the general impression gained from flying over a rain-forest area is one of monotonous uniformity, examination of airphotos of the same area will show definite vegetative patterns following corresponding trends in soil or drainage conditions. In spite of high rainfall, gravels and sands in well-drained positions will have a "dry" soil-climate in contrast to other textural combinations found in association with them. At the other extreme the dry climate of northern interior Alaska includes areas having a wet soil-climate regardless of texture. These are coincident with the areas of perennially frozen ground, and here vegetation changes accordingly. Consequently, in areas where the ecologic balance is undisturbed, vegetation will reflect subtle changes in the soil-climate.

Combining these various elements of the soil pattern and interpreting them in the light of experience and principles that are universally applicable makes airphoto interpretation a medium of obtaining and presenting information regarding the physical properties and conditions of surface materials.

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III e 2 CORRELATION BETWEEN PERMAFROST AND SOILS AS INDICATED BY AERIAL PHOTOGRAPHS

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SUMMARY.

This paper reports, in part, the results of a study covering the relationship between soil textures, soil position, vegetation, and permafrost as indicated by airphoto patterns of materials from Arctic and Subarctic regions. The work was performed by the Engineering Experiment Station, Purdue University, for and in co-operation with the St. Paul District, Corps of Engineers, War Department. This phase of the permafrost program has been under way since 1945 and covers both the airphoto identification features as well as field observations in many sections of the Territory of Alaska.

On the basis of correlation surveys of many and varied areas it was found that the Territory could be divided into a series of regions, each of which had characteristics peculiar to that region. These areas, in effect, are climatic-vegetative bands consisting of (1) Tundra Zone Permafrost; (2) Timber Zone, Permafrost; and (3) Timber Zone, Unfrozen. These areas, generally speaking, are representative of physiographic regions.

In general each of these major areas produces a definite standard or typical airphoto pattern, the successful interpretation of which makes engineering soil evaluation possible. Even though the study is in the development stage, it has been found that airphotos can be used to evaluate and predict permafrost conditions.

The correlation between permafrost-soil conditions and their corresponding airphoto pattern was made first by obtaining high-grade aerial photographs for several and varied areas throughout the Territory. The areas for airphoto coverage were selected so as to include a range of climatic and physiographic conditions; also, the areas were selected so that rock textures from several geologic ages would be represented.

Experience has shown that trimetrogon aerial photographs having an approximate scale of 1 : 20,000 are best-suited to general airphoto-soil analysis. In addition it has been found desirable to obtain photo coverage of several square miles of a region so that all of the topographic variations can be associated with each other and thus assist in the interpretation of the physiographic land forms. The oblique photographs of the trimetrogon series are extremely useful in identifying local and surrounding physiographic land forms. In those cases where detailed analysis is required the conventional vertical aerial photographs having a scale of 1 : 10,000 are well adapted to the airphoto analysis of soils and permafrost conditions and should supplement the trimetrogon photo coverage.

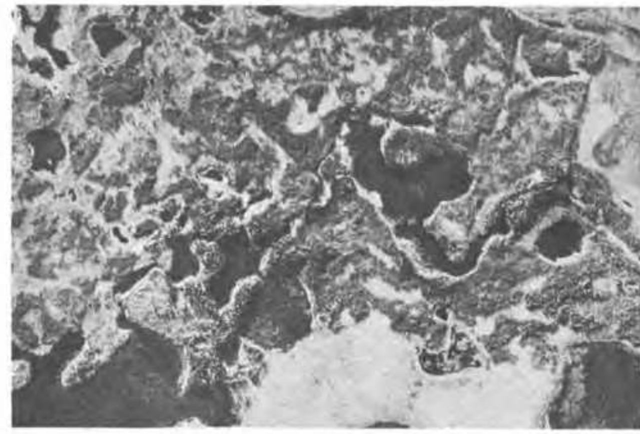
After airphoto coverage was obtained for the several areas throughout Alaska, these airphotos were carefully studied. Detailled office notes were made on the airphoto patterns for each of the areas being studied. This preliminary analysis consisted of identifying, where possible, the physiographic land forms; the erosional features; the prevailing types of vegetation and their association with topographic position. In those cases where the airphoto pattern could not be deciphered, the patterns were marked for field checking. Further, all available geological information covering the region being studied was reviewed and where this information dealt specifically with the prevailing soil and rock textures additional notes were taken

Following the preliminary airphoto analysis, field parties were organized and were flown to the selected sites covered by photography. This feature of air transportation made it possible to cover remote areas; also the field parties were able to obtain general information of the topography and vegetation of sections not covered by aerial photographs.

The field work consisted of making detailed inspections of the local areas covered by photography. Borings were made to determine the characteristics of the soil profile. Field notations covered topographic position, the type of vegetative cover, the thickness of the organic surface horizon, the texture and character of the soil, and where possible the depth to permafrost. On the steep slope of bedrock areas

Airphoto pattern of a braided stream in a broad, silt-filled valley. In this instance permafrost prevails in the silt flood plains.

FIG. 1



A typical airphoto pattern of a muskeg area in a broad, valley-fill region. The soils in this instance are frozen peat and silt.

FIG. 2

where the soil mantle was thin, practically all of these items were readily discerned by a visual inspection. However, in other sections, where the soil mantle was well-developed, a number of borings were necessary to determine the representative profile conditions. By selecting typical topographic positions for making the soil borings, it was possible to correlate the soil and permafrost conditions with the respective airphoto patterns in a relatively short period of time.

Ground photographs were taken of the local topography, vegetation, soil profile exposures, as well as any other features pertinent to the phenomena of permafrost. The "on-foot" inspections were supplemented by low-altitude reconnaissance flights over the survey areas. Photographs were taken of local features that would be of assistance in rendering an interpretation of the airphoto patterns.

After the airphoto patterns for several areas had been correlated with the permafrost-soil conditions it was found that the Territory of Alaska could be divided into a series of regions, each of which have characteristics peculiar to the region in question. The Tundra Zone for the most part is confined to the Coastal Plain and Arctic Piedmont regions. This includes the region north from the Brooks Range to the Arctic Ocean, most of the Seward Peninsula, and the Coastal regions adjacent to the lower reaches of the Yukon and Kuskokwim River valleys. The Timber Zone, Permafrost, in general, lies between the Alaska Range and the Brooks Range. This region may be considered a low, interior plateau which is traversed by many large rivers, including the Yukon, Tanana, Koyukuk, and the Kuskokwim. The Timber Zone, Unfrozen includes the Coastal region south of the Alaska Range. This section is rough topographically and is timbered along the immediate coast line and the major river valleys. The influence of the Japanese current gives this region a mild climate which is in contrast to the frigid climate of the interior regions.

Tundra Zone, Permafrost

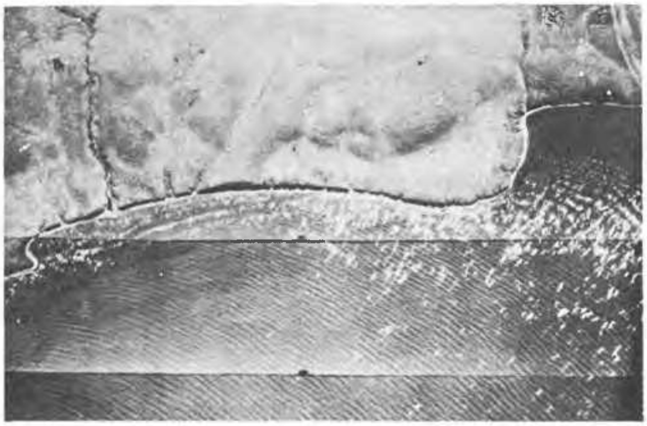
The tundra zone includes the Arctic Coastal Plain, the Arctic Piedmont Region, and a major portion of the Seward Peninsula. The soils of the coastal plain sediments consist largely of fine sands, silts, fine gravels, and in some places, clays. The airphoto pattern of the coastal plain is characterized by polygons, extremely flat topography, numerous elongated lakes and elongated sand ridges. Two types of polygons prevail, including the depressed-channel and depressed-center types. In each instance the presence of these polygons indicates that detrimental permafrost exists. Throughout a great portion of the coastal plain there are frost mounds (often called pingos) some of which attain a height of 80 or 90 feet. The second important great soil area of the tundra zone is the Arctic Piedmont which lies between the Brooks Range and the Coastal plain. This is a broad, gently-tilted-shale-plateau-like region somewhat dissected by streams. The area contains clay and sandy shales, sandstones, broad alluvial flats of the river valleys, granular terraces, and in places a mantle of fluvitile outwash which overlies the shale. These materials are also readily identifiable from airphotos despite the general permafrost conditon and absence of vegetation other than the tundra type.

Timber Zone, Permafrost

The soils of the interior region between the Brooks Range and the Alaska Range consist primarily of vast expanses of fine-grained alluvial materials, bordered by low-lying hills of metamorphic, sedimentary, and igneous rocks. The transitions in topography between the low rock hills and the flat alluvial areas consist frequently of colluvial materials.

Generally speaking, the soil cover on the bedrock hills and the colluvial slopes is very thin; however, the soil mantle becomes thicker on the flatter portions of the colluvial slopes. Where the ground slope is favorable to good runoff there is but little permafrost development; in contrast, however, the flatter ground slopes frequently contain permafrost. This is especially true where fine-grained soil materials are encountered.

The airphoto pattern of the bedrock hills can be readily identified, in some instances, by the absence of vegetation; also the topographic expression of the hills can be seen in either oblique photographs or in stereoscopic vertical photographs. The colluvial slopes also have a distinctive airphoto pattern. The surface runoff produces an alignment of the surface vegetation which in turn gives a characteristic fan-like-flow markings to the airphoto pattern for these colluvial slopes.



Intense polygon development indicating detrimental permafrost.

FIG. 3

An airphoto pattern of a dissected basalt plateau. Permafrost prevails in the soil mantle developed on the basalt.

FIG. 4

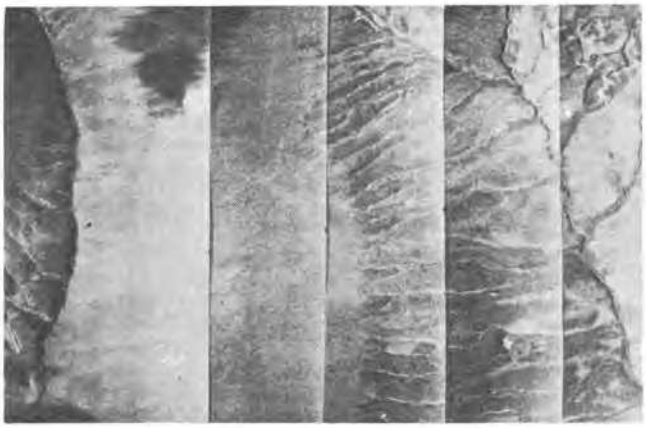
Glaciation has played an important role in the distribution of soil materials in this region, particularly in those areas adjacent to the Brooks and Alaska Ranges. In the immediate vicinity of these mountains a wide range of glacial materials are to be found in the morainic deposits, granular outwash plains, and terraces. Also, streams emanating from the mountain glaciers have produced extensive granular outwash plains and gravel terraces which form the bench topography that continues from the foothills of the mountain ranges toward the major stream valleys.

Although there is some variation in the texture of the soil materials found in the outwash plains and terraces, they are all distinctly granular and are therefore well-drained when they occupy elevated positions. For this reason, permafrost in the detrimental stage occurs only rarely in these materials. Accordingly, these granular outwash plains and gravel terraces make exceptionally good sites for the location of structures, whether they be cities, highways, or airports. Moreover, the level topography of these granular deposits hold grading operations to a minimum.

The airphoto pattern for the granular outwash plains and gravel terraces can be identified principally on the basis of their level topography and the dense stands of poplar, birch, and aspen trees which seek, naturally, well-drained locations for growth. Areas supporting these types of timber growth produce an airphoto pattern that is in distinct contrast to the patterns for areas covered with black spruce, which grows readily in poorly-drained locations and is the predominate type of timber growth in the interior of Alaska.

In addition to producing granular terraces and out-wash plains, the glacial streams have also produced a marked effect upon the alluvial areas. Enormous quantities of fine sands and silts have been deposited in the river and stream valleys, thus producing vast expanses of alluvial sands and silts, studded with small lakes, muskeg bogs, and a lace work of stream meanders and meander scars. These features are readily seen in aerial photographs and serve to identify the airphoto patterns for alluvial areas.

In alluvial areas permafrost prevails under practically all conditions, since the low topographic position makes water readily available at all times. The surface vegetation con-



Contrasting airphoto patterns of contrasting soil types are illustrated in this photo. Two materials, upland residual soils and colluvial materials, are shown.

FIG. 5

sists principally of sphagnum moss, which grows vigorously and overlies thick deposits of peat. This vegetative mantle acts as a natural thermal insulation for the permafrost and is a distinct factor in the growth and preservation of permafrost in these areas.

The combination of extremely low temperatures, available ground water, and to a certain extent fine-grained soil materials, produce ground surface features called polygons, which are shallow, trench-like depressions connected in the configuration of a polygon. Polygons in the interior of Alaska are associated with the severest form of permafrost since massive wedges of clear ice are found frequently in the substratum of the polygon trenches. The fine-textured sediments of the alluvial areas abound with polygons, which form a distinctive airphoto pattern despite the fact that in some areas polygons are difficult to see by ground inspections.

Timber Zone, Unfrozen

The predominate soil materials south of the Alaska Range consist of glacial outwash sediments. This area is still one of many active glaciers which continue to develop outwashes and gravel terraces. In many areas these glacial sediments have been laid down over deposits of soft clay-shale and lignite of Tertiary Age. Because of the highly plastic nature of this clay-like material it is an extremely undesirable engineering material and is to be avoided whenever possible. Permafrost in this region is not a problem since the climate is relatively mild. A mean annual temperature well above 32° F prevails.

The airphoto pattern for the sand and gravel terraces can be readily identified on the basis of the bench-like topography and the bench-like topography and the predominance of decidious tress which seek well-drained locations. The outwash areas which are extensive in this region contain "island" areas of sand and gravel terrace remnants which usually a growth of black spruce and are surrounded by shallow channels filled with moss and other vegetal debris. These features form a distinct airphoto pattern for the outwash areas.

CONCLUSIONS

Even though the work on this project is not complete, it has been demonstrated that aerial photographs can be used to identify permafrost in Arctic and Subarctic regions. As a result, airphotos become an engineering tool in locating airports, highways, and railways, not only in developed areas but also in relatively undeveloped regions where maps and other sources of information on soils and materials of construction are meager. In Arctic and Subarctic regions the detrimental permafrost areas can be determined from the aerial photographs and structures can be designed with at least some knowledge of subsurface ice conditions.

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III e 3 AERIAL PHOTOGRAPHS USED FOR AN ENGINEERING EVALUATION OF SOIL MATERIALS

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SYNOPSIS.

This paper reports, in part, the results of studies covering the use of aerial photographs in determining the distribution of soils, the boundaries between unlike soils, and the engineering characteristics of soils and soil materials occurring on or near the earth's surface. The work was initiated originally by the Joint Highway Research Project— an organization sponsored jointly by Purdue University and the State Highway Commission of Indiana. During the last World War, the air photo method was extended to cover a study of United States soils. Currently, Purdue University is co-operating with the Corps of Engineers, United States Army in a field and laboratory study to determine the engineering significance of the aerial photograph pattern of permanently frozen soils. The air photo studies have been under way for a period of more than six years and some statements of progress have been published in technical journals and bulletins. This paper consists essentially of a summary of the developments resulting from these studies.

The aerial photograph has become an important tool for all phases of Civil Engineering construction dealing with soils and rocks as surface materials-highways, airports, location of construction materials, and many others. In modern engineering the aerial photograph is almost indispensable, be the job one of the construction of a drainage map of a water-shed area, site selection for a highway, airport, or pipe line, or laying out the program for the sampling operations necessary for completing a soil survey.

Aerial photographs have been used extensively and for many years as an aid in developing soil survey maps for agricultural use. Bushnell states 25 P. 41) that "Most of the areas published since 1912 are considered to be at least reasonably good, although all surveys made after 1929 meet higher standards of accuracy because they have been made with the aid of aerial photographs."

PROCEDURES.

The procedures which were and are used in developing the air photo technique are logical and are easily followed. Essentially they consisted of detailed laboratory studies of serial photographs covering the specific areas followed by intensive field checks with the aerial photographs in hand. Step by step, the fine details of the pattern of each aerial photograph were worked out in the field. By this method such items as soil-texture variations within the soil profile, ground-water conditions, and topographic position were gradually correlated with the pattern found on the aerial photograph. The next step consisted of checking widely separated areas which produced identical or near identical airphoto patterns. Thus, it was established that a given soil material, including the entire developed soil profile, produced a specific pattern on the airphoto, which pattern was similar for similar soil materials regardless of where or how far apart these similar materials occurred. The process, essentially, became one of "finger printing" the various materials within a region or regions.

It was found that aerial photographs could be used with speed and accuracy in establishing boundaries between areas of dissimilar textured soils. Furthermore, it was established early in the research that the resulting areas of similar soils frequently coincided, either directly or indirectly, with areas mapped by pedological