of field research projects might well be set up on the shoulders of these new roads to determine, for example:

1. How soils of various textural classification and sand, silt, clay proportions may be mixed with granular materials (cinders, gravel, etc) to produce an earth shoulder which will support traffic in all weather.

2. What the relationships are between plastic index and other soil test reactions, and the ability of a shoulder soil to support good turf.

3. How far may soils of various granular and clay, silt, and loam components be compacted toward maximum density without unduly prohibiting turf growth.

4 What grasses form the best turf cover particularly in those areas which represent transitions between typical cool, humid, western dry, and southern warm humid regional conditions

5. What the relationships are between various soil and climatic conditions, topography, and slope and gutter cross sections, and the design of shoulders as to surface pitch, surface soil, subgrade soil, width, type of best protective surface cover, etc.

The American public and highway engineers are alike disturbed by the increase in serious traffic accidents daily recorded by the press and radio. The Committee on Roadside Development suggests that nothing may do more to make our highways safer, more convenient and more beautiful than improvement in design of highway cross sections. The traffic lanes, the shoulder, the drainage area, the slopes and the strip of land bordering the highway must be considered as of equal importance in improving highway design.

We have learned to construct excellent pavements. Is it not high time that we resolved to design shoulders, and other portions of the highway cross section to equally high engineering standards?

DEPARTMENT OF MATERIALS AND CONSTRUCTION

C. H. Scholer, *Chairman*

IDENTIFICATION OF GRANULAR DEPOSITS BY AERIAL PHOTOGRAPHY

By Robert E. Frost, *Research Engineer*

Joint Highway Research Project, Purdue University

SYNOPSIS

This paper discusses the techniques used to interpret granular materials from aerial photographs This method of granular surveying is of great importance to highway and airport engineering because good sand and gravel are always at a premium whether it be as a source of borrow for subgrade improvement, base courses, for concrete aggregrate, or for location purposes Often it is not possible to locate highways or airports on ideal natural granular situations such as terraces or outwash plains because other influencing factors outweigh that of soils The importance of granular material to successful construction and performance makes it necessary to survey the area in great detail for available materials

In making a field reconnaissance, one is often handicapped by the inability to trace the areal extent of a deposit because of such factors as inaccessibility to the land because of lack of roads, dense vegetation or lack of co-operation on the part of the owner Such is not the case when studying a large area with the aid of aerial photographs The observer is able to view large areas from above and when a stereoscope is used the relief of an area can be studied Since the average pattern produced by granular materials is one of the easiest to identify, it is possible to make an airphoto survey of an exceedingly large area in a very short time

There is no standard airphoto pattern that contains all elements of the granular pattern. This is due chiefly to the variations in occurrance and to the variations in depth and type of natural overburden on such land forms. The various land forms in which granular material can occur are kames, eskers, glacial outwash, terraces, lacustrine beach ridges, recent alluvium, coastal plains, and great plains and great plains outwash mantle.

The various elements of the airphoto pattern needed for identification of any soil region are color tone, land form, gully shapes, land use, erosion, vegetative cover, and drainage pattern The more general elements of the gravel pattern are· one of the characteristic land forms associated with the physiography of the region; light color tones, a mottled effect; occasional current scars, orchards, gravel-type gullies; and a general absence of surface drainage

The paper presents illustrations of granular patterns from such widely spaced states as Washington, Ohio, Montana, Indiana, Utah, Wisconsin, South Dakota, and Minnesota.

One of the greatest advantages of aerial photographs in highway engineering is their use in locating deposits of granular materials. Good sand and gravel are always at a premium in highway and airport runway construction whether it be as a source of borrow for subgrade improvement, for base courses, for concrete aggregate, or for location purposes—the engineer must know the location and extent of such deposits. It is not always possible to locate highways or airports on ideal natural granular situations such as terraces or outwash plains because often the other influencing factors outweigh that of soils. However, because of the importance of granular materials for successful construction and performance it is essential that the surrounding area be studied in great detail for available improvement materials.

Considerable time and expense may be involved in locating granular materials by the conventional methods of field reconnaissance which at times may be inaccurate and unreliable. In making a field reconnaissance, one often is handicapped by inability to trace the areal extent of a deposit. Such factors as the inaccessibility to the land because of lack of roads, dense vegetation, or lack of co-operation on the part of the owner may prevent successful surveying. In the field it is difficult to grasp or recognize the topographic positions and land forms associated with granular materials simply because of inability to see great distances. To grope blindly throughout an area, boring here and there, asking land owners about gravel on their lands, or to drive countless miles through an area is not only time consuming but costly.

Such is not the case when studying a large area with the aid of aerial photographs. The observer is able to view large areas from above and when a stereoscope is used the relief of an area can be studied. Since the average pattern produced by granular materials is one of the easiest to identify, it is possible to make airphoto surveys of exceedingly large areas in a very short time—once the elements of the pattern are fully understood and are properly utilized. For example, in some of the larger glacial outwash areas granular surveys of hundreds of square miles could be made in a few hours' time by merely outlining the general granular areas on an assembled mosaic of that area. The speed with which granular material can be located depends on the type of area and the extent of gravel deposits Some areas contain little or no granular material, in which case considerable time would have to be spent in studying the area to make certain that no deposits were overlooked.

GEOLOGY OF GRANULAR DEPOSITS

In locating sand and gravel by any method considerable time and expense can be saved if the surveyor or engineer is familiar with a few of the basic principles concerning the various ways in which such materials originate. Even slight geologic knowledge about the "rhyme and reason" of granular deposition often will be a deciding factor in the amount of time spent in an area. Granular deposition follows the natural laws or methods of deposition and can be expected to be found only under certain conditions and never found occurring under others.

In general, granular deposits are closely associated with one of the many methods of deposition by running water Running water has the ability to sort materials, carried by its force, into sizes from coarse to fine, depending on the velocity and changes in velocity of the currents. This may occur on a scale varying in magnitude from that of a small gully carrying and depositing clay and small pebbles to the tremendous outflow of glacial melt water many miles in width flowing outward from beneath a mass of ice many thousands of feet in thickness and moving boulders weighing several tons.

Geologically speaking there are two types of granular deposits: (1) those formed in the geologic past and occurring on a grand scale and associated with the destruction of mountain ranges by erosion and the subsequent deposition of vast fluvatile plains such as portions of the great plains or the coastal plain; and (2) the recent granular deposition associated entirely or indirectly either with glaciation or the development of stream terraces, lake terraces, and recent alluvium.

Granular materials associated with glaciation will be found occurring in such land forms as valley trains or stream terraces, outwash plains, kames, and eskers. Often large glacial lakes are fringed with associated granular deposits occurring as beach ridges, granular beaches, or granular terraces. The granular deposits associated with normal stream development, other than the glacial streams, are either found in terrace position or in the stream bed itself Granular deposits associated with lakes, other than the glacial lakes, may be found as elevated terraces, beach ridges, or granular beaches In general, the great plains gravels are found either as isolated remnants of a once great fluvatile plain or as terraces in the stream valleys that drain the plains Usually the granular materials in such instances are not too far distant from the mountains which were their source.

AIRPHOTO INTERPRETATION OF GRANULAR DEPOSITS

There is no standard airphoto pattern that contains all the major elements of the granular pattern This is due chiefly to the many variations in depth and type of natural overburden. For instance, the gravel pattern of kames and eskers has elements differing from those characteristic of outwash or terrace gravels. On the other hand, glacial outwash gravels produce a pattern similar in many respects to that found in some areas of the great plains. Even though granular deposits exhibit a pattern that rarely is duplicated in non-granular areas it is important that the general geologic events related to the area be traced because if the structure and the geologic events of an area were such that granular deposition could not have taken place, then surveying by any method would be futile. By proper use of the techniques of airphoto interpretation, it is possible to identify the major deposits of parent materials of an area and to trace, with a fair degree of accuracy, the geologic history pertinent to the development of the region.

The technique of identifying soils from airphotos is based on evaluation of certain elements of the soil pattern which are directly related to geology, climate, texture, physiography, ecology, pedology, and certain man-made influences. The more important photo elements of any soil pattern are: land form, vegetation, gully shapes, drainage system, color tones, and land use The main photo elements of a gravel pattern are: a characteristic land form (dependent on geologic events); a light soil color tone; a well-drained appearance by an absence of surface drainage; evidence of water or ice deposition; and a characteristic gravel-shape in gullies, if such occur.

AIRPHOTO INTERPRETATION OF GRANULAR TERRACES

Since granular terraces are perhaps the simplest of all granular land forms to illustrate and discuss, the major portion of this paper will be devoted to presenting a detailed analysis of the airphoto patterns of such land forms. One important reason for using terraces to illustrate granular materials is that they contain possibly the greatest number of airphoto elements of any of the granular patterns. Further, the wide range in climatic conditions under which terraces are found makes it possible to study the granular elements under moisture conditions ranging from arid to humid. The discussion on terraces is accompained by airphoto and ground-photo views of each of the pattern elements. Rather than exhibit terrace patterns that contained all the elements, which often is rare, each element is presented in individual photos. Figure 1 is an idealized sketch showing the relation between alluvium, terrace, and upland.

Land Form. Terraces, whether granular, non-granular, or granular covered with an overburden, will always have one element present in the airphoto pattern, which happens to be the dominating element—that of the terrace-type land form. The land form of

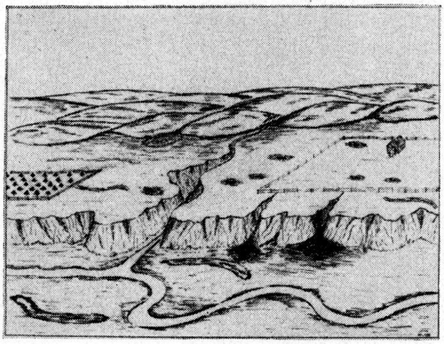

Figure 1. Idealized Sketch of a Stream Valley Containing a Granular Terrace. The sketch illustrates many of the identifying elements of a gravel terrace pattern. The most important of which are: elevated position situated between the alluvium and the upland; flat topography; near vertical faces; current scars; an orchard; short, steep-sided gullies that do not extend far into the terrace; absence of a surface drainage system; alluvial fans at the contact between upland and terrace and between lowland and terrace; and a mottled surface.

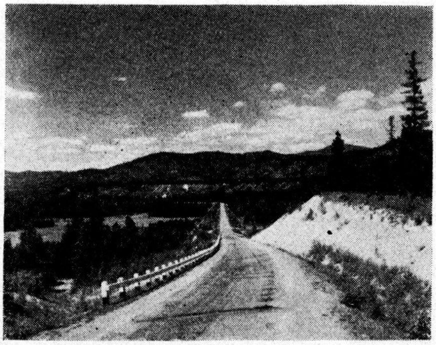

Figure 2. Terraces in the Kootanai Valley in Western Montana. This view illustrates the relationship existing between alluvium, terrace, and upland.

all terraces is essentially that of a flat-topped plain whose topographic position is higher than that of the recent alluvium. Figure 2 is a view of a gravel terrace situation in a relatively young glacial valley in western Montana. Figure 3 illustrates the flat topog-

Figure 3. Terraces are essentially flat topped plains as is illustrated in this Whitewater Valley (Indiana) terrace photo.

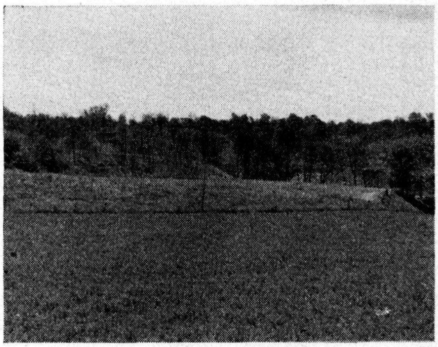

Figure 4. Multiple Terraces in the Whitewater Valley (Indiana). Both of these terraces are granular.

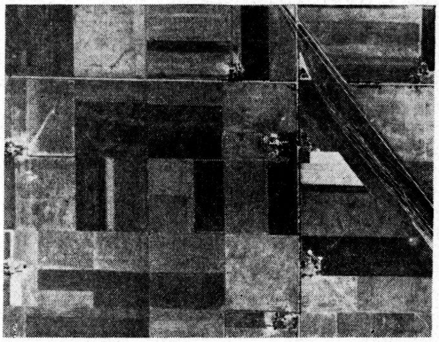

Figure 5. Airphoto Illustrating flat Topography. This Rock River (Wisconsin) terrace portion contains such elements as absence of erosion scars, a rectangular highway system, and a checkerboard field pattern.

raphy associated with gravel terraces (Whitewater Valley, Dearborn County, Indiana). Often multiple terraces occur in stream valleys

Figure 6. Airphoto pattern of a terrace in which the terrace face is indicated by a narrow band of short parallel gullies. (Spokane Valley, Wash.)

Figure 7. Airphoto pattern of a terrace in which the terrace face is indicated by a narrow band of trees. (White-water Valley, Indiana.)

Figure 8. Airphoto pattern of a granular terrace that contains some typical gravel-type gullies. (Wabash Valley, Indiana.)

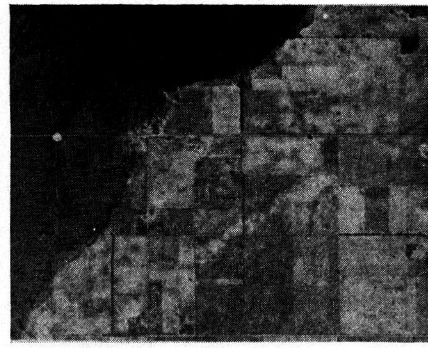

Figure 9. Airphoto showing the contrast in color tones existing between light colored (well drained) terrace soils and dark colored (poorly drained) alluvial soils. (Wabash Valley, Indiana.)

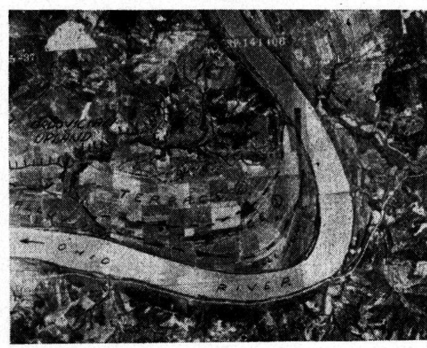

Figure 10. Airphoto pattern of a terrace situated in a bend of the Ohio River (Indiana) in which the characteristic current streaks are clearly seen.

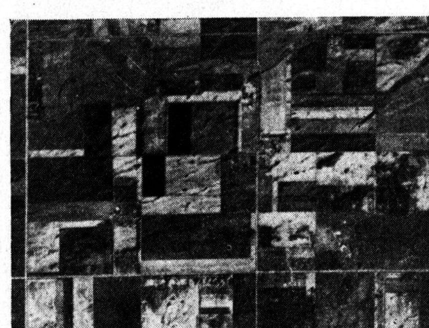

Figure 11. Current Scars and Ridges in the James River Valley of South Dakota.

as is illustrated in Figure 4. In the airphoto pattern the flat topography is illustrated by such elements as absence of erosion scars, a rectangular highway system, and a checkerboard field pattern (See Fig. 5, Rock County, Wisconsin).

Near-Vertical Faces. Another element of the terrace pattern is that showing near-vertical and often vertical faces on the stream side of the land form. The airphoto pattern exhibits this in many ways, of which the most important is made possible by stereo-vision. Under stereo-vision, if terrace faces appear steep it is a strong indication that the material is coarse in texture. Without stereo-vision the steep faces are shown in other ways. A terrace face will either appear as a narrow fringe or band of trees, or as a narrow band of gullies, all of which are very short in length and are parallel. Figure 6 illustrates a terrace pattern in a semi-arid region (Spokane River, Washington) which shows a narrow band of short gullies outlining the face of the terrace. The absence of vegetation makes it possible to see such gullies. In humid regions the vegetative cover will hide the gullies and the terrace face will be outlined by the trees. Figure 7 is an airphoto pattern of a terrace (Whitewater Valley, Indiana) that is outlined by a narrow fringe of trees. If the fringe is narrow, a steep face is usually suggested.

Gullies. Gullies in granular material are short, have a steep gradient, and are V-shaped. In the photographs, gullies are light in color (often white) and often appear as notches or nicks on a terrace face. Under stereo-vision such gullies are very steep and usually have small alluvial fans at the contact between the terrace and alluvium. Gravel gullies do not extend well back onto the terrace plain. The airphoto pattern of such gullies is shown in Figure 8 (Wabash Valley, Indiana).

Color Tone. Nearly all well-drained soils exhibit a relatively light color tone, especially when occurring in an elevated position such as that occupied by stream terraces. Often color contrast alone is sufficient to rate the relative porosity of two adjacent soil areas. (See Fig. 9, lower Wabash Valley, Indiana). This is because wet or moist soils or soils having a high clay content always photograph darker than soils with low moisture content. In humid regions where rainfall is frequent and regular, the well-drained soil areas dry out at a much faster rate than those having a high silty clay or clay content which results in high contrast between color tones.

Flow Pattern. Often terraces exhibit a stream-flow pattern which consists of a series of light and dark streaks which are usually parallel to the direction of flow. These white, or lighter colored, streaks are ridges of sand or sand and fine gravel deposited by current action in a manner similar to the deposition of sand bars. The elongated darker streaks are depressions carved by strong undercurrents. These appear dark because they were left as lakes following the high water period and have a high clay and silty-clay content. Those occurring in the large bends of stream valleys have a photo pattern similar to that shown in Figure 10 (Ohio Valley, Indiana), while others situated in larger valleys and on broad terraces resemble the pattern shown in Figure 11 (James Valley, South Dakota). The chief significance of such markings lies in the fact that they suggest stream deposition and in order to have stream deposition at such elevated positions and occurring on such a large scale, there must have been large volumes of swiftly flowing water. Since swiftly flowing water allows only the coarse material to settle, the terrace must contain a large percentage of gravel.

Stream Dissection. Terraces occurring in large valleys, especially the larger glacial valleys, may be considerably dissected and often are left as isolated remnants. This is particularly true in portions of a valley that receive the tributary streams. Figure 12 illustrates an isolated terrace remnant in Clark County, Ohio, which is the result of the carving action of two large streams and a small tributary stream. The significance of this development lies in the fact that streams whose capacity is sufficient will cut a deep channel across a gravel terrace rather than flow on the top of the terrace as it would if the terrace were clay or silty clay. In a granular terrace such a stream channel would have steep faces and be flat bottomed while in fine-textured soil terraces, the channel would have softly rounded slopes.

In instances where a tributary stream does not have sufficient discharge and velocity to cut across the main valley terrace, the granular material may resist the flow and cause the stream to be deflected and to flow along the contact between terrace and valley wall. Figure 13 illustrates a condition in which a granular terrace has forced a tributary stream to flow two miles along this contact line before reaching the major stream (Ohio River Valley in Switzerland County, Indiana).

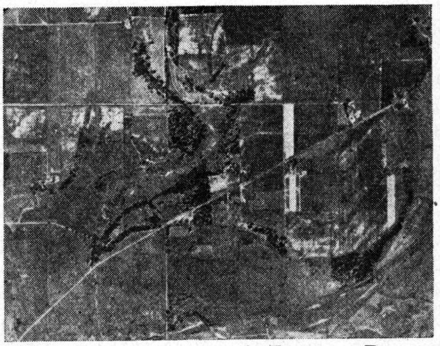

Figure 12. An Isolated Terrace Remnant Caused by the Erosive Action of Two Main Streams and One Small Tributary Stream. The terrace face is outlined by a fringe of trees. (Clark County, Ohio.)

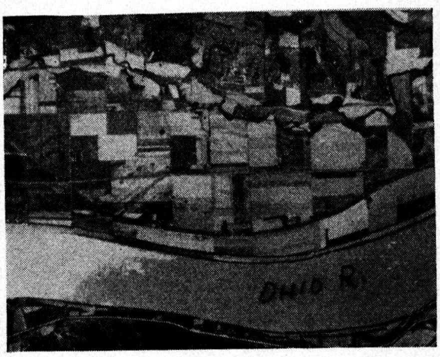

Figure 13. Ohio River Valley Terrace Isolated by a Tributary Stream. In this case the gravel caused the stream to be deflected and to flow along the contact line between terrace and valley wall.

Figure 14. This Wabash Valley airphoto illustrates the mottling effect which is an excellent indication of granular material. (Vigo County, Indiana.)

Drainage Pattern. The drainage pattern is one of the most important elements of the terrace pattern because if interpreted correctly it is possible to evaluate the texture of not only the terrace proper but of the overburden as well. Figure 14 illustrates the characteristic mottling effect of a well-drained terrace situation on the Wabash Valley at Terre Haute, Indiana. This mottling is perhaps one of the most difficult of all elements to describe; however, it is one of the most important since it nearly always is an indication of gravel. Roughly speaking the pattern is said to be "worm-eaten" or "tapioca-like" in appearance since it is generally light and is speckled with small irregularly shaped dark areas. The dark areas are small clay-like pockets that have been formed by the normal weathering processes of the gravel-sized material. The coarse material usually contains

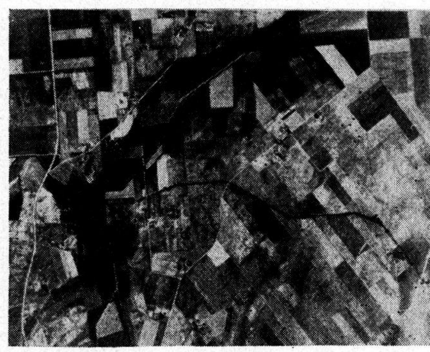

Figure 15. Channeling often occurs in low and broad terraces as is illustrated in this lower Wabash Valley photo. (Knox County, Indiana.)

limestones, granites, and other clay-forming materials which weather to a soil material. Situated, then, as depressions they act as small infiltration basins which result in a higher moisture content and a darker color pattern. The stage of development of such phenomenon usually is related to the amount of "B" horizon, or clay, in the upper portion of the terrace. This does not occur in flat, sand areas which are composed of weather-resistant quartz.

Channels in Low Terraces. Low terraces situated in broad valleys occasionally are flooded and they receive deposits of silt and clay which tend to destroy certain phase of the gravel pattern. This flooding is usually accompanied by channeling and scouring which dissect the area considerably. Figure

15 illustrates this condition with an airphoto pattern of a Wabash Valley terrace in Southern Indiana. The channels often resemble abandoned stream meanders since they are broad, have sweeping flow lines, are dark in color, and are softly rounded in cross section. The dark color is due to the increased clay content, which often is organic, and has a higher moisture content.

Land Use. Because terraces occupy elevated topographic positions, are flat, easily cultivated, well drained, and contain relatively rich top soil, they are farmed extensively. The field pattern is vastly different from that of either the upland or of recent alluvium. In the alluvial areas the field pattern is controlled largely by sand ridges, old channels, slack water areas; in the upland areas the field pattern is controlled largely by relief. Orchards occurring on flat ground usually suggest porous soil conditions.

INTERPRETATION OF OTHER GRAVEL PATTERNS

Even though the gravel pattern of each of the various land forms will vary somewhat, certain dominating elements will always be present for identification purposes. There may be variations in certain elements themselves and new ones may be present, but detailed stereo-inspection of the land form, gullies and color tones, together with logical reasoning, will combine for successful interpretation. Often the more general elements of a stream-terrace pattern will apply to the pattern of gravel occurring in outwash areas, the great plains, or the coastal plain. Some of these elements are color tone, gully shapes, flow markings, and mottling effect. On the other hand such granular deposits as eskers, kames, and beach ridges contain a different set of elements which, if properly evaluated, will correctly identify the deposits. Figures 16 to 33 contain airphotos and ground photos which illustrate many of the other granular patterns.

Great Plains Granular Deposits. The granular deposits located in the great plains region occur either as isolated remnants of fluvatile plains or as terraces in stream valleys which drain the plains. However, because of the magnitude of geologic events contributing to the general physiography of the area, such land forms often will not be recognized as such in one aerial photo or even in a small group of pictures. Stream terraces, such as

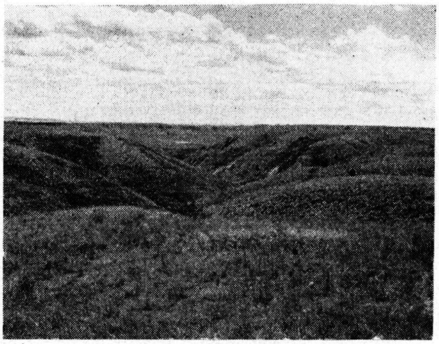

Figure 16. Ground View of the Slopes of a Gully Near the Edge of a Large Terrace in the Yellowstone River Valley in Eastern Montana. The stream has cut through the terrace gravels and through the underlying shale which has caused, in part, the badlands of the Yellowstone Valley.

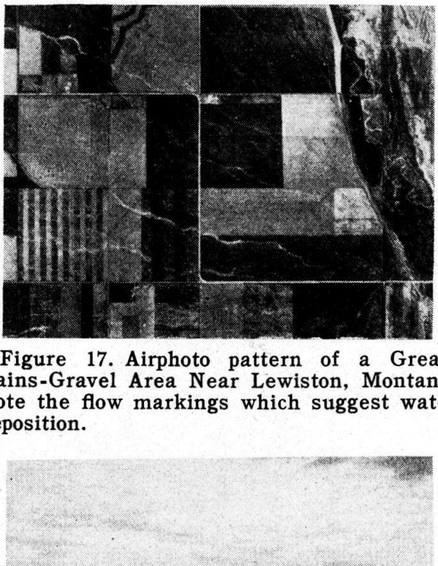

Figure 17. Airphoto pattern of a Great-plains-Gravel Area Near Lewiston, Montana. Note the flow markings which suggest water deposition.

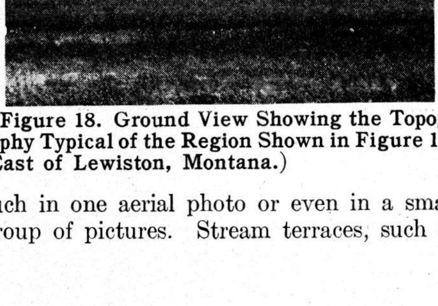

Figure 18. Ground View Showing the Topography Typical of the Region Shown in Figure 17. (East of Lewiston, Montana.)

Figure 19. Airphoto Pattern of a Glacial Outwash Plain in Elkhart County, Indiana. This contains the elements of light color tone, mottling effect, and glacial lakes.

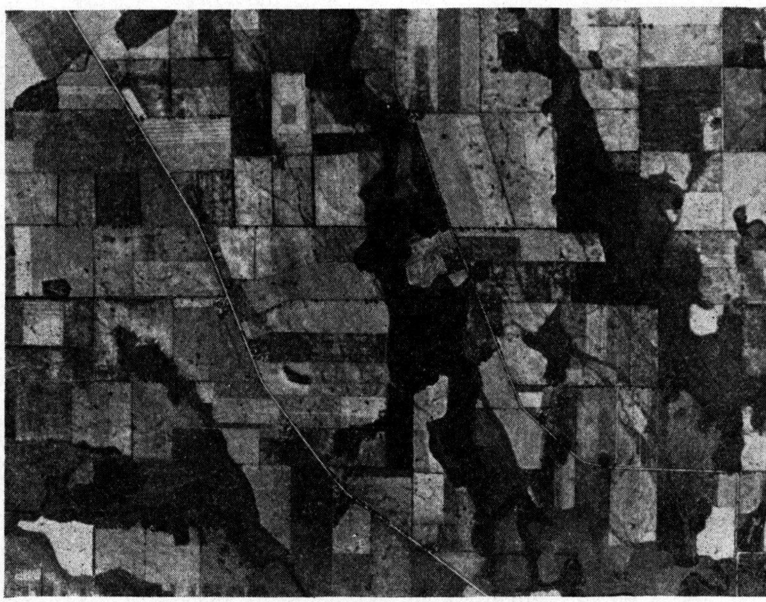

Figure 20. Airphoto Pattern of a Glacial-Outwash Plain in LaGrange County, Indiana Containing the Additional Elements; Flow Markings and Parallel Streams and Lakes.

those associated with the Yellowstone River in Montana may be 20 miles wide and several hundred feet high. (See Fig. 16, which shows dissection occurring on one of the terraces of the Yellowstone in eastern Montana.) Figure 17 is an airphoto which shows the pattern characteristic of considerable areas of the great-plains outwash mantle.

This photo is from an area near Lewiston, Montana, which is on the western border of the great plains region. Note that this photo pattern contains numerous current scars, suggests a flat topography, has a relatively light color tone, and does not have a developed surface drainage system. A ground view of this region is shown in Figure 18.

Figure 21. Airphoto Showing the Pattern Created by a Series of Dissected Lacustrine Terraces Situated as Steps on the Steep Slopes of the Wastach Mountains Near Salt Lake City. This gravel pattern is characterized by the terrace type land form with steep slopes on the faces of each terrace, light color tones, and gravel type gullies. Note that the gullies in the face of each terrace are short and occur in bands which outline the terrace face.

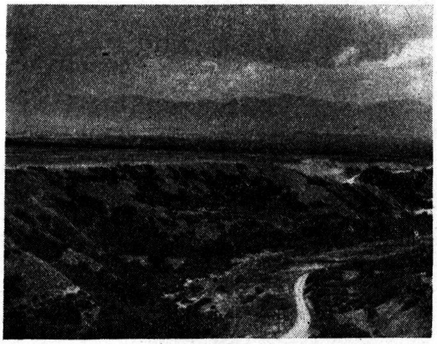

Figure 22. Ground View of a Lacustrine Terrace Situated Several Hundred Feet Above Salt Lake City.

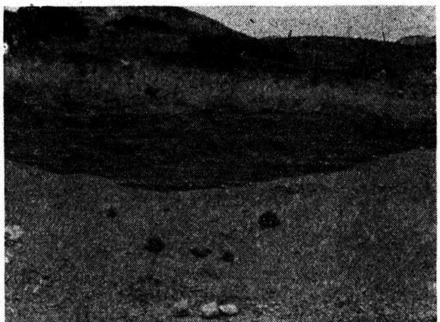

Figure 23. Close-up View of a Gravelpit in a Lacustrine Terrace (Salt Lake City) Showing the Texture and the Horizontal Stratification of Materials.

Glacial Outwash Gravels. The airphoto pattern of glacial outwash gravels is characterized by the following elements: land form consisting in general of a broad flat plain which is interupted only by outwash channels or glacial lakes; light color tones; flow markings; mottled pattern; rectangular highway systems and checkerboard field pattern;

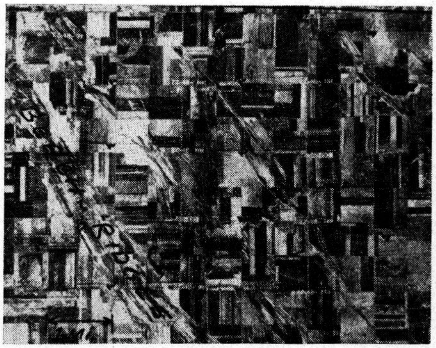

Figure 24. The parallel light colored streaks shown in this airphoto, Grand Forks county, North Dakota, are granular beach ridges. These ridges, outlining the lake, are often the only sources of granular materials in lake-bed areas. The chief identifying element is that of color tone and continuity of tone.

Figure 25. Airphoto Showing One of the Characteristic Shapes Eskers Assume. This Steuben County, Indiana esker is shaped like a "fish hook" in plan.

Figure 26. This esker near Indianapolis, Indiana is partially outlined by a heavy timber cover. The esker is crescent shaped and over a mile in length.

and an absence of surface erosion and surface drainage. Figures 19 and 20 are airphotos

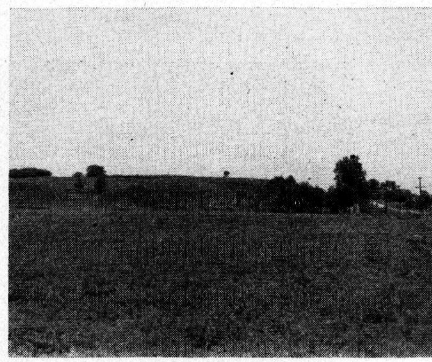

Figure 27. Ground View of a Portion of the Indianapolis Esker.

Figure 28. Ground View of an Esker in Southern Wisconsin.

Figure 29. Note the stratification and the steep dip of the strata of this Minnesota esker.

showing many of the characteristics of the gravel-outwash plain.

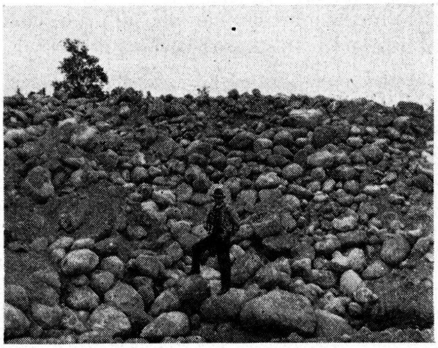

Figure 30. This pile of discarded material contains boulders, taken from an esker, which are too large for the crusher. This is an illustration of intense glacial activity.

Figure 31. Airphoto of an Area in Clark County, Ohio that Contains a Kame. Note the radiating effect produced by the erosional features.

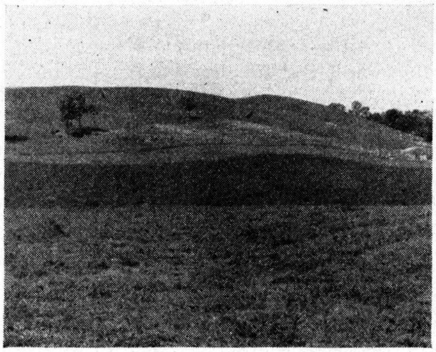

Figure 32. Ground View of the Kame Shown in Figure 31

Lacustrine Terraces. Figures 21, 22, and 23 illustrate one form of lake terraces—those associated with the pleistocene lakes of the West. Figure 21 illustrates the airphoto pattern of the lake terraces near Salt Lake City, Utah. These terraces (or more properly terrace remnants) occupy a topographic position high on the slopes of the mountains. The terraces are delineated by bands of gullies which are similar to those in other terrace patterns previously illustrated. When viewed stereoscopically, these terrace remnants appear as steps or shelves on the steep slopes. Figure 22 is a ground view of such a terrace remnant near Salt Lake City. Figure 23 illustrates the granular texture and horizontal stratification typical of such deposits.

Granular Beach Ridges. Another source of granular material is that contained in the beach ridges that fringe the larger glacial lakes. Noticeable among these and perhaps the most famous, are those associated with Glacial Lake Agassiz in North Dakota. Such ridges are formed by wave action during storms. The action of waves and shore currents piles sand and gravel on the beaches in the form of ridges. Figure 24 is an airphoto showing the pattern associated with the beach ridges in Grand Forks County, North Dakota. The chief identifying element of this pattern is that appearing as unbroken elongated light colored streaks which extend many miles. Where observed on an airphoto index sheet or a mosaic of a large area, such streaks appear as the line of contact between two vastly different general patterns—the lacustrine pattern on one side and the upland glacial drift on the other. Beach ridges often are the only sources of granular material in areas covered by large glacial lake beds.

Eskers and Kames. The airphoto pattern of eskers and kames is different than the previously illustrated granular patterns. Kames and eskers are granular deposits associated with glaciation only. In origin it is believed that they were formed by the deposition of sorted sand and gravel beneath the soil-ice mass by the discharge of glacial melt water through cracks, crevices, or holes within the lower portions of the glacier. In addition to the fact that eskers occur only in glaciated regions they can be thought of as having one dominating element—that of the characteristic land form. The land form, or shape of the deposit, as illustrated in Figure 25, often is sufficient for esker identification. Such hills often appear as the only major relief in an area and occur as prominent ridges (which are the eskers) or as dome shaped or conical shaped hills (which are the kames). Either may occur at random in an area; however, the usual occurrence is in clusters or groups forming a chain that may extend for many miles. Figure 26 is an airphoto which illustrates how the shape of an esker may be outlined by a dense vegetative cover. Figures 27 and 28 are ground views of eskers in Indiana and Wisconsin.

Because of the steep slopes and porous nature these deposits contain little or no more representative sample of the coarse material. In the northern portions, where glaciation was very active and intense, eskers are very numerous and very large. Often these eskers contain material too large for ordinary crushers and the oversize materials are discarded as shown in Figure 30.

Kames are similar to eskers with respect to origin, texture, and in general airphoto-pattern elements with the exception of shape. Eskers are elongated ridges and kames are conical shaped or dome shaped. Figure 31 illustrates the airphoto pattern of a kame

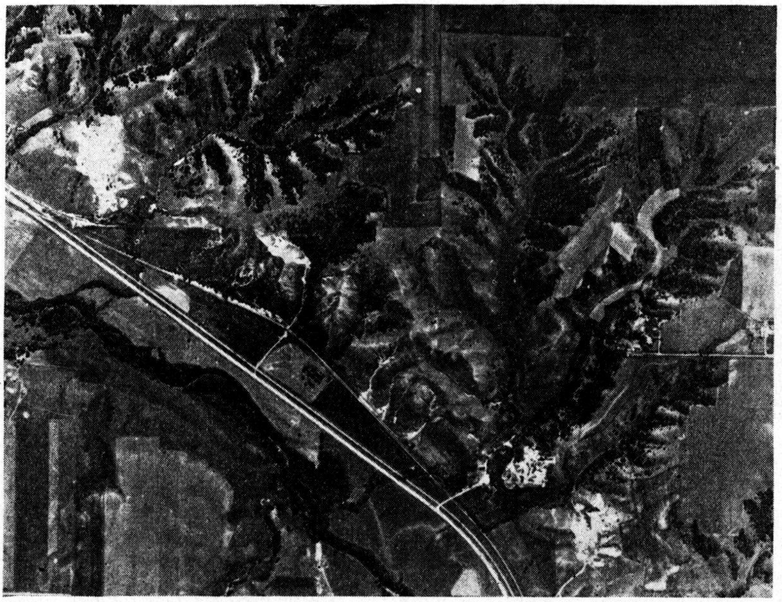

Figure 33. View of Stream Valley Near Sioux Falls, South Dakota that Contains Numerous Kames Along One Valley Wall.

weathered soil profile which fact is revealed by the absence of clay-type gullies and dark soil color tones. However, because of the sorting action of running water during the deposition, such deposits are likely to be stratified with material of sizes ranging from coarse to fine from the center outward. The significance of this lies in the fact that, when sampling such deposits, one is sure to encounter fine sand and silt near the base and for some distance up the slope which may be the cause for the rejection of such a deposit (See Fig. 29). On the other hand, the sampling should be done near the crest or at greater horizontal depths into the side to obtain a

in Clark County, Ohio. One outstanding element of kame patterns is a radiating effect produced by sweeping lines originating at the apex or crown of the deposit. Chief among these are the erosional features. Occasionally a series of kames will be found in close association with large glacial streams. Figure 33 shows such a situation occurring near Sioux Falls, South Dakota.

There are many other situations in which all the contributing factors have acted to create gravel patterns still different from these. The wide variety of gravel patterns presented in this paper illustrate the more general conditions under which gravel occurs. It is believed that surveying via the media of airphotos will make it possible to locate granular deposits more accurately, more efficiently, more rapidly and at a greater saving in cost than by land surveying.

CONDITION OF CONCRETE PAVEMENTS IN KANSAS AS AFFECTED BY COARSE AGGREGATE

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Kansas State Highway Commission

SYNOPSIS

In a survey made under the direction of Kansas State College Engineering Experiment Station and the Materials Department of the Kansas Highway Commission, 330 highway projects were examined comprising 1170 miles of concrete pavement

The purpose of survey was to investigate the relationship between certain classes of failure (mainly D-lines) and the materials incorporated into the concrete, (principally the coarse aggregate).

The coarse aggregate consisted of five general types, crushed limestone including one crushed sandstone, chert gravels, crushed flint, flint chats, sand gravel (mixed aggregate) Sand came from two general sources—Kaw river valley and Arkansas river valley Frequency of D-lines occurrence is 38 per cent for each sand, which was considered to be a uniform material in this study

Cement was from 12 or more sources Many old records do not give brand used; some projects have used several brands Although the influence of the composition of various types of cement is known to be of importance in the service life of a pavement it is considered here as uniform throughout the pavements examined

Coarse aggregate came from 60 different sources Some appear only once or twice In order to consolidate into groups for comparative service records the coarse aggregates were gathered into 13 commercial sources and 9 vicinity sources.

Each pavement was rated Good, Fair or Poor depending on the frequency and extent of failures counted per mile in D-line disintegration (material failure)

Lincoln Sandstone, Garnett limestone, Douglas gravel, Holiday gravel, Ottawa limestone, Johnson-Miami Counties limestone, Dickinson County limestone and flint chat show very good records over life periods of 10 to 25 years

Moline limestone, Bazaar gravel, Joplin flint and Kansas City limestone show predominantly poor records

The examination was based upon the condition of the concrete as a material rather than the condition of the slab The survey points out the relationship between one set of conditions (the CA component) and is limited to one type of failure (disintegration as a material)

It is not intended to imply that the cause and effect of such failures are limited to the relationships between the coarse aggregate and D-crack failures It is intended to convey the thought that this particular relationship is highly significant and should contribute to the selection of better coarse aggregates for Kansas concrete highways of the future.

Serious deterioration and severe damage has occurred in many concrete pavements in Kansas. These conditions have been aggravated in the past few years by increased heavy traffic and curtailed maintenance programs, both brought about by the war. The causes of such damage and deterioration are known to be numerous, and complete