of readjustment of other existing underground utilities including sanitary sewers, water and gas mains, telephone and electric power installations and the many other costly investments in underground as well as overhead work.

Actually, the air photographs have proved an invaluable method of making reconnaisance surveys, and it is doubtful if the location and design of any of the limited access routes now being planned within the densely built up areas of the Region of Chicago will be finally determined upon without the use of such air photographs.

In studying and weighing all of these detailed matters, the Cook County highway engineers were constantly in close touch with the staff of the Chicago Plan Commission, the zoning authorities and the engineers for all of the overhead and underground utilities.

AERIAL PHOTOGRAPHS AND THE DISTRIBUTION OF CONSTRUCTIONAL MATERIALS

By A. J. Eardley, *Department of Geology*
University of Michigan

SYNOPSIS

Any means that speeds the mapping of extensive foundation areas and helps in the location of materials for borrow purposes is immediately valuable. Aerial photographs record individual and distinctive photographic patterns and textures of the different types of soil and rock. It is the interpretation and mapping on the basis of limited sampling, that lend value to the aerial photographs.

By sampling at the critical places revealed by aerial photographs, the respective soil or rock types can be identified over wide areas.

Sources of data on the distribution of constructional materials in an area are contained on soil maps and geologic maps; and aerial photographs should be considered as another form of map for distribution studies. Since detailed soil and geological maps are not available everywhere, aerial photographs may be the only source of information preliminary to field surveys. Aerial photographs may best be interpreted by considering them as soil maps or geologic maps. Soil and geologic maps are briefly described, and their relation to aerial photographs is illustrated. The examples chosen demonstrate the great utility of aerial photographs in mapping soil types as well as hard rock formations.

The engineer in charge of soil and rock investigations for an airport or highway project will appreciate any method that speeds up the survey work necessary to secure accurate information on the nature and distribution of the constructional materials. Aerial photographs are being used advantageously to this end, and already several publications (11)[1] have appeared that demonstrate their utility in soil and bedrock mapping. The present article is chiefly a summary of the earlier reports.

[1] Numbers in parentheses refer to the list of references at the end of the paper

AERIAL PHOTOGRAPHS AS DISTRIBUTION MAPS

Aerial photographs record individual and distinctive patterns and textures of the different types of soil and rock, and the boundaries of these types can usually be readily traced on the photographs. A soil or rock sample of each photographic pattern will usually serve to identify the material of the entire area of the distinctive pattern. It is this feature, viz., interpretation and mapping on the basis of limited sampling that lends value to the aerial photographs. The boundaries are commonly revealed in a detail not caught by ground surveys, and often variations are recognized on the photographs that might otherwise be missed on the ground. Over all, the photographs reveal the critical places for sampling, and after the samples have been identified the respective soil or rock types can readily be traced over wide areas—not simply along the proposed route of the highway. By recognizing the areal instead of linear distribution of material, better routes for the road bed may be selected and the most convenient sources of borrow material located. In recent years the distribution of constructional materials and also data for engineering design have been correlated with soil maps and geologic maps, and thereby ground surveys have been greatly accelerated (9).

By means of soil and geologic maps engineering design data of soil and rock types in one locality may be used at another with a minimum of field or laboratory study. A soil map of a small area will serve as a key to the identification of the soil types on photographs of a much larger surrounding area Aerial photographs should be considered as another form of map for distribution studies. Since detailed soil and geological maps are available only of scattered parts of some States and not at all of large parts of some continents, aerial photographs may be the only source of information preliminary to field surveys

Aerial photographs may best be interpreted by considering them as soil maps or geological maps, and for that reason the elements of the soil map and the geologic maps hould be understood [2]

SOIL MAPS AND AERIAL PHOTOGRAPHS

Soil maps show the locations and limits of the different kinds of soil Soil is unconsolidated material and may be unlithified sediment or weathered bedrock In fact, unconsolidated sediments like the glacial drift of the Great Lakes States or the wind deposited loess of Oregon and Washington may become weathered and develop a top soil unlike the subsoil. The term soil is used in such a broad way that on modern soil maps certain types imply considerable hard bedrock exposed in patches at the surface or buried by only a few inches of loose material. A soil map emphasizes the weathered material; the geological map ignores the weathered products and charts the distribution of bedrock. There are two kinds of geologic maps of Michigan, for instance· one that shows the bedrock below the glacial deposits, and another that shows the distribution of the different kinds of glacial materials such as moraines, outwash plains, kames and lake beds. The soil map of a county in Michigan will show considerable resemblance to the glacial drift map, but none whatever to the bedrock map. In other states like Oklahoma and Alabama the soils in large parts are weathered products of the bedrock, and in distribution reveal approximately the outcrop of the bedrock. In desert country vast areas of bedrock with almost no loose material make up the surface, unconsolidated material, where present, is flood wash gravel and sand, alluvial fans, playa lake basins and local areas of sand dunes where a soil profile normal to the region has failed to develop.

The soil engineer in most places works with the weathered or unconsolidated material, and consequently he is more interested in the evolution of the soil than in the geologic deposit from which it has been derived The concept of the soil profile as a function of the parent material, of the climate, of time, of the vegetation that grows on it, and of the bacteria that teem in it is well understood by the soil scientist (pedologist) and also by increasing numbers of highway engineers. Modern soil classifications embody this concept and, therefore, soil types as shown on soil maps signify the features of the profile. The physical properties of the soil types in an area can be transcribed into fundamental engineering properties. hence the value of the soil map to the engineer in selecting sites for airports and roads, and in avoiding poor subgrades from the standpoint of bearing capacity and drainage.

Different soils have different colors and textures and also support different floral assemblages. Therefore, they yield contrasting photographic patterns distinctive of the differ-

[2] Vertical aerial photographs are those used for mapping purposes in the United States and a general knowledge of their kinds, characteristics, use in making planimetric and topographic maps, and geological interpretation may be obtained from two recent books, namely. Aerophotography and Aerosurveying (8), and Aerial Photographs: Their Use and Interpretation (3) When used as a basis for the identification and distribution of soil types or bedrock formations a working knowledge of the two sciences, pedology and geology, is necessary

ent soil types. Not only can the distinctive patterns be recognized but they permit a close comparison of the photograph with the geologic and soil maps of the same area.

GEOLOGIC MAPS AND AERIAL PHOTOGRAPHS

Geological maps show the areas of outcrop of the various rock units in an area. The rock units are usually called formations and their limits are arbitrarily selected for mapping The boundaries between rock units are called contacts. The areas of formational outcrop may be shown in various colors or by some ruled pattern, the colors or patterns are generally overprinted on a topographic base map. A geologic map without topographic contours is called a contact map.

The engineer will be more interested in distribution than in structure of the rock layers and, therefore, it may not be necessary for him to be familiar with the interpretation of the maps for determining the kind and location of geologic structures He can regard the geologic maps simply as distribution maps of geologic formations The similarities of geologic maps and aerial photographs, as well as their differences, should be appreciated The aerial photograph shows the culture in great detail, whereas the geologic map shows only a few of the landmarks considered essential by the maker of the map; the aerial photograph shows what is at the surface and not what is below, whereas the geologic map usually shows the spread of outcrop of bedrock formations beneath soil, thin alluvium, glacial drift, and vegetal cover; the aerial photograph shows relative but completely detailed relief, whereas the geologic map shows actual relief but only as correct and as detailed as was determined by the objectives and the conditions under which the field geologists worked. The geologic map is, in a sense, already an interpretation, whereas the aerial photographs are entirely objective.

EXAMPLES OF INTERPRETATION OF AERIAL PHOTOGRAPHS

Schoolcraft County, Michigan

Schoolcraft County is in the east-central part of the Northern Peninsula of Michigan. Lake Michigan forms its southern boundary. Excellent soil (1) and geologic (2) maps are available, as well as aerial photographs Because of the availability of these three means of expression of the distribution of materials, the county seemed a favorable place to test the utility to the highway engineer of aerial photographs The aerial photograph, Figure 1, covers an area about 2 by 3 miles in size in the middle of township T 43N, R 16 W.

Three geologic units are mapped, moraine, outwash plain, and swamp. A moraine is usually a heterogeneous deposit of sand, clay and boulders dumped by the ice sheet at its margin, an outwash plain is mostly sand or sand and fine gravel spread out by aggrading, melt water streams from the ice. The moraine here stands 60 to 70 ft above the swamp, is subdued and fairly level and was covered completely by the waters of an ancient predecessor of Lake Michigan (2). As a result of the activity of the waves the low lying margins of the moraine have been reduced to a level plain and the bordering outwash has been greatly modified. The demarcation between moraine and outwash is not always distinct because the two features merge at a common level. The boundary of the outwash plain and the swamp on the photograph is sharp and well defined The pattern of the outwash plain is distinct from that of the moraine but the boundary between the two is not very sharply defined The moraine is cultivated, the outwash plain is not; the moraine supports the larger and darker trees, the outwash plain has the pit lakes. With these characteristics in mind the boundary would be drawn on the photograph by the writer from the upper margin, as shown in Figure 2A, southward to where it veers eastward, but then northward around the nearly circular lake near the road junction at a section corner. The boundary would then run southeastward to the end of the largest lake with the island in it; thence irregularly south southeastward. Such a boundary includes considerable material in the outwash plain that the geologic map designates as moraine. This seemed disconcerting until the detailed soil map was studied, and there a very close correlation with the photograph was found. The area of disagreement with the geologic map is almost precisely that of the Blue Lake loamy sand. This soil type is more closely related to the Blue Lake fine sandy loam of the moraine than to the Rubicon sand of the outwash plain, but evidently its second growth of timber is much more similar to that of the outwash plain, and therefore yields a similar photographic pattern. It is the zone of mergence of the moraine and outwash caused by the overwash of the old lake. It seems clear, therefore, that the photographs may reveal certain minor soil differences (types), such as the boundary between the Blue Lake loamy sand and the Blue Lake fine sandy loam, but other greater differences (series), like that of the Rubicon sand and the Blue Lake loamy sand, may not be distinct. Still, with the photograph in the field, the boundary between the Rubicon sand and the Blue Lake loamy sand could be mapped with greater speed than on a topographic or planimetric map.

An irregularity in the boundary between the Carbondale muck and the Rubicon sand may be seen on the photograph near the upper left-hand corner. A crescent-shaped lighter strip is separated from the main mass of Rubicon sand. A white spot where the road crosses it is probably sand and marks a borrow pit. The road is particularly white, with sand leading away from the borrow pit. The soil map shows the crescent to be Wallace sand, of sand dune origin.

Figure 1. Vertical aerial photograph of an area in the center of township T 43 N, R 16 W, Schoolcraft County, Michigan. Compare the photographic patterns with the geologic and soil maps of the same area, Figure 2A and 2B. Courtesy Abrams Aerial Survey, Inc.

The areas of peat around the lakes are fairly clear and if a stereoscope is used their identification becomes very secure. Peat builds up to the level of the lake and results in a flat area at lake elevation. The flatness and lake level of peat areas are conspicuous under the stereoscope. Relief is lost in large part when photographs are viewed without the aid of a stereoscope, and since topography is closely related to the geologic nature of the deposit and is one of the factors that determine the soil profile, the stereoscope is a valuable instrument to use when studying aerial photographs (3).

Additional interpretation can be inferred from study of the aerial photograph, Figure 1. The topography of the moraine, outwash and swamp could be detected stereoscopically. The swamp (Carbondale muck) must be a shallow deposit since it presented no apparent engineering difficulty in the location of the railroad. The railroad would probably have been placed on the outwash if the swamp was deep and required a large amount of fill to obtain an adequate subgrade support. The present outwash is covered with a second growth of poplar which suggests that it is

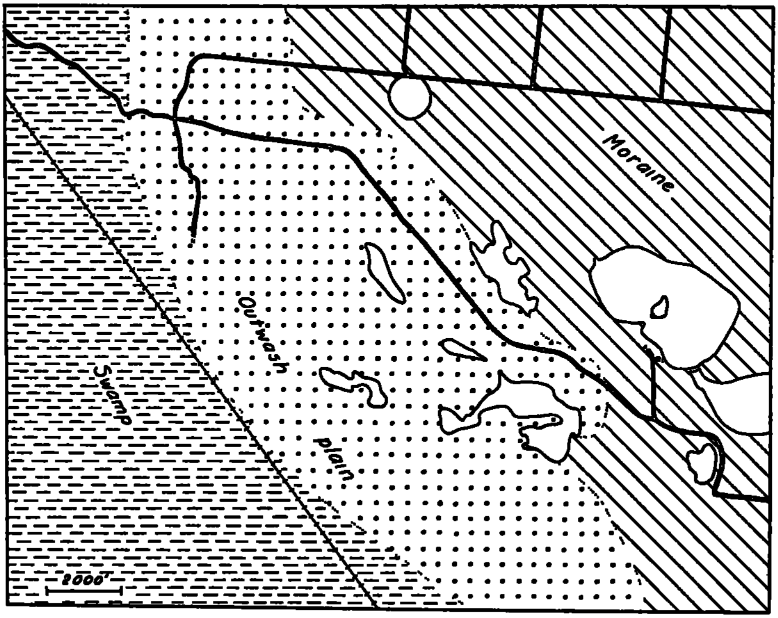

Figure 2A. Geological map of the same area as Fig. 1

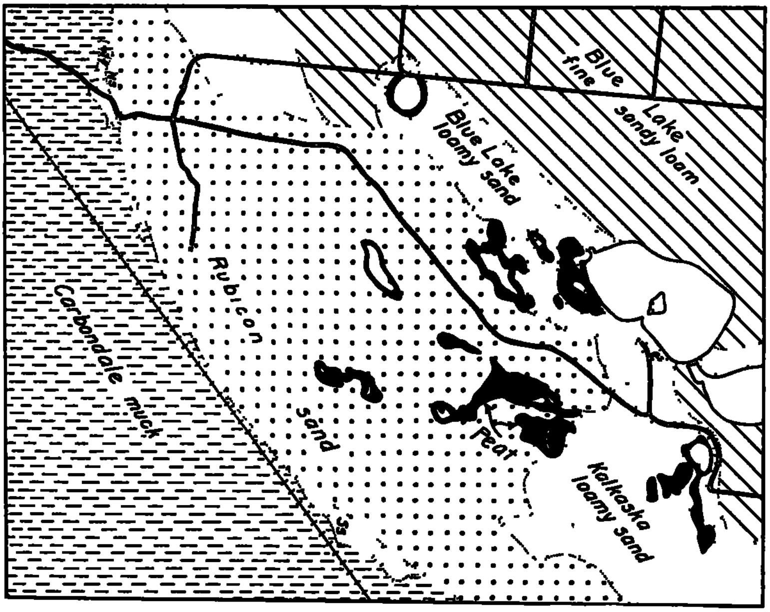

Figure 2B. Soil map of the same area as Fig. 1. Wf, Wallace fine sand; Ns, Newton sand, Ss, Saugatuck sand

fairly well drained. This deduction is supported by another, namely; that the outwash is not cultivated, and the soil is therefore, too well drained for agriculture. A small cluster of sand dunes (*Wf*) in the upper left corner of the photograph, over which the roads and

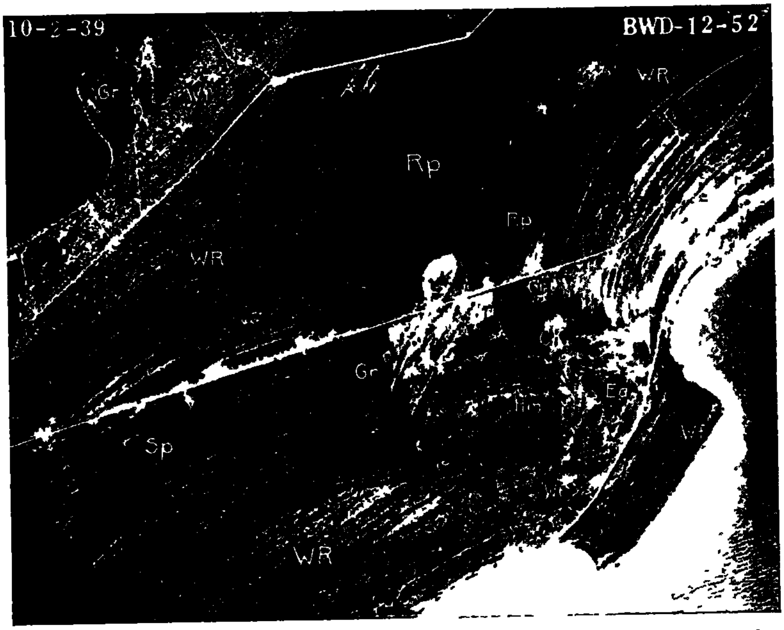

Figure 3. Vertical aerial photograph of an area in township T 41 N, R 16 W, Schoolcraft County, Michigan. Compare with the soil map of the same area, Figure 4. WR, Wallace-Rifle complex; WH, Wallace-Houghton complex; Wf, Wallace fine sand; Gr, Granby sand; Ea, Eastport sand; Rp, Rifle peat; Sp, Spaulding peat; Hm. Houghton muck; Ck, Carbondale muck. Courtesy Abrams Aerial Survey, Inc.

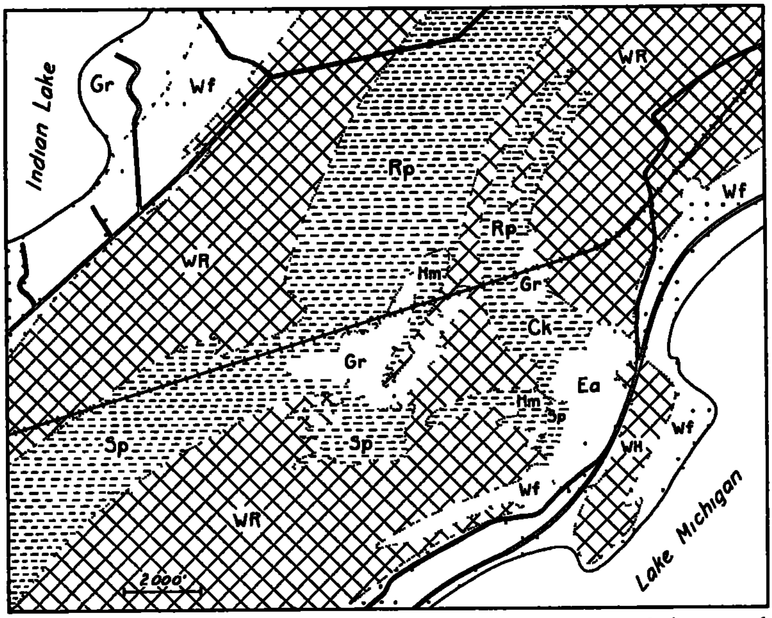

Figure 4. Soil map of the same area as Fig 3. For identification of symbols see title of Fig. 3

trails are very white, shows that the outwash is of such granular texture that some wind drifting occurred in the past. The area of both the moraine and the outwash must be overlain by a rather permeable soil inasmuch as there is little evidence of erosion caused by surface runoff. Field work will be required to verify these deductions, but it is clear that in a field survey only three samples will need to be taken to determine positively the main soil types as identified on the aerial photograph.

If an airport is to be built in the area of the aerial photograph, the most desirable site could be quickly located on the basis of the photograph and soil map The Rubicon sand is granular and well drained, it makes a nearly level, dry, sand plain, and it is subject to wind erosion if the plant cover is removed. The Blue Lake loamy sand and sandy loam is also well drained but since it has more fine-textured material and a greater limestone content than the Rubicon sand it is less likely to be subject to wind erosion and is better suited to produce an effective sod cover. It, therefore, represents the best material on which to build the airport. The site should, of course, have access to the road and highway.

Another kind of area in Schoolcraft County is illustrated in Figures 3 and 4. Since the ice sheet withdrew, the level of Lake Michigan has fallen considerably, and a series of successively lower sand beaches has formed The rows of trees mark the low sand ridges and the intervening strips are peat accumulations. In places the peat areas are wide and extensive. The white areas are beaches or bare sand. The soil map, Figure 4, does not show each separate sand ridge and each intervening strip of peat, but has lumped the areas of narrow belts together into a sand-peat complex By means of the aerial photograph, however, every individual unit could be fairly well charted.

In the upper left hand part of the photograph, the area of Granby sand (*Gr*) can be separated from the Wallace fine sand (*Wf*). The Granby has a much darker tone than the Wallace. The area of Granby located south of the railroad in the center of the photograph can not be identified as Granby sand, but it is not peat or muck or the sand-peat (Wallace-Rifle) complex Study of the upper center area of the photograph reveals that some of the sand beaches must contain coarse material or suitable granular material for road construction because parts of the beaches have been removed for construction purposes. If the engineer is familiar with the pedological soil classification, he will be able to look up the texture, the subgrade support and the average depth of the water table for each soil type. He will also be able to determine the availability of borrow material, and the desirable location of the grade line over the soil types.

Weber County, Utah

As a contrasting example to the Schoolcraft County area, one in Weber County, Utah, is selected for illustration Here in an arid climate a rugged mountain mass rises abruptly from the western piedmont. See Figure 5. The principal river of the area, the Weber River, has cut a deep canyon through the range. The rock is a complex of granite, gneiss, and schist. The range has been undergoing vigorous erosion for some time and is practically a complete exposure of bedrock. Many crags are visible, although oakbrush is plentiful on the lower slopes. The piedmont, on the other hand, has been one of deposition. See Figure 6. At the time the glaciers were depositing the drift in Michigan, a body of water, ancestral to Great Salt Lake, rose to its highest level against the range front and formed a prominent beach along the strips marked B, Figure 6. At a somewhat lower level a large delta of fine sand was built into the lake at the mouth of Weber Canyon. The lake fell still more and the delta was exposed and subjected to erosion by the Weber River, which previously had built it As a result, a wide, shallow valley has been cut through the delta. The area marked Fs on Figure 6 is the only remnant of the top of the delta in the area of the photograph. It is called Fresno sand on the map of an early soil survey (5). Considerable can be inferred of the other soil types shown on Figure 6, because each one makes up approximately a terrace level cut by the river in response to a lowering lake level. The terrace risers and treads are easily distinguished on the aerial photograph. Cut out of the Fresno sand, the terraces are veneered irregularly by flood gravels and sand of the Weber River The present flood spill-

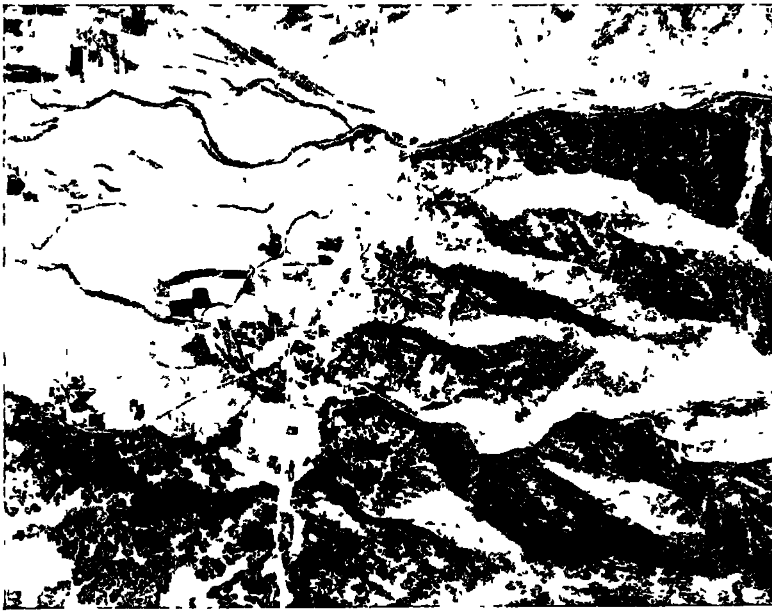

Figure 5. Vertical aerial photograph of the mouth of Weber Canyon, Weber County, Utah. Compare with Figure 6. Courtesy U.S. Dept. Agric., A.A.A.

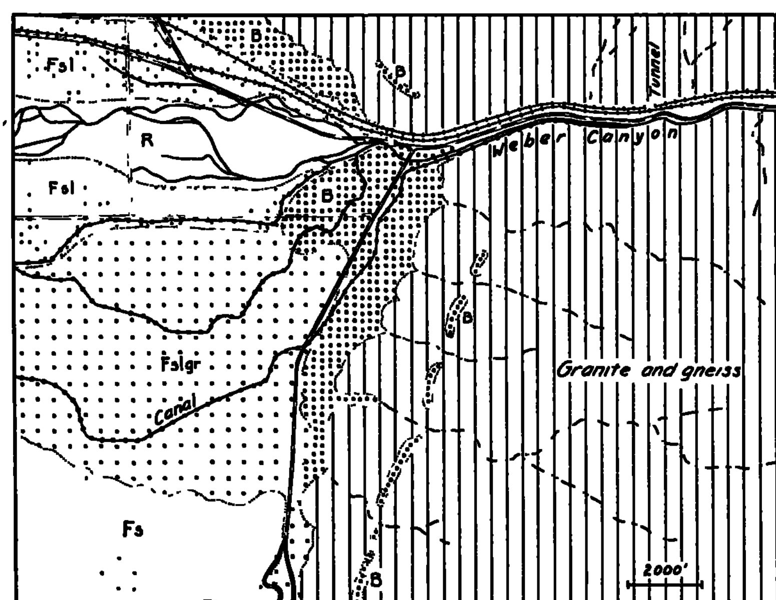

Fig. 6. Soil map of the same area as Fig. 5. Fs, Fresno sand; Fsl, Fresno sandy loam; Fslgr; Fresno sandy loam strewn with gravel; B, Bingham stony land; R, present river flood belt

way of the river is denoted by the letter R. The soils denoted by B are of several varieties Those along the broken strip are beach sands and gravels and have proved the best source of clean sand and gravel for concrete. Those skirting the foot of the mountain generally above the highway are recent gully flood materials (alluvial fans) and contain a mixture of fine particles to extremely large boulders. Those at the mouth of Weber Canyon are the most recent flood gravels of the Weber River.

The soil map descriptions, although not modern, are the best information available for highway, railroad, and canal design, and should be consulted before a detailed field survey along a proposed route is made.

rock variations and broken zones. The extreme detail of the photograph is very helpful in determining location and it provides an unexcelled base map for a materials survey before route surveys have been made.

The aerial photograph of Figure 5 has a fairly uniform pattern for all of the bedrock area. This would be interpreted to mean one kind of rock. Where several formations occur they usually yield contrasting photographic patterns and are easily identified. Figures 7 and 8 represent this feature. In most of our mountainous areas, and many others as well, aerial photographs not only expedite the mapping of the outcrops of the different rock formations, but greater detail of the contacts is obtained. Where construction involves excavation through the soil and into the unaltered rocks below, it is necessary to have the bedrock variations surveyed, and the value of aerial photographs in this procedure is obvious. For more information on the geologic interpretation of aerial photographs see reference (3).

Figure 7. Vertical aerial photograph of an area in the Wasatch Mountains northeast of Ogden, Utah, upon which the contacts of the various rock formations have been inked in. AR, Archean granite and gneiss; A, Proterozoic quartzites and phyllites; C + q, Cambrian quartzite; Cos, Cambrian shale; Cll, Lower Cambrian limestones; Cul, Upper Cambrian limestones. Courtesy U.S. Forest Service

The two railroads, the Lincoln highway, the dam, canal and water conduit through Weber Canyon have had to contend with hard bedrock along a major part of their routes. As far as mapping the bedrock here is concerned, it is a simple problem because for engineering purposes it is one kind of rock, all fairly fresh and strong, although rather badly broken in places. It is an intimate complex of granite, gneiss, and schist. The photograph could be enlarged twice or three times so as to provide a scale large enough for recording detail of the

AVAILABILITY OF MAPS AND PHOTOGRAPHS

Geologic Maps

Geological maps of small scale are hardly usable by the engineer except in a broad way in determining the distribution of geologic units. The 1933 geologic map of the United States does not show glacial drift, and, moreover, rock units of several lithologic aspects are grouped under one color pattern. Information must be sought in the detailed quadrangle maps of the Folios, Bulletins, and Professional Papers of the U. S. Geological Survey, and in the publications of the several State geological surveys. Three geologic journals have many maps and might be consulted. They are: the Journal of Geology, the Bulletins of the American Association of Petroleum Geologists, and the Bulletins, Special Papers, and Memoirs of the Geological Society of America. Bibliographies to be consulted are:

Bibliography of North American Geology, U. S. Geological Survey Bulletins 746 and 747 (1785–1918), 823 (1919–1928), 834 (1929–1930), 858 (1931–1932), 869 (1933–1934), 892 (1935–1936).

Bibliography and Index of Geology, Geological Society of America, Vols. 1 to 8.

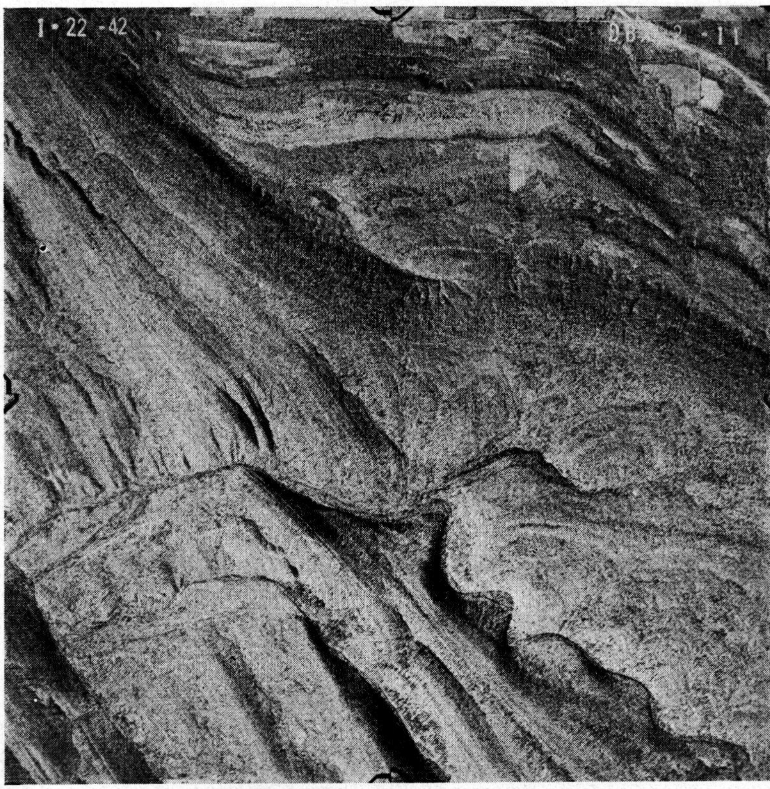

Figure 8. Vertical aerial photograph of a hilly area in Oklahoma. The bevelled edges of inclined sedimentary rocks produce the conspicuous pattern. Courtesy Southwestern Aerial Surveys.

Soil Maps

The most extensive set of soil maps will be found in the U. S. Department of Agriculture's Soil Survey Series. A map of the great soil groups of the United States is found in the highly recommended article "Development and Significance of the Great Soil Groups of the United States" by C. E. Kellogg, U. S. Dept. Agriculture, Miscellaneous Publication No. 229, 1936.

The Atlas of American Agriculture, Part III, Soils of the United States, 1935, U. S Department of Agriculture, contains small-scaled but fairly detailed soil maps of all of the United States The U S. Department of Agriculture's Yearbook of Agriculture, 1938, entitled "Soils and Man" is very informative, especially the chapter "Soils of the United States."

Aerial Photographs

At least three-fourths of the United States has been photographed from the air. Some states have been entirely covered for the Agricultural Adjustment Administration, the U S. Forest Service, and the Soil Conservation Service. In almost any local office of one of these agencies index maps may be seen, from which index numbers of the photographic prints of the area desired may be obtained. The index numbers are necessary for ordering the prints. A number of large, well-equipped commercial companies have flown considerable areas and are the source of index sheets for certain areas sometimes not tabulated by the government agencies Some of the commercial companies are Fairchild Aerial Surveys, Incorporated, Los Angeles; Edgar Tobin Aerial Surveys, Incorporated, San Antonio, Texas, Abrams Aerial Surveys, Lansing, Michigan; and Holmberg Aerial Survey Company, Chicago.

Since the war the sale of aerial photographs is forbidden unless clearance is obtained through the U. S Army Defense Command of the Corps Area in which the photographed area lies. The limits of the area and the index numbers of the photographs should be specified, the use for which they are desired indicated, and a statement included to the effect that they will be kept under lock and will not be available to the public It is best that they do not cover any industrial areas and military emplacements or activities

When permission to order is received from the Defense Command, an order may be directed to one of the following for whose Service or Agency the photoflying was done·

J. M. Snyder, Chief, Cartographic Division, Soil Conservation Service,

Ralph H Moyer, Chairman, Aerial Photography Committee Agricultural Adjustment Agency,

G. H Lautz, Assistant Chief, Division of Engineering, Forest Service

After the war aerial photographs and planimetric maps made from the photographs will probably be available for large parts of the several continents Extensive areas have been photographed by the Army solely to aid in highway planning and construction

CLIMATIC ZONES, GREAT SOIL GROUPS, AND AERIAL PHOTOGRAPHS

The great soil groups of the world are now known to be related to distinctive climatic regions, whereas, geologic deposits bear little relation to modern climates. The zones of the great soil groups have evolved discordantly over the great geological units, i e, as if one rag rug were laid across another. For this reason it has been suggested that climate should be a guide to the highway engineer in anticipating the kinds of soils he will have to deal with in an assignment to any part of the world Furthermore, it is suggested that the soil series and types within an area of a known soil group might be recognized and charted on aerial photographs before he goes into the field.

Definite limitations must be attached to these suggestions. In the first place, the zones are irregular since irregular shorelines and great variation in altitude introduce pronounced irregularities in the position of the climatic and biological zones. Nevertheless, it would be inexcusable neglect to overlook such information on the distribution of the great soil groups as contained in Glinka's "The Great Soil Groups of the World and Their Development" (6) and Kellogg's "Great Soil Groups of the United States" (7) In Asia the soil zones have a very general east-west trend. This is true also in the eastern United States; whereas, in the middle western and western parts of the country the soil zones parallel the mountains and run approximately north and south. In many places conditions unfavorable for the development of a normal soil, such as rugged mountains, wide sandy plains, or swampy basins may cover rather large areas The important constructional materials in such places may be better interpreted as a result of geological processes than from the standpoint of a soil classification; or at least if a soil map is available the soil names applied to a deposit must generally not be construed to mean a certain soil profile because from the geologic nature of the deposit none may exist

Positive identification of rocks and soils cannot be made on aerial photographs alone. This does not preclude, however, the gathering together of all the geologic and soil survey data possible on the area of the assigned project and making the most of the aerial photographs by way of interpretation before entering the field. Their greatest value however will lie, it is believed, in the reduction of sampling and the speeding up of mapping of the rock and soil units in the process of the field work

CONCLUSIONS

Rock formations produce distinctive patterns on aerial photographs, and in many areas the photographs serve as unexcelled base maps for the charting of bedrock outcrops Much has been made of this concept in geology It is also true that the various local soil series and types are commonly discernible on aerial photographs Positive identifications cannot be made but distribution of a certain pattern may be readily traced and the area defined Then only one or two samples need be taken unless some doubt exists about transitional zones. The photographs guide the soil surveyor, engineer, or geologist to critical localities and when once a soil or rock is properly identified in the field and its boundary defined, the photograph may allow the whole area to be charted in a minute, and perhaps, equally fast, many other separated areas like it

Aerial photographs reveal detail in boundaries usually not caught even in the most careful ground surveys Often it is not possible to trace the complexities of boundaries between two intimately intergrown types except on the photographs. Anyone who maps on aerial photographs in the field will quickly become convinced that he is doing a better job in running out the boundaries and that the time saved is great

For the highway engineer whose practice is first to make a reconnaissance trip along the route, and then to start the mapping of a strip 200 ft. wide by sampling at 100 ft. intervals more or less as the exigencies demand, the aerial photographs has an added advantage. Besides making unnecessary much of the sampling, it permits the lateral extension of the soil boundaries far beyond the 200-ft. strip without further field work and thereby much borrow material may be discovered and its most accessible locations easily noted

The writer is indebted to F. R. Olmstead of the Michigan Highway Department for considerable assistance in preparing the present article.

REFERENCES

(1) Foster, Z C, Veatch, J O, and others, Schoolcraft County, Michigan, Soil Survey, Series 1932, No 37, Issued Sept, 1939
(2) Bergquist, S G, "Glacial Geology of Schoolcraft County, Michigan," Occasional Papers, Geological Survey Division, Michigan Dept Conservation, pp 1–148, 1936
(3) Eardley, A J, "Aerial Photographs: Their Use and Interpretation," Harper and Bros, 1942
(4) Stokstad, O L, "Practical Utilization of Subgrade Soil Information in Highway Design Practice," *Proceedings*, Engineering Conference in Soils for Engineers, Mar 3, 1941, Michigan State College, Michigan, p 49–60
(5) Gardner, F D, and Jensen, C A, "Soil Survey in Weber County, Utah," U. S Dept Agric, Field Operations of the Div of Soils, 1900, Second Report, p. 207–242
(6) Glinka, K D, "The Great Soil Groups of the World and Their Development," Transl by C. F Marbut, 235 pp., mimeographed Edwards Bros, Ann Arbor, Michigan.
(7) Kellogg, C. E, "Development and Significance of the Great Soil Groups of the United States," U S. Dept. Agriculture, Misc Pub No. 229, 1936.
(8) Bagley, J. W, "Aerophotography and Aerosurveying," Book published 1941.
(9) Olmstead, F R, "Systematic Planning For Low Cost Roads," *Proceedings*, Association of Asphalt Paving Technologists, Volume 12, 1940
(10) "Soil mechanics and its applications," *Proceedings*, Purdue Conference on Soil Mechanics, Sept 2 to 6, 1940
(11) Belcher, D J, Gregg, L E, and Woods, K B, "The Formation, Distribution and Engineering Characteristics of Soils," Highway Research Bull No. 10, Engineering Bull, Purdue Univ, 1943. See bibliography on aerial photographs, p. 374