartzite, chert, and disintegrated granites. Some characteristics of these old drift materials are shown in Figures 8 to 13.

Conglomerates

Conglomerates are quite often found in many of the complex glacial areas—usually in association with the major stream valleys. It is believed that these conglomerates are limited in lateral extent, since the only visible influence on the pattern occurs on steep valley faces. Here dense vegetation destroys the more obvious changes in slope that are caused by the presence of massive conglomerate. In general, the conglomerates comprise a cemented cap overlying loose gravel, found beneath Wisconsin drift and above Illinoian drift and, in some places, pre-Illinoian drift. Figures 14 and 15 illustrate the type of conglomerate commonly associated with the major streams.

Wisconsin Terrace Gravel on Older Drift

One of the most important patterns involving pre-Wisconsin glacial influence, and one that is confusing to the interpreter, is the pattern resulting from shallow Wisconsin terrace gravels on older drift (Illinoian or older). This condition is frequently found along the Wabash Valley. The airphoto pattern of this combination so closely resembles the pattern of deeper terrace gravels that unless extreme caution is exercised, the underlying dense, impervious material may be overlooked. Figure 16 illustrates this con-

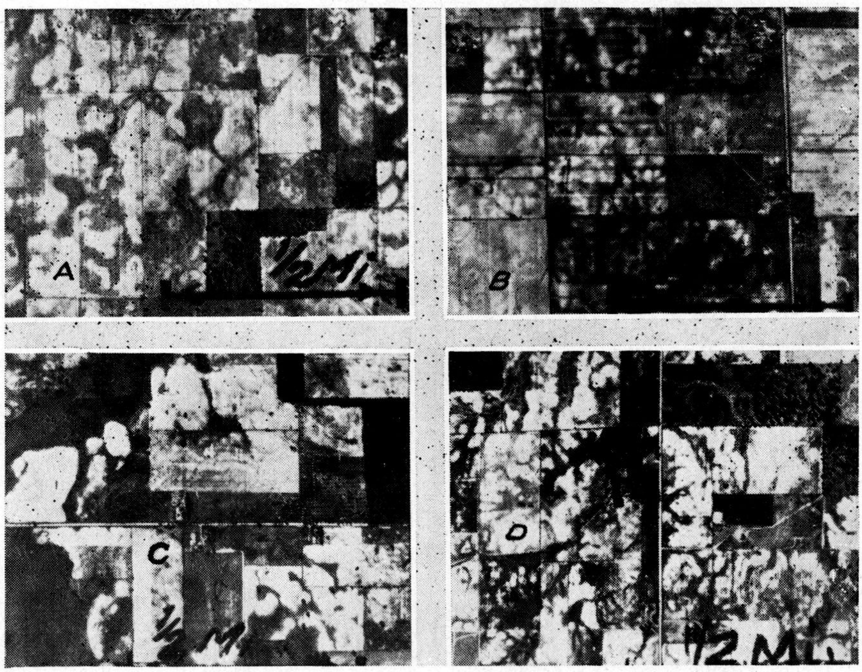

Figure 5. Four Wisconsin Glacial Moraine Patterns. The four moraines shown here are kame morain, A; till moraine, B; semi-granular moraine, C; and ground moraine, or rolling till plain, D. All patterns are similar in that they each have a black and white mottled soil color; however, the shape and extent of the mottlings and their color contrasts are different enough to show a variation in textures. The kame moraine exhibits conical hills, erosion on the steepest slopes, muck-filled channels, and sharp color contrasts. The till moraine, or silty clay moraine, has an over-all gray color tone with very little contrast between the dark and light soils. The dark soil areas are narrow, often elongated, and form subtle drainage channels. The granular moraine is very hummocky, has the infiltration-type pattern, and contains numerous eskers and kames. The ground moraine is gently rolling—a topographic variation of the till plain. This is shown by interconnected dark soil areas.

dition by showing the airphoto pattern, a soil map, a topographic section, and a gully-gradient section in such an area. The area covered by the airphoto is divided into Wisconsin drift upland; a terrace area containing a slack-water zone, sanddunes, and recent gravels, all underlain by pre-Wisconsin drift; and recent stream alluvium. Field investigations have aided in developing the airphoto pattern elements of this complex area. The upland has a modified Late Wisconsin pattern—that is, rolling topography, and black and white irregularly shaped mottlings (see locations 1 and 2, Fig. 16). Some of the gullies flowing from the upland stop at the contact between the upland and inner section of the terrace; others discharge into a large gully which flows along the contact line between the upland and terrace. The drift along the valley wall is semi-granular and, in places, shows evidence of being reworked by water (location 4). The transition zone between the terrace and upland consists, for the most part, of a broad, poorly drained basin (slack-water area) containing deposits of organic clay and silt on dirty gravel (clay-gravel), which in turn rests on pre-Wisconsin drift. In this zone a large pond, dark color tones, depressed position, and a broad, shallow, U-shaped gully indicate the imperviousness of this section of the terrace. In places the pattern gradually changes from a slack-water area to gravel, while in others the two are separated by an area of water- and wind-worked ridges and dunes. Soils of these topographic expressions are very fine sands and silts (see location 5). The gravel area contains the normal terrace gravel pattern inasmuch as it has flat topo-

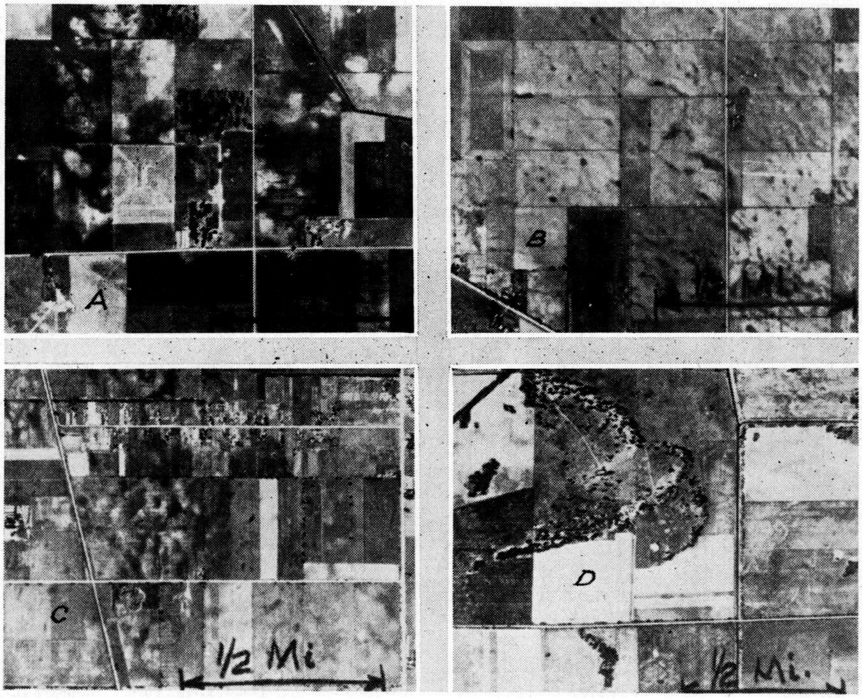

Figure 6. Water-worked and Wind-blown Materials of Wisconsin Drift Region. The chief identifying features of the re-sorted till pattern, A, are: gently undulating topography; sinuous, beachlike ridges; small, irregularly shaped, ponded areas; and a striking color contrast between dark and light soils. Area B contains outstanding features, typical of a granular outwash: light color tone, minute mottlings of infiltration basins, current scars, and flat topography. The gravel terrace pattern in C contains elements similar to those in B. Area D is a lacustral sand plain which has been reworked by the wind, resulting in the formation of crescent-shaped dunes

graphy (Fig. 17); short, V-shaped gullies on the terrace face; an absence of surface drainage; and light, slightly mottled, soil color tones. Field sampling at locations 6, 7, and 9 revealed 8 ft of gravel on pre-Wisconsin drift (Fig. 18).

The influence of pre-Wisconsin drift is shown in several ways, the most outstanding of which is gully gradient and cross-section. The largest gully of the area is labeled B-B. Detailed stereoscopic study followed by field observations shows that: (1) gullies in the slack-water area have broad saucer shapes and light-fringed borders, accompanied by long, uniform gradients; (2) when the gully cuts into the gravel of the recent terrace portion, the cross-section changes to the typical shape, accompanied by a steeper gradient, (Fig. 19); and (3) as the underlying indurated, old drift is reached, the gully can no longer maintain its saucer shape, thus causing the grade and cross-section to change; the grade is lessened and the gully section becomes flat-bottomed with sharp, steep sides.

Other elements which suggest the presence of the underlying material are numerous circular-shaped basins resembling sinkholes and an abrupt slope change on the terrace face.

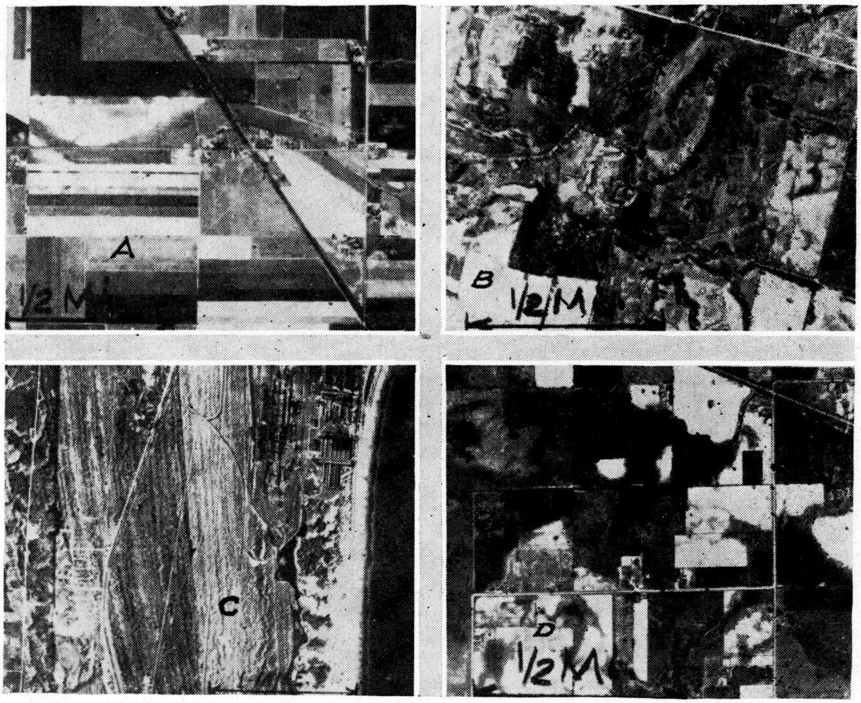

Figure 7. Miscellaneous Patterns Associated with Glaciation. Pattern A shows a southern Indiana glacial lakebed, formed by the damming-up of the Ohio River during or following glaciation. The main identifying elements are flat topography rectangular road and field patterns; and broad saucer shaped, meandering gullies. Eskers and kames are contained in B. Crescent-shaped forms identify sand dunes; long, sweeping, parallel streaks identify beach ridges which occur along the shore of Lake Michigan (shown in C). Area D illustrates the dark color tones of muck and peat areas.

Intermixed Wisconsin Drift and Gravel on Illinoian Drift

Quite often the airphoto pattern is complicated by patches of Wisconsin till or gravel over Illinoian drift, rather than the usual upland-terrace-alluvium relationship, (see Fig. 21). Several features of this pattern are pertinent. As far as engineering materials are concerned, gravel deposits occur along the main stream valley and along the large gullies; shallow Wisconsin drift occurs elsewhere throughout the area. The most prominent feature of this pattern is its similarity to deep gravels, thus making it easy to mistake for a terrace. Another significant feature is the presence of sharp, V-shaped gullies on the break of the valley face. Elements which indicate the presence of underlying Illinoian drift are the irregularly shaped sinklike basins, compound gully gradients and cross-sections, interconnected basins, a pre-Wisconsin drainage channel, A, and a modified white-fringed gully system.

Several locations where ground studies were made have been marked on the photo. Location 1 (Fig. 21) is a highway cut on the face of the valley wall. This cut exposes a conglomerate cap on 20 ft of blue, dense, parent Illinoian drift. Figure 22 is a ground view at this site. The arrow at 2 locates a borrow pit situated about 500 ft from the upland edge of the valley wall, somewhat higher in elevation than the conglomerate. At this location the pit appears to be in an old gravel-filled channel in the Illinoian drift. An exposure on one face of the pit revealed about seven feet of Wisconsin drift on conglomerate, (see Fig. 23). The conglomerate grades into loose sand and gravel which, in turn, rests on Illinoian drift. The borrow pit occurs at a slight break in the topography and it is believed that the gravels being removed are from two glacial epochs. The

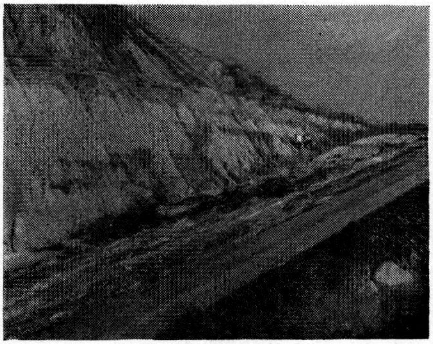

Figure 8. This photograph illustrates three glacial drift deposits exposed in a coal mine in central Indiana. The various drift sheets here are separated either by layers of sand and gravel or by gumbotil.

Figure 9. The dense cubelike structure of pre-Illinoian drift is clearly revealed in this picture.

Figure 10. This flat-bottomed gully is found in areas where Wisconsin drift rests on pre-Wisconsin drift. Gully formation has been altered upon reaching the compact, subjacent drift.

Figure 11. Wisconsin on Pre-Wisconsin Till. That these soils are of different age is manifested by an abrupt change in structure, texture, color, and induration.

arrow at 6 indicates crop terracing—an erosion control measure occurring on the slight topographic break between the old drift and gravel terrace. Field inspection of the gully at

Figure 12. An Example of the Intense Fracturing Which is Characteristic of the Dense, Unweathered Illinoian Till. The high natural density of this material is an adverse factor in highway excavation.

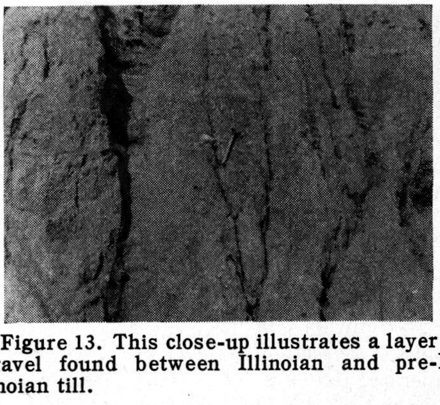

Figure 13. This close-up illustrates a layer of gravel found between Illinoian and pre-Illinoian till.

location 3—the headward part of the gully—revealed 1 to 3 ft of gravel on Illinoian drift. This gully appears to be orientated by a chain of sinklike basins with white fringes.

At location 4 was found a large gully or channel in Illinoian drift containing small late Wisconsin gravel terraces. This channel is of local interest, since it can be traced from the Wabash River to its junction with the Tippecanoe River, several miles north; this suggests that at one time it may have served as an outlet for that river. Evidence that this channel carried vast quantities of water

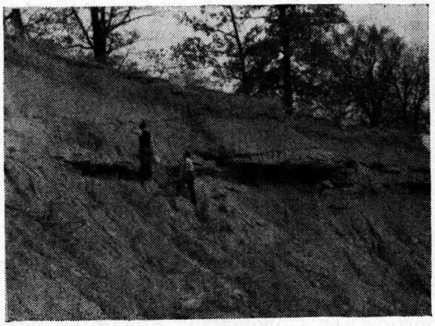

Figure 14. Wisconsin Drift on Conglomerate (Probably Illinoian in Age)

Figure 15. A Close-up of Conglomerate

is illustrated by gravel terraces in its valley. (See location 5.)

Pre-Wisconsin Gravels or Outwash

Until the State has been completely mapped and all of the airphotos studied, the extent of the sand-clay and gravel-clay deposits will not be thoroughly known. These deposits often occur as elevated terrace remnants, higher topographically than the recent terraces in the major stream valleys; or they may also occur as upland outwash. The origin of these sand-clays is not entirely understood, nor is the airphoto pattern. However, even though this material has not been fully explored, the airphoto pattern has certain distinctive elements. The significant elements are generally light color tones with dark, irregularly shaped mottlings, many of which resemble small sinks; broad surface drainage ways; and a County deposit is similar to that in Parke County inasmuch as it occurs as an elevated terrace, higher than the recent terraces. The Morgan County sand-clay area occurs as an outwash mantle over rock; however, this pattern has been influenced by a granular moraine of recent Wisconsin age.

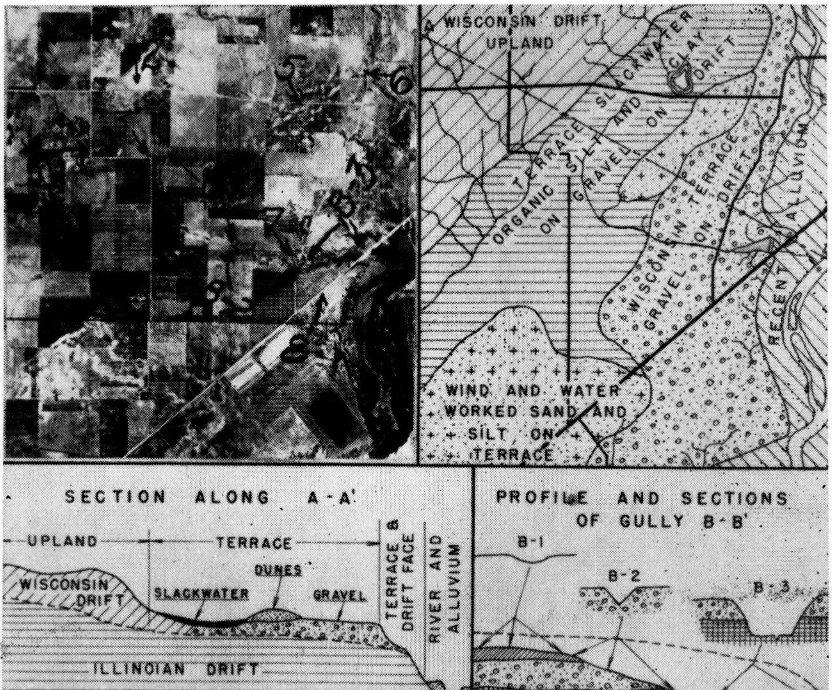

Figure 16. Wisconsin Gravels on Older Glacial Drift. This combination of airphoto, map, and sketch illustrates a condition commonly occurring along the Wabash Valley, where a shallow deposit of recent terrace gravel overlies older drift. The importance of this combination is that greater quantities of gravel than present may be predicted; and the absence of a dense, impervious underlying material may be overlooked. A hasty examination indicates the typical upland-terrace-alluvium relationship; however, a detailed examination of the photos in conjunction with field inspection reveals shallow gravel on Illinoian drift. (See the text for the pattern elements and description of the sketches.)

white "overwash" appearance. Figure 24 illustrates sand-clay materials in Owen, Parke, Morgan, and Fountain counties. In Owen County this material occurs as a surface outwash, covering limestone and situated in an upland position. In Parke County the sand-clay occurs as a terrace remnant, and is considerably higher in position than are the recent Wisconsin glacial river terraces. Another deposit is found as valley-fill material in a sandstone-shale valley. The Fountain

Changes in the Drift Borders

One of the glaciological questions in Indiana is the location of the southern limit of glaciation, or the lower Illinoian glacial drift border. The Illinoian glacial drift border was first established early in the 1920's after much field reconnaissance and study of the glaciated regions of Southern Indiana (*18*). Since the original determination, geologists have done much work in modifying this border. Foremost were observations made by W. D. Thornbury (*21*), who found glacial boulders several miles south and west of the existing glacial border in southeastern Indiana. Evidence of glaciation west of a high sandstone escarpment (locally, the "Knobstone") was an important discovery, which meant that the Illinoian glacier overrode the escarpment rather than butting up against it, as previously thought. He noted, furthermore, that the topography of this region strongly resembled the glacial regions to the north.

Figure 17. Flat Topography, an Identifying Element of Gravel Terraces. This photo was taken at location No. 8, Figure 16.

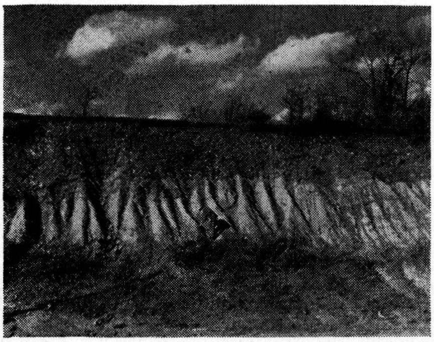

Figure 18. Wisconsin Gravel Terrace on Illinoian Glacial Drift. This was taken at location No. 9, Figure 16.

An airphoto analysis of the Wisconsin-Illinoian border shows rather close agreement with the presently recognized drift borders, with the major exception being the presence of either Illinoian drift or an Illinoian drift-like material in Washington and Harrison counties. Additional field investigation is needed before the border can be established in these counties.

The lower limit of glaciation in southwestern Indiana cannot, at present, be as accurately determined from airphotos as in the southeastern part because of the deep loessial overburden. Considerable field exploration and sample data correlated with detailed airphoto interpretation will be required before this border can be plotted. Other revisions may be necessary as mapping progresses.

Figure 19. Gravel Gully. As long as the gully remains in granular soils it maintains its usual "V" shape. See location 7 or B-2, Figure 16.

Figure 20. A Flat-bottomed Gulley, Illustrating the Gully-shape When the Subjacent Pre-Wisconsin Drift is Reached. See Location 7 or B-3, Figure 16.

ENGINEERING SIGNIFICANCE

There are undoubtedly a great many questions which might be raised concerning certain aspects of airphoto soil interpretation, soil mapping, glacial phenomena, and their relation to highway and airport engineering. A first question might be: What are the limitations of airphoto interpretation in highway or airport engineering? Another: Why should the highway engineer, engaged in airphoto soil mapping, be concerned with buried valleys and glacial features, such as sand clay terraces, old drift or others, obviously of a geologic or even perhaps an academic nature? Still another: What difference does it make to the highway engineer whether the Illinoian glacial drift border is in one county or another? Questions like these involve pertinent issues and, therefore, should not remain unanswered.

As mentioned before, some limitations have been imposed upon the prediction of deep gravel terraces along the major channels in central and northern Indiana. This is due to the fact that these areas contain thin gravel beds on older glacial drift. Ability to predict the presence of underlying pre-Wisconsin glacial drift means predicting difficult excavation, seepage difficulties, and perhaps the extent of granular materials; all of which are of utmost importance to the highway engineer.

In addition to relatively clean gravels and sands are sand-clay and gravel-clay deposits, believed to be associated with Illinoian glaciation. From the composition of these materials it appears that they should be a potential source of base course material. Their use in surfacing county roads also should not be overlooked.

Because of differences in soil characteristics

Figure 21. Wisconsin Drift and Gravel on Pre-Wisconsin Drift, Illustrating the Resemblance of This Pattern to That of a Gravel Terrace. The surface materials are erratic in their distribution over this area. The Late Wisconsin gravels occur chiefly along the valley exposures in the main stream and in a narrow band flanking the three main gullies of areas A, B, and C. The remainder of the area consists of shallow Wisconsin drift on pre-Wisconsin drift (Illinoian). (See the text for a description of the pattern.)

Figure 22. Conglomerate on Illinoian Glacial Drift. Location 1, Figure 21.

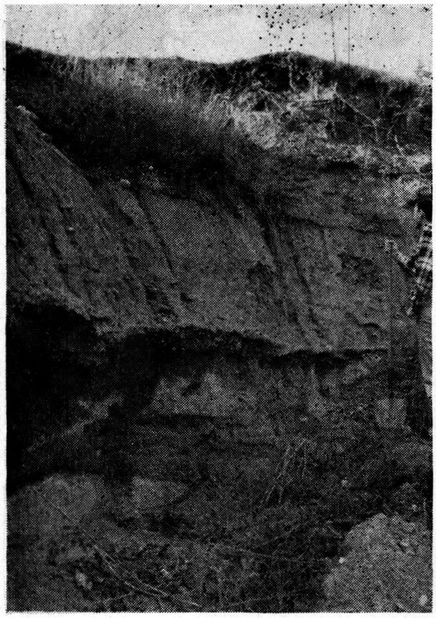

Figure 23. Wisconsin Drift on Conglomerate. Location 2, Fi_ure 21.

of the Wisconsin and Illinoian drifts, as well as in the residual soils to the south, as much refinement as possible in these borders is desirable. This refinement assists the engineer in coping with the problems concomitant with significant soil-boundary changes, such as construction, maintenance, and drainage requirements. In a few instances the glacial drift borders may be revised considerably.

The location of pre-glacial drainage from airphotos is still in its preliminary stages. As yet it is debatable whether the pre-glacial network can be discerned from the photographs; however, much study is being devoted to this problem. The ability of the observer to obtain an over-all picture from assembled mosaics aids in locating any surface features which might be indicative of these ancient channels. Dark areas meandering haphazardly across several Indiana counties lead the interpreter to wonder about their origin. These broad depressions, many of which do not carry streams, cross one another at many angles; and several which were investigated in the field contain deposits of drift which may

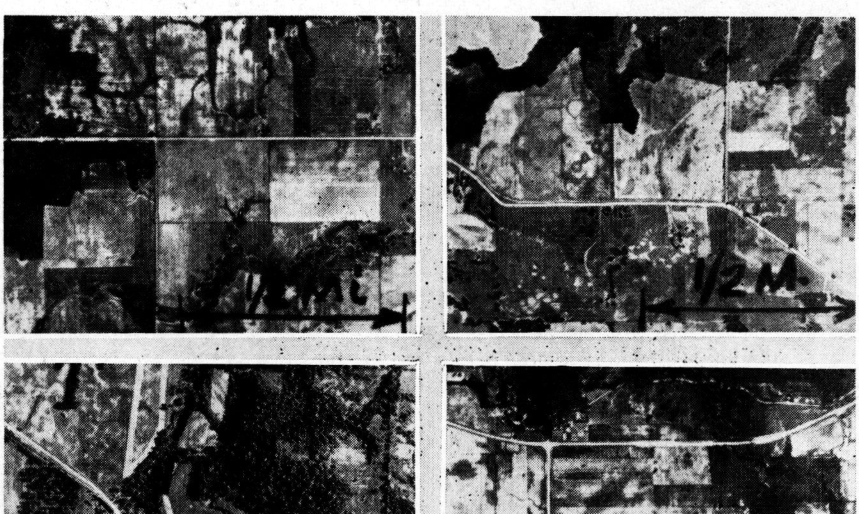

Figure 24. Patterns associated with the sand-clay and gravel-clay terraces or outwash areas are believed to be associated with the Illinoian glacier. The general pattern elements are light, mottled color tones; subtle, broad drainage ways; dark basin-like depressions; and modified current scars. The soils consist of deep deposits of sand-clay and gravel-clay. These patterns occur in Parke, Owen, Morgan, and Fountain counties.

be older than Illinoian in age. Should additional research correlate pre-glacial drainage with airphoto patterns, such studies will prove of great value in tapping deep water supplies.

The recently initiated soil mapping program, is comprehensive and data are now being obtained in great detail. When the project is completed, maps will be available which will show the location of potential sources of aggregates, base course materials, and materials for low-cost state and county roads. Soil maps will be available for use in evaluating pavement performance, and also for the design of pavements on a regional basis. The speed with which the program will proceed depends largely on the accuracy and refinement with which these complex glacial features can be evaluated from aerial photographs.

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