USE OF AERIAL PHOTOGRAPHS FOR TERRAIN INTERPRETATION BASED ON FIELD MAPPING*

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GEOLOGISTS, botanists, and soil scientists of the U. S. Geological Survey use aerial photographs as a standard tool both in field investigations and in compilation of terrain studies based on these investigations. Valuable criteria for use in photo interpretation grow out of these routine uses of aerial photographs in field mapping projects.

For remote and little-studied regions, such as most of the Arctic and Subarctic, a primary use for aerial photographic coverage is in the planning of field work. Study of the photographs provides a reconnaissance of the terrain, particularly its landforms and geomorphic history, in the project area. From this, specific critical sites for field examination can be located, and itineraries and logistics can be planned accordingly.

The investigators in the field use the photographs for navigation during traverses and for accurately locating the stations where data are collected. For many regions where suitable base maps are lacking, field data are plotted directly on the aerial photographs. The terrain analysis required for compiling engineering-soils maps or state-of-the-ground maps, for example, depends upon study of the gross landforms and regional lithology in order to determine the basic geologic conditions. Also attention must be given to subtle relationships of vegetation, microrelief, drainage patterns, and similar features in order to determine local surficial conditions. These smaller surficial features are most easily mapped directly on an aerial photographic base.

Following the field work, the office compilation phase relies upon aerial photographs for interpolation between the field localities that were thoroughly examined. The aerial photographs provide the scientist with a model of his field area, which he inspects again and again for additional critical information. During this phase specific field data are used to test regional generalizations formulated during the early reconnaissance with the photographs.

The geologist who correlated the natural conditions with the natural features shown on the photographs, after he has completed the field project, will have other occasions for using his accumulated experience. With this experience he may solve problems requiring extrapolation to contiguous areas, or to remote but analogous areas. The problems may involve determination of analogies between areas, or rapid survey of many areas to establish regional principles and generalizations. Specialized capabilities for recognizing and understanding terrain elements on photographs develop naturally from experience in field projects. These incidental skills make possible the so-called photo interpretation of terrain.

The Geological Survey has prepared for publication a report entitled "Geology and photo interpretation of permafrost and ground-water in Alaska," under the editorship of D. M. Hopkins and T. N. V. Karlstrom. This report is one of three companion reports relating to problems of ground-water development in Arctic regions, prepared by the Geological Survey for the Engineer Research and Development Laboratories, U. S. Army, Fort Belvoir, Virginia. The data and background for the report by Hopkins and Karlstrom were ac-

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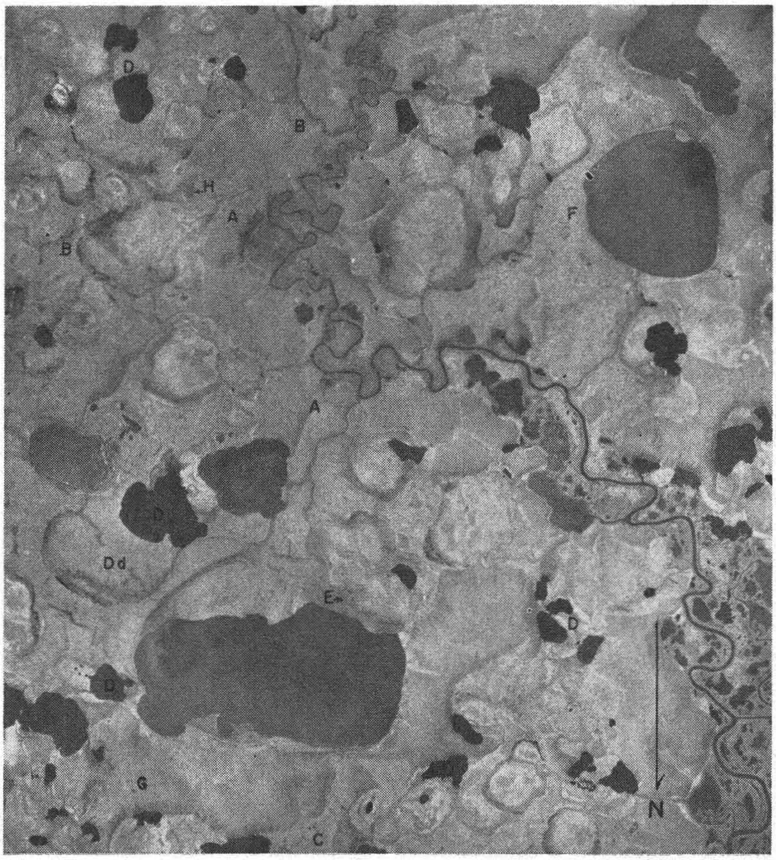

FIG. 1. Vertical photograph (approximate scale of original photo 1:40,000) of the coastal plain of northwestern Seward Peninsula, Alaska, illustrating terrain features indicative of permafrost. North arrow represents approximately one mile. Photograph by U. S. Navy.

cumulated in the course of field mapping of the terrain in Alaska. The discussion of aerial photograph interpretation dwells particularly upon the validity of indicators of permafrost conditions, but the principles established may be applied more or less directly to other types of terrain investigations.

It is generally acknowledged that the photo interpreter working on permafrost conditions depends upon such indicators as he can recognize on the photographs, features such as certain vegetation patterns and microrelief forms. The accuracy of the interpreter's estimate of the permafrost conditions depends upon his understanding of the significance and the limitations of these indicators within the area of study.

In Figure 1 (Figure 15 of the report), a portion of a vertical photograph of the northern coastal plain of the Seward Peninsula along the Chukchi Sea on a scale of 1:40,000, indicators of permafrost are numerous and conspicuous. Reticulate gully patterns at *A* mark thawing ice wedges. The beaded drainage at *B* is caused by thawing of ice masses at intersections of ice wedges; this gives rise to ponds along poorly integrated drainage lines. Thaw lakes (*D*) and basins of drained thaw lakes (*Dd*) cover about 75 per cent of the area shown. Field observations in nearby areas indicate that all the lakes are enlarging by thawing and caving of their banks. But no unequivocal evidence of active caving can be recognized on the photograph. The following features, however, are suggestive

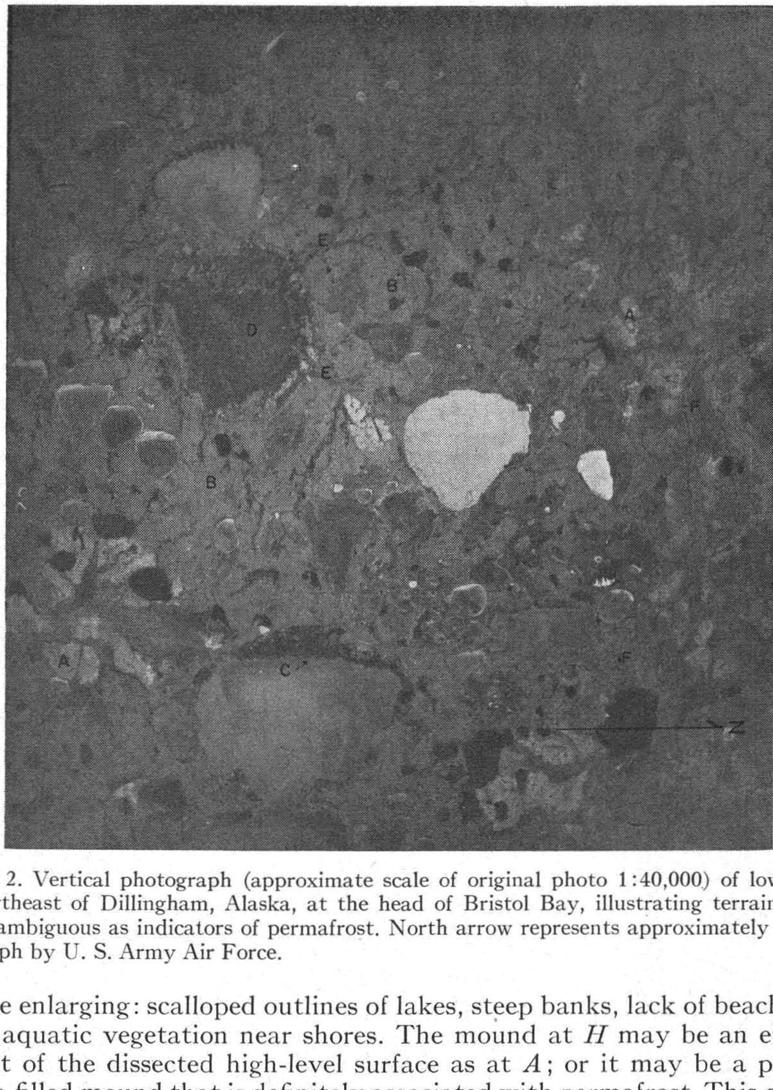

FIG. 2. Vertical photograph (approximate scale of original photo 1:40,000) of lowlands 25 miles northeast of Dillingham, Alaska, at the head of Bristol Bay, illustrating terrain features that are ambiguous as indicators of permafrost. North arrow represents approximately one mile. Photograph by U. S. Army Air Force.

of active enlarging: scalloped outlines of lakes, steep banks, lack of beaches, and lack of aquatic vegetation near shores. The mound at *H* may be an erosional remnant of the dissected high-level surface as at *A*; or it may be a pingo—a large ice-filled mound that is definitely associated with permafrost. This question cannot be resolved on photographs at this small scale.

In contrast, Figure 2 (Figure 8 of the report) is a photograph in which no dependable criteria for permafrost can be recognized, yet permafrost conditions can be evaluated over the area of the photograph because there is a small amount of subsurface control. In this area the subsurface control is based upon a few shallow test pits, knowledge of materials near the surface, and origins of the landforms, and to a lesser extent upon information on geomorphic processes associated with the microrelief features. The scale is 1:40,000; the north arrow is approximately 1 mile long; and the terrain is tundra-covered glacial moraine in the Bristol Bay region of southwestern Alaska, in the zone of sporadic permafrost. Areas of uniform medium-gray tone (*B*) consist of sedge-heath tundra growing on peat. Light-gray tones (*A*) are local patches of till and sand exposed on low hillocks covered with subalpine tundra plants. The lakes (*C*) resemble thaw lakes in outline; but they show no active caving due to thawing, so may be relict. Pools along the stream at *F* suggest beaded drainage. Actually they are due to damming by peat-forming vegetation and by formation of frost-heaved mounds. Ground studies reveal that in this area the peat soils are underlain locally at depths of 2 to 3 feet by a thin layer of permafrost. Permafrost is lacking or occurs at depths greater than 8 feet beneath lakes, drainage lines, and sand and till exposures. Some streams in the area widen themselves by thaw collapse, but these cannot be recognized on the photograph. Photo-interpretation of permafrost conditions in areas such as this is highly speculative unless supplemented by ground control (specifically relating to the subsurface) obtained through field work.

Analysis of criteria for recognizing permafrost conditions on aerial photographs demonstrated the following general limitations to the use of microrelief features and vegetation patterns as indicators:

(1) Most indicators merely suggest the presence of permafrost; and the more indicators that can be recognized in a given area, the more likely the presence of permafrost.
(2) Most indicators are significant only when considered in relation to the climate, topography, and geology of the region in which they occur.
(3) Most indicators reflect near-surface soil conditions and offer little or no information concerning the thickness, shape, and character of permafrost below depths of a few feet.

The report also points out that several orders of information are obtained from aerial photographs. First-order information—topography, microrelief, drainage patterns, gross aspects of vegetation, etc.—can be observed and measured directly on the photograph. Analysis of this primary information yields second-order information, such as the general lithology of exposed bedrock, the identities of plant associations on different sites, and the probable geomorphic origins of landforms. On the basis of this, third-order information is deduced concerning such matters as the probable composition and texture of the subsurface materials. The interpretation of permafrost and ground-water conditions is still further removed from the original observational data and must be founded upon further deductions concerning such items as the insulating properties of the vegetation, the character of the substratum, drainage conditions, and the geomorphic history. Keys can be readily established for derivation of the second-order, or even third-order information; but keys for fourth-order information, concerning permafrost conditions, for example, would be exceedingly complicated and unwieldy, and would be for the most part unreliable. For the evaluation of permafrost conditions in a given region the report recommends several partial keys leading to correct analysis of second- and third-order information. The partial keys permit evaluation of various sites in relative terms of favorability or unfavorability for the formation and preservation of permafrost rather than in absolute terms of permafrost or no permafrost.

The report concludes that to interpret permafrost conditions from aerial photographs the interpreter must be a specialist in the study of permafrost, with firsthand knowledge of the basic geologic, geomorphic, pedologic, botanical, and climatic factors that determine its forms and occurrence. We may expect to find that photo-interpretation of other aspects of terrain also requires groups of specialists in the elements of terrain, and that they will work with photogrammetrists, who can provide means of detecting and measuring the basic evidence.