DETERMINATION OF SOIL CONDITIONS FROM AERIAL PHOTOGRAPHS

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THE progress made in photo-mapping techniques during the past fifteen years has been phenomenal. More and more, the aerial camera has increased the efficiency of effort in the many mapping fields. Particularly in civil engineering, the impact of this progress has been the greatest. In surveying, the aerial camera ranks as one of the primary surveying instruments.

While photogrammetry has claimed the attention of engineer-surveyors, the steadily broadening use of photo-analysis is now rounding out the usefulness of aerial photography to the profession. In the overall field of aerial photography, photo-analysis should be considered as a qualitative function and photogrammetry as a quantitative one. Singly or combined, they are an important force in engineering today and tomorrow, at home or abroad.

Aerial photographs can be analyzed to determine ground conditions; specifically applied, photo-analysis produces evidence of:

(1) *Soil texture.* Identification of silt, clay, sand or gravel, or in the soil profile sense, the occurrence of horizons or "layers" of soil beneath the surface.
(2) *Soil moisture and ground water conditions.*
(3) *Type of rock and approximate depth below surface.*
(4) *Vegetative cover.*

Interpreted for engineering use, these data are converted as follows:

(1) Soil properties, including Atterberg limits and compaction requirements for fills; approximate bearing capacity or general road requirements where correlations exist.
(2) Equipment requirements for excavation and embankment in soil and/or rock.
(3) Influence of weather on construction.
(4) Location problems, i.e., avoiding unstable soils, landslide susceptibility zones, potential washout areas, etc.
(5) Drainage requirements; culverts, watershed areas, routing of ditches.
(6) Sources of borrow material for subgrades, embankments and dams.
(7) Amount and type of clearing.
(8) Aggregate sources.

Briefly, they provide unlimited assistance to engineering projects particularly in the planning and design stages where the rapid collection of data is important.

Basically, airphoto analysis depends upon a well-versed acquaintance with ground features and soil characteristics. The aerial pictures provide a means of making a deliberate and a detailed study of an area and an evaluation of the land forms by an enlarged perspective. Theoretically, the same things that can be studied in the airphotos can be examined on the ground; time and limited information prevent this. The optimum condition is represented by a judicious ground investigation guided by a photo-analysis. In most instances, to see a ground feature in its entirety is to understand its origin, its composition, and its influence on the surrounding terrain. When standing on the ground, man is so dwarfed in size, even by features of micro-relief, that their outline and overall character is obscure or hidden.

Photo-analysis is founded upon observation and inference. Only features that are surficial can be directly observed; conclusions must be inferred from these. Studying the surface pattern of an area is a means of evaluating subsurface conditions. Judgement must be based on an interpretation of certain visible conditions that represent the net effect of surface and subsurface conditions. The ability to infer correctly is based on experience and on a working knowledge of geomorphic, pedologic and ecologic principles. Currently, these requirements are being reduced by the development of analysis charts.

In the process of analyzing aerial photographs to obtain information on the engineering characteristics of soils, the first and perhaps the most important step is to identify the land form. The land form may consist of individual hills, valley floors, alluvial fans, outwash plains, terraces, beaches, dunes, and other topographic units created by the forces of nature. See Figure 1. The importance of the land form lies in its relation to the mantle of soils that has been produced by the weathering of the land form; the parent material of the soil. One requirement, then, is to become acquainted with these land forms.

FIG. 1. Two adjacent, unlike land forms are shown in this aerial oblique. The numerous low hills in the central portion of the picture make up a group of morainic hills (one glacial land form). The massive ridges (upper left) are of hard shale. Rock cuts and drainage are major items in road construction in this land form, while items of frost heave, soft subgrades, swamps and earth excavation are important in the moraine.

We unconsciously develop a faculty for recognizing friends from a distance even in strange surroundings. So it is with land forms. It is surprising to analyze this ability and to find the slight and insignificant things upon which this recognition is based. In detail it may be a person's configuration. It may be the way one walks, or dresses, or gestures. It is, in fact, so many of these that we seldom rely on a single detail but instead on an impression—an impression of all of these associated details. It is much the same in traveling. Without analyzing why, one often feels that landscapes are familiar. Occasionally we hear, "These hills look like home" as we drive through new country. It is probable that they are similar to the hills at home. This is typically true in Switzerland where portions of the country resemble central New York, while adjacent sections resemble our Glacial National Park.

Those who work with aerial photographs rapidly develop a capacity to recognize the various earth or land forms. When the analyst becomes well acquainted with land forms, they are readily recognized even in foreign surroundings. For example, a sand dune (of the barchane form) appears as a crescent when viewed from the air. These "quarter-moon" shapes are found on the Peruvian plains, in Africa's Sahara, in many of our states and in the frozen area of Alaska and Canada. In fact, dunes in some form are common in every sand area of the world. Because of their distinct outline and shape, they soon become "friends" to be recognized on sight. Because they are often covered with a dense timber growth in humid or wet climates, we might expect the dune's outline to be obliterated. Examination will show, however, that the type of trees and undergrowth on the dune will differ markedly from that surrounding the dune. Consequently, the land form of the dune and the accompanying change in vegetation become characteristics that we learn to associate with these hills of sand.

The land forms considered in this work deal with the individual materials. Where "plateau" may indicate one of several sedimentary rocks, engineers must deal specifically with limestone, or sandstone, or shale, or with combinations of these. Each is a rock differing from all others in physical and often chemical properties. Because of these differences, they weather differently to assume characteristic forms related to their individual properties.

Sketches, photographs and tabulated soil data are necessary to give the completely integrated relationship that connects the ground pattern appearing in the airphotos with the soil texture, moisture conditions and bed rock characteristics existing on the ground and beneath the surface.

Without this it must suffice to rely on the principles that govern this relationship. These lie in the simple facts that the origin of a land form and its resistance to weathering determine its shape, while the soil mantle covering it is produced by the weathering of land form material.

Because origin and composition differ, it is possible to assign definite characteristics of shape to land forms composed of:

- Sandstone
- Sandstone and sandy shale
- Sandy shale
- Sandstone and clay shale
- Limestone
- Granites & similar rock
- Slate
- Gneiss and schist
- Basalt (Trap rocks)
- Porous lavas
- Outwash plains (sand & gravel)
- Alluvial fans (sand & gravel)
- Eskers and Kames (sand & gravel)
- Terraces (clay, sand or gravel)
- Till plains
- Lake beds (dry)
- Moraines
- Flood plains
- Natural levees
- Beach lines
- Loess (windblown silt)
- Sand dunes
- Coral
- Muck and peat
- Swamp and marsh

Since the action of weathering in each instance carries on an orderly process of producing a soil mantle, certain types of soil are associated with each. Again, in most engineering work, a more exact delineation of soil boundaries is necessary. Further refinement is based upon three elements of the soil pattern—color, erosion and surface drainage. These have been established as indicators of texture and other soil or moisture conditions.

Gullies and drainage ways possess distinctive characteristics depending chiefly on the texture of the soil materials that are being eroded. Gully shapes, both in cross section and profile, are indicative of texture and changes in texture below the surface.

Earth materials, such as ice-laid drift and valley trains, that can be described as slightly cohesive, are marked by short, sharp-edged V-shaped gullies having a steep but rather uniform gradient from head to foot. In contrast, gullies in plastic, cohesive soil materials have long, low, uniform gradients. An example appears in Figure 2. In cross section these gullies will have well-rounded, sloping sides. Where these characteristics change in the length of a gully, a change in the soil profile is indicated. Where gullies erode through a surface mantle and encounter a deep and contrasting substratum, the cross section shape will change. Erosion features of sand-clays and silts have distinctive and individual

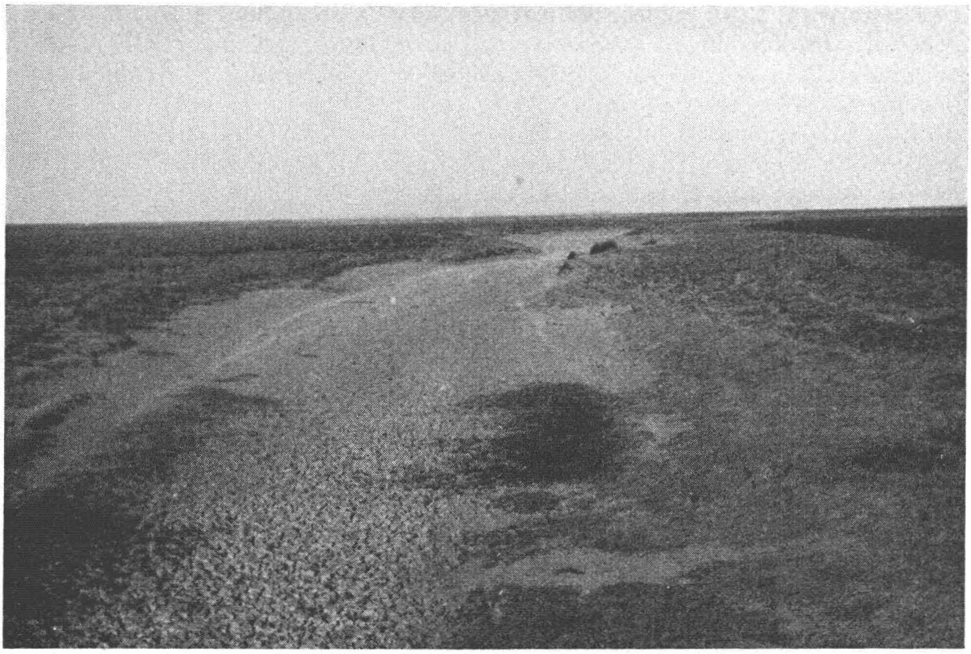

FIG. 2. A broad shallow gully in a plastic silty clay soil in North Africa illustrates the gently sloping sides characteristic of gullies in this type of material. In airphotos the features of tributaries, length and outline are obvious.

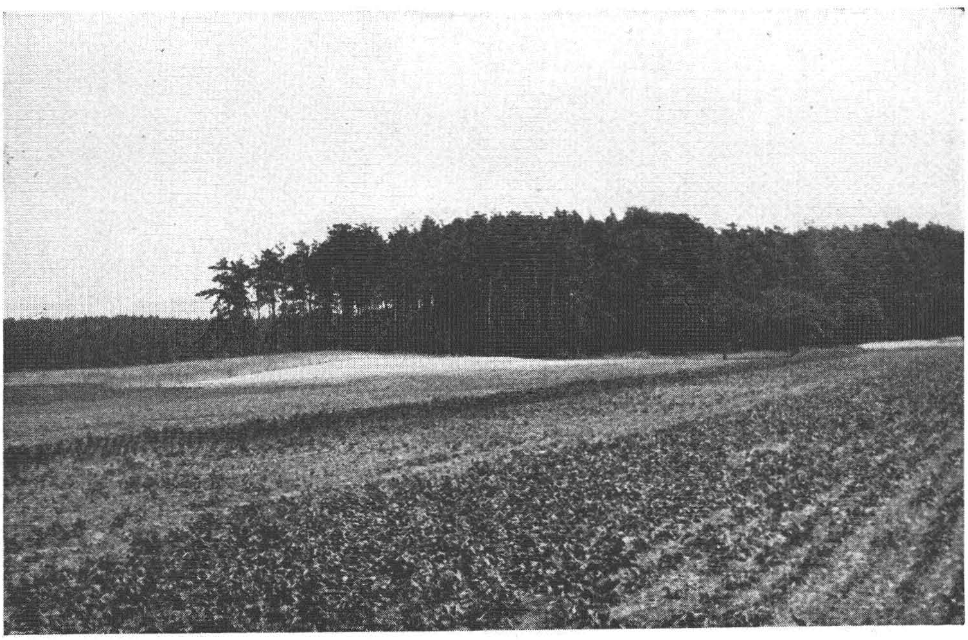

FIG. 3. The slight rise in ground left of center is also defined by a sharp decrease in gray value. The well-defined line marking the change in color constitutes a soil boundary on an aerial photograph. This feature, occurring along the autobahnen in Germany, is basic to all photoanalysis.

characteristics; their gullies, for instance, have a compound gradient and are generally U-shaped in cross section. Since these features are impartially recorded on an aerial photograph, the analyst can make a deliberate and detailed study of elements of the soil pattern.

Like other elements in the soil pattern, color is only a relative indicator of texture. Each element by itself is ordinarily insufficient evidence on which to base a judgement of texture; therefore, it is desirable to examine and evaluate each of these elements present in an area. This is usually practical, even on large land forms, since a single photograph will record nearly 10 square miles of area. Even in dry areas as in Spain, North Africa or our West, color changes are often a most obvious and direct indication of subsurface conditions. Light color tones (grays) are usually associated with well-drained soils, while clays, principally because of their water-retention capacity, appear dark. Well-drained silts, sands (Figure 3) and sand-gravel mixtures appear as light tones on aerial photographs. Such color values are often ascribed to vegetation and cover crops. While surface cover obviously will tend to obliterate a soil color, as shown in Figure 4, there are few cultivated crops sufficiently extensive and dense to obscure entirely the trend of the pattern.

Vegetation is a product not only of soil and climate, but of soil-climate—i.e., the same soil material occurring on different slopes will contain different amounts of clay. This is particularly important in tropical regions where long seasons of high rainfall are common. While the general impression gained from flying over a tropical 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

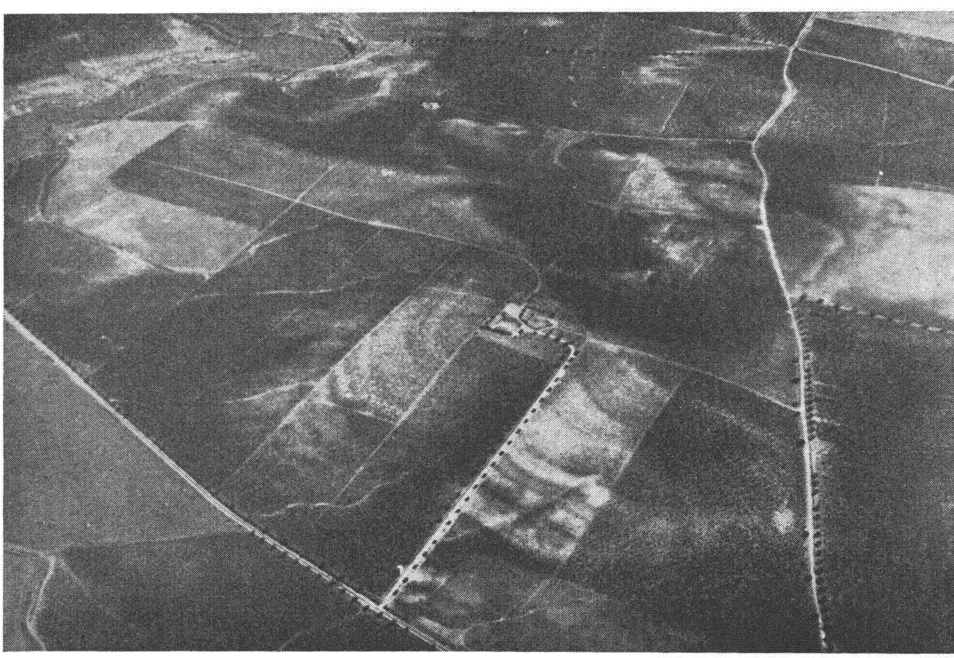

FIG. 4. Intensive, long-time cultivation of the land in dry southern Europe fails to obliterate the color pattern defining areas of clay, silt and other types of soil. Highways lined with trees diverge from the lower portion of the picture.

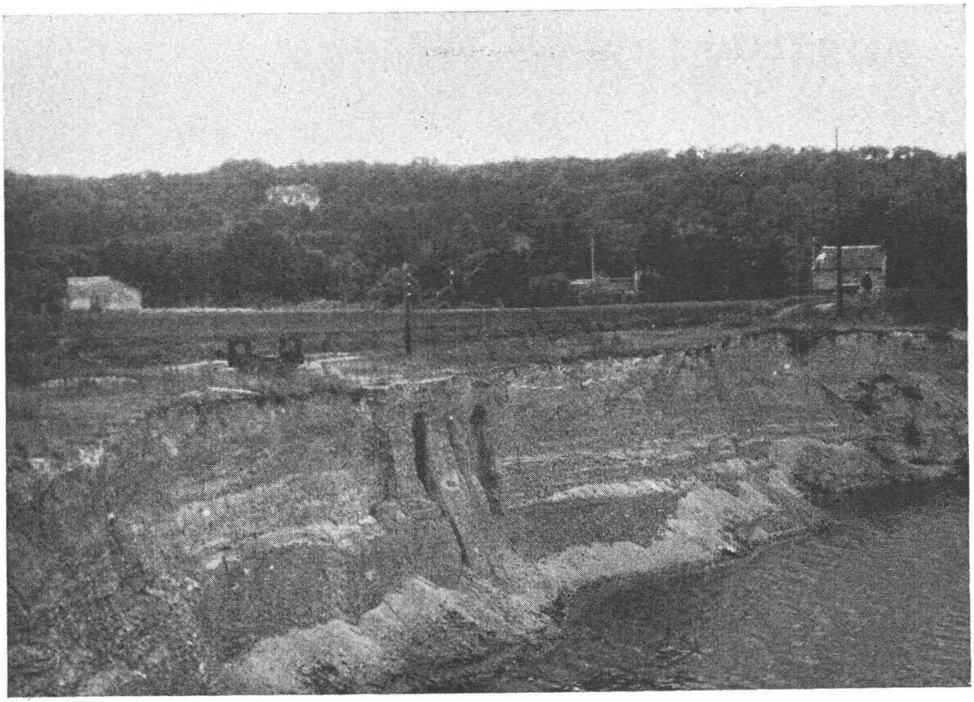

FIG. 5a. A gravel terrace in France, as elsewhere, represents a dry soil. Vegetation, whether natural or cultivated, forms an element of the soil pattern. Where wet spots or local deposits of clay occur on these terraces, changes in color and vegetation define the area.

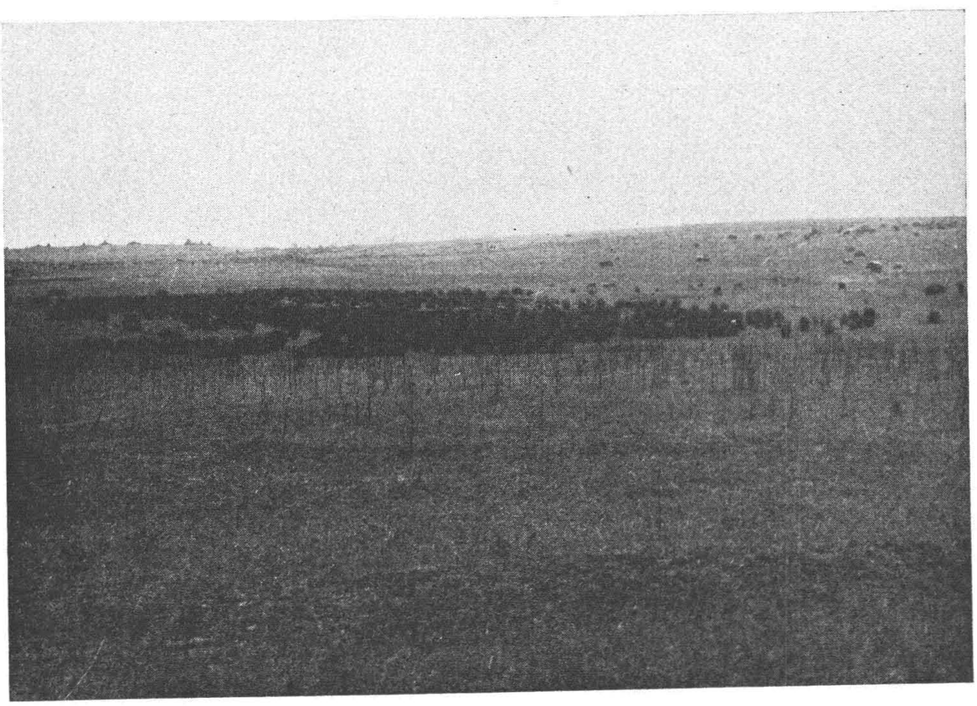

FIG. 5b. In desert climates, wet soils produce relatively dense vegetation in contrast to dry ground. Just how sharp the boundary is, depends upon whether the soil is a sand or a clay.

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 moisture conditions.

The amount and type of surface drainage on these land forms is related to slope and permeability of a land mass. Where there is a large amount of surface drainage on level to undulating relief, the soil material can be expected to be relatively impervious, while a lack of surface drainage indicates a porous land mass. Recent alluvium is an exception since it is periodically refreshed by overflow.

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 and subsurface deposits. As usage increases and experience is developed, numerous organizations are finding that engineering costs are less and a better quality of work results when full use is made of aerial photography.

PHOTO-INTERPRETATION IN MILITARY GEOLOGY[1]

John T. Hack

INTRODUCTION

MILITARY geology is a field of military science and of geology concerned with the application of geologic knowledge and techniques to various military tactical and strategic problems.

It has a great variety of uses in military terrain intelligence. The most common application is in predicting soil and foundation conditions at proposed sites for military installations, such as airfields, roads, bridges, piers, tunnels, water wells, and other large works whose location and design depends upon the terrain. Geology is also applied in studies of terrain appreciation which involve predicting ground conditions affecting ease of movement. All of these applications depend on knowledge, observed or inferred, of the structure, texture, porosity and other physical properties of the rock and soil on the surface and at depth.

Aerial photographs are an aid in this field just as they are in many other fields of military science and geology. Because they show the details of topography, drainage, vegetation and cultural patterns, they may be used as base maps or for the construction of base maps. Aerial photographs may also be used in interpreting geology or in extending a geologic map from a geologically mapped area into an adjacent area where the geology is unmapped. Much has been written about the great value of aerial photographs in interpreting geology, and some make the claim that aerial photograph interpretation may be used as a substitute for geologic field work. It is true that aerial photographs are an especially valuable tool in military geology when detailed information is required because they are often the only available source of such information, but they are not a substitute for geologic maps and reports resulting from detailed and careful field observation. I wish to describe in the following pages some of the methods of applying photo-interpretation to geology and to point out some of the limitations of these methods.

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