AIRPHOTO INTERPRETATION AS AN AID IN MINERAL RECONNAISSANCE AND DEVELOPMENT*

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ABSTRACT

A brief general review of the possibilities of applying airphoto interpretation to systematic mineral reconnaissance. The basic elements of the airphoto pattern are described. Important mineral localization factors are reviewed. Research possibilities are suggested. Uses in the development of deposits are described.

INTRODUCTION

THE introduction to the 1952 yearbook of The Colorado Mining Association contained the following paragraph: "Too often we take for granted the metals and non-metallics that we use in our everyday activities. Little thought do we give to the future sources of supply of these all-important items. We have gradually come to believe that America no longer possesses the mineral reserves necessary to maintain the ever-increasing demands on our economy. Those who plan our future generally fail to realize the importance of encouraging new people to go into the worthy occupation of searching for, seeking out, and producing new mineral wealth."

This paragraph serves as the theme for the following discussion—a discussion concerned with the value of airphoto interpretation as a method for aiding mineral reconnaissance and development. A method that can be used advantageously by those who search for and seek out mineral deposits, not only in foreign lands but also in North America.

DESCRIPTION OF AIRPHOTO INTERPRETATION

First, it is necessary to define airphoto interpretation. Actually, a concise definition is impossible. Some explanatory statements seem to do the best job. These are as follows:

1. Airphoto interpretation is based upon a *stereoscopic examination* of *all* the features shown on an airphoto.
2. It depends upon the application of common sense and field experience backed up by physical and economic geology, geomorphology, and pedology.
3. It reveals information on the type and characteristics of the rocks, soils, and water conditions in a given area.

A 9 inch×9 inch airphoto, taken with a 6 inch camera from an elevation of 10,000 feet, shows an area of approximately nine square miles. At this scale, the photo shows most of the visible ground features that are important in a preliminary mineral reconnaissance. In addition it shows many features that may be impossible to detect in a ground survey.

It is apparent that if such a photo be examined by a qualified interpreter—one who is able to evaluate the significance of the various airphoto features—

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a cheap, efficient means is provided for the reconnaissance of large areas in little time.

To determine the significance of various airphoto features, an airphoto interpreter must stereoscopically examine and evaluate *all* of the airphoto elements. These elements include land form, surface drainage, gray-tones, erosion features, vegetation, boundary characteristics, and micro-details.

Recent work at the Cornell Center[1] has shown that it is possible to identify rock types and characteristics by determining and evaluating characteristic associations of two or more of these elements. Already it has become possible to identify—in most cases—such rocks as clay shale, silt shale, clean limestone, sandstone, granite, slate, tuff, rhyolite, basalt, etc., as well as unconsolidated deposits such as glacial drift, loess, outwash, etc. (Figure 1).

The first of these elements is land form. A land form is a terrain feature formed by nature in such a way that it can be considered *as a unit.* and described in terms of *typical individual, repetitive* characteristics. Like a mineral, it may occur throughout the world, often with variations in detail, but always with basic characteristics and properties that are recognizable to one who is familiar with them.

Some well known simple land forms are flat-lying sedimentary rocks, tilted sedimentary rocks, flood plains, alluvial fans, glacial moraines, and playas.

Land forms may tell a great deal about the materials in an area. Often, all that is needed. Sometimes, however, land form is not sufficient.

It is not enough to call a terrace a terrace. The construction engineer wants to know whether it is composed of sand, gravel, or silt. It is not enough to classify an area as tilted sedimentary rocks. The geologist wants to know whether they are sandstone, limestone, or shale. It is desirable to know whether a given area is composed of silt shale, clay shale, slate or schist. It may be important to de-

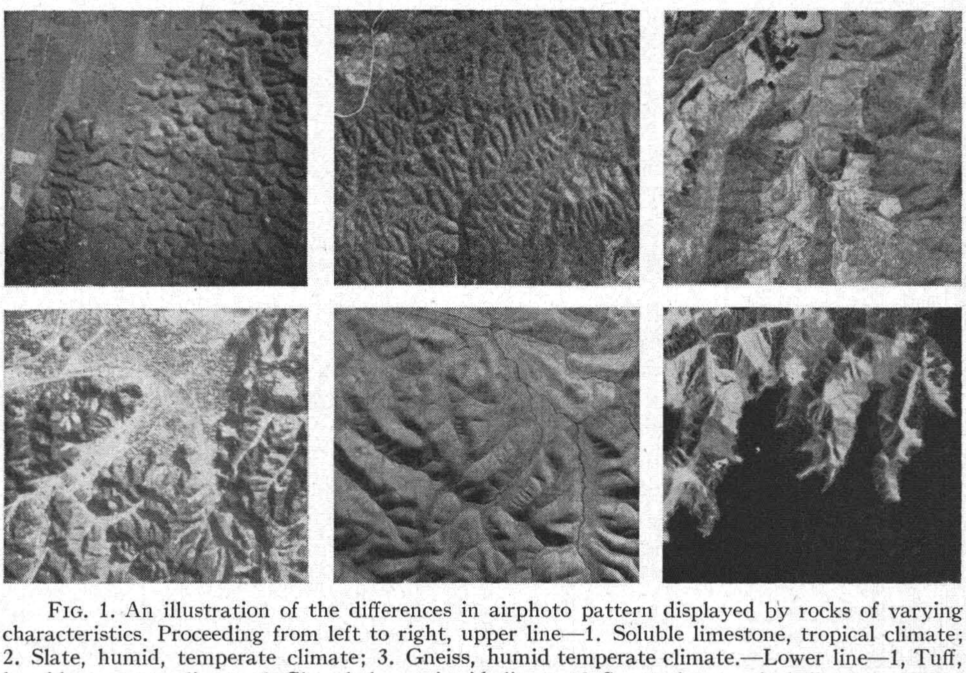

FIG. 1. An illustration of the differences in airphoto pattern displayed by rocks of varying characteristics. Proceeding from left to right, upper line—1. Soluble limestone, tropical climate; 2. Slate, humid, temperate climate; 3. Gneiss, humid temperate climate.—Lower line—1, Tuff, humid temperate climate; 2. Clay shale, semi-arid climate; 3. Serpentine, tropical climate.

termine whether a given area is igneous or metamorphic—acidic or basic—quartzite, basaltic, or granitic.

A good interpreter usually can answer these and other similar practical questions. Why? Because he goes beyond pure geological landform. He recognizes that shales, sandstones, gravels, and granites respond differently to the forces of weathering and that these different responses are reflected by many details shown in the airphotos as changes in drainage pattern, tone, erosion, etc.[2,3,4] He, therefore, analyzes these features.

He looks at the area surface drainage pattern. The characteristics of the materials in the area determine the density, arrangement, and other features of the over-all pattern. Conversely, the characteristics of the pattern are a clue to the type of material, as well as its boundaries.

He examines tone. A so-called "black and white" photo includes a great number of gray-tones. These reflect many things—actual soil and rock colors, the degree of moisture or moisture holding capacity, and the effects of vegetation. In most cases they are valuable indications of the texture and properties of area materials.

He examines erosion features. Since gullies cut through soil and bedrock, their *cross section* and *length* are largely controlled by the physical properties of the soil and serve as an additional tool for correct interpretation.

Numerous other details are important. Vegetation, culture, and local or regional *micro-indications*[5] gained only through experience, all contribute to the interpreter's accuracy.

In order to complete an airphoto interpretation, therefore, the interpreter examines *all* of the airphoto features, weighs the significance of each one, and forms his conclusions concerning the materials in the area. (See Figures 2 and 3.)

Sometimes the process of airphoto interpretation is complicated. At times it may call for photo-planned field sampling. At other times it requires only a few minutes work. In all cases, however, it yields valuable information at relatively small expense in a relatively short time.

Application of Airphoto Interpretation to Mineral Reconnaissance

The application of airphoto interpretation to mineral reconnaissance must now be considered specifically.

First, what is mineral reconnaissance? It is simply a search for, examination of, and evaluation of, *features that may indicate mineral deposits.* It is fairly general in scope, being followed, in favorable areas, by detailed rock study, sampling, assaying, and possibly, development.

What are the features that indicate the possibility of mineralization? To review briefly, they are features that *indicate* the *operation* of mineralizing processes or that tend to *facilitate, channel,* or *limit* that operation. These features, which may be called localizers or indicators, are reviewed briefly, in the following paragraphs, for the single process of hydrothermal mineralization.

Primarily, there is igneous activity. Hydrothermal deposits, according to economic geology, result from the movement and crystalization of fluids originating in bodies of igneous rock. Igneous rock bodies, therefore, are prime localizers.

Then there are "host" rocks—rocks whose physical and chemical characteristics affect mineralization. For example, it is reasonable to assume that hydrothermal fluid movement will be affected by rock permeability. Therefore, under usual conditions, relatively impervious rocks, such as shale and schist, do not favor mineralization, while porous rocks, such as breccia, soluble limestone, basalt, and sandstone do favor it. This assumption has been borne out by field observation.

Next, there are structural controls. These may be features of mass warping, such as evidences of folding, uplift, and subsidence, that indicate igneous activity. Or they may be faults, fissures, joints, and cracks that bring different rock types into contact or provide channels for hydrothermal fluid movement. (See Figure 4.)

Although not a "localizer," color may be an "indicator" of mineral deposits. The color may be associated with an actual outcrop (see Figure 5), an oxidation strain indicative of underlying minerals, or an alteration halo. In any case, the

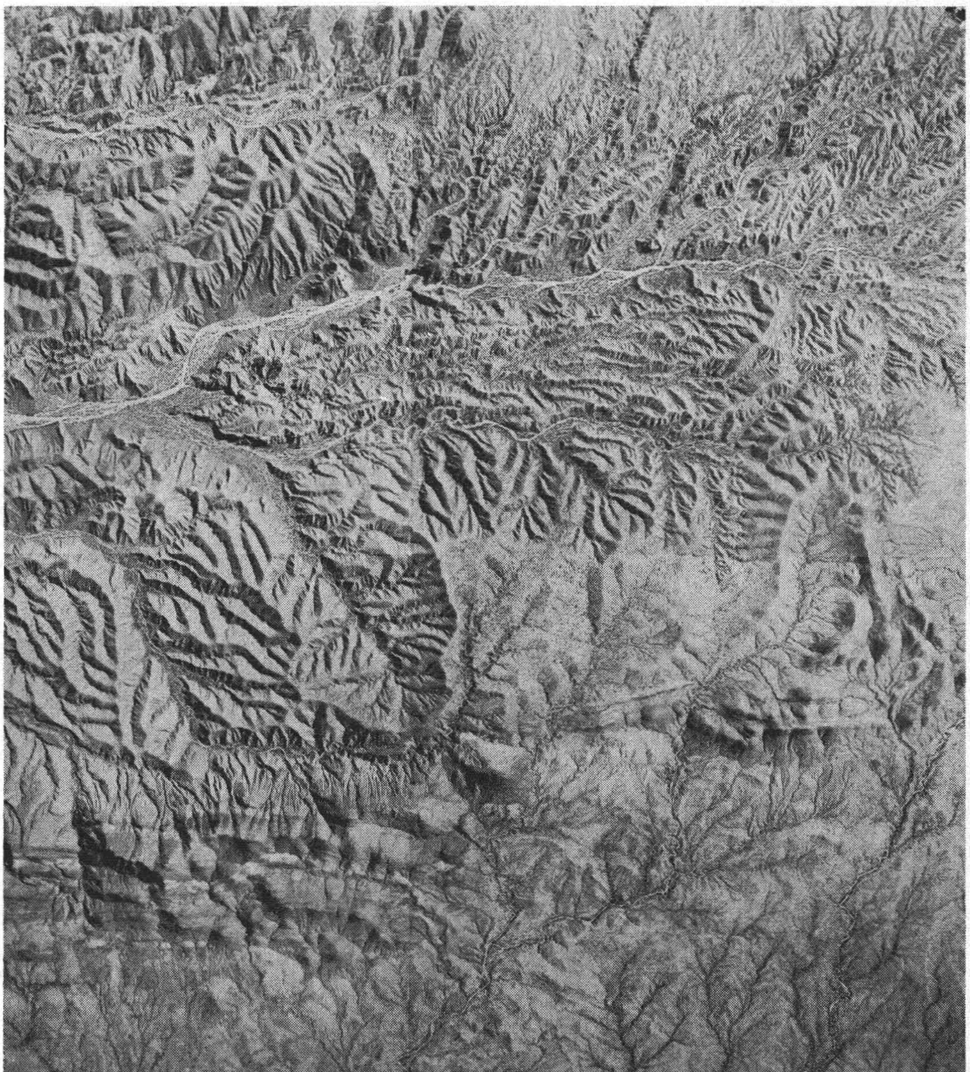

FIG. 2. An illustration of the varying response to arid weathering exhibited by earth and rock materials of varied characteristics. At least five, and possibly six, materials can be distinguished together with their boundaries, by separating them on the basis of surface drainage patterns alone. Note the sedimentaries that stand out boldly in the lower part of the picture.

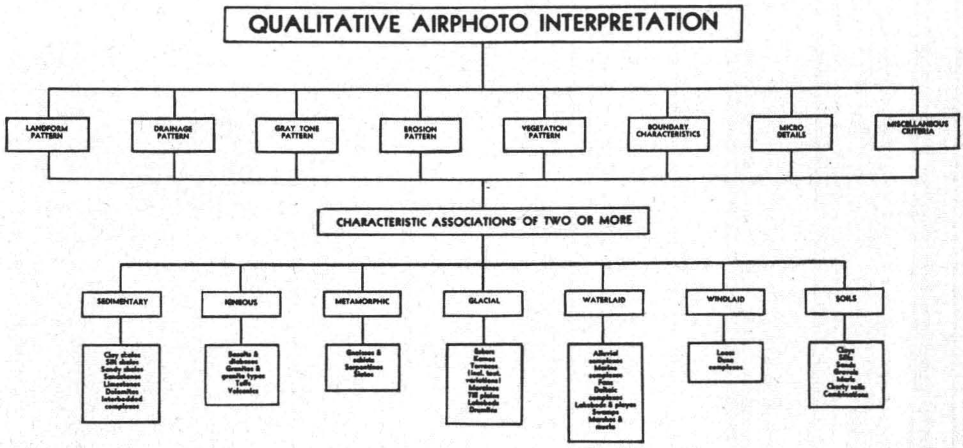

FIG. 3. A schematic diagram illustrating the basis of qualitative airphoto interpretation. The lower boxes indicate those types of rocks and materials that have been successfully identified (in most cases) by analyzing the characteristic associations of the major airphoto pattern elements.

blacks, reds, greens, browns, and yellows associated with mineralization always bear investigation.

Plant association may be an indicator. Practically no scientific information was available on plant-mineral associations until Goldschmidt published the results of some tests in 1934,[6] describing what has since been called the Goldschmidt Enrichment Principle.

According to this principle, minerals are dissolved in soil water and absorbed by plant root systems. In the plant they ultimately migrate to the foliage. When the foliage withers and falls, and eventually decays on the ground, some of the minerals remain, enriching the soil. Concentrations of minerals results.

Since about 1940, the Finns,[7] Swedes, Norwegians and Russians, together with some Canadians,[8] have found that mineral concentrations may affect plants in several ways:

1. They may change the appearance of foliage.
2. They may cause certain tolerant (or indicator) plants to thrive while stunting or killing all others.
3. The minerals may be concentrated selectively in the foliage of certain plants.

Many plant-mineral associations have been found. For example, zinc may be indicated by luxuriant ragweed in the presence of other stunted growth; the so called zinc pansy is often a luxuriant grower in the vicinity of zinc dumps; the two-foot brilliant red campion has been found to thrive in a soil having a copper concentration of 14℔/ton while other plants die. Douglas fir, larch, and the lodgepole pine may concentrate copper and zinc selectively in their foliage. If space permitted many similar associations could be described. (See Figure 6.)

Most of these localizers and indicators can be seen on airphotos. In addition, recent work in airphoto interpretation facilitates the identification of many rock types in a manner described in the initial portion of this paper. Therefore, using airphotos, large areas can be covered rapidly. The origins, types, and general characteristics of the rocks can be determined. Stress signs, color, and vegetative features can be located and examined. *Various locations can be rated according to the weight of favorable evidence.*[9,10,11] The most promising of these locations can be subjected to large-scale color photography, re-interpreted and possibly subjected to aeromagnetic or airborne scintillometer surveys. Finally, detailed

FIG. 4. An illustration of structural controls. At least five types of rocks have been brought into contact by forces of mass movement. On the photograph these are roughly separated by the white lines. On the original photograph, only the fault line at the right of the photo is easily apparent, the other rocks being distinguished only after careful inspection. As an example, the upper left part of the photo shows a coarsely jointed, possibly pegmatitic, dike. The arrow immediately below shows a parallel dike. However, since it has not been outlined, it is not immediately evident.

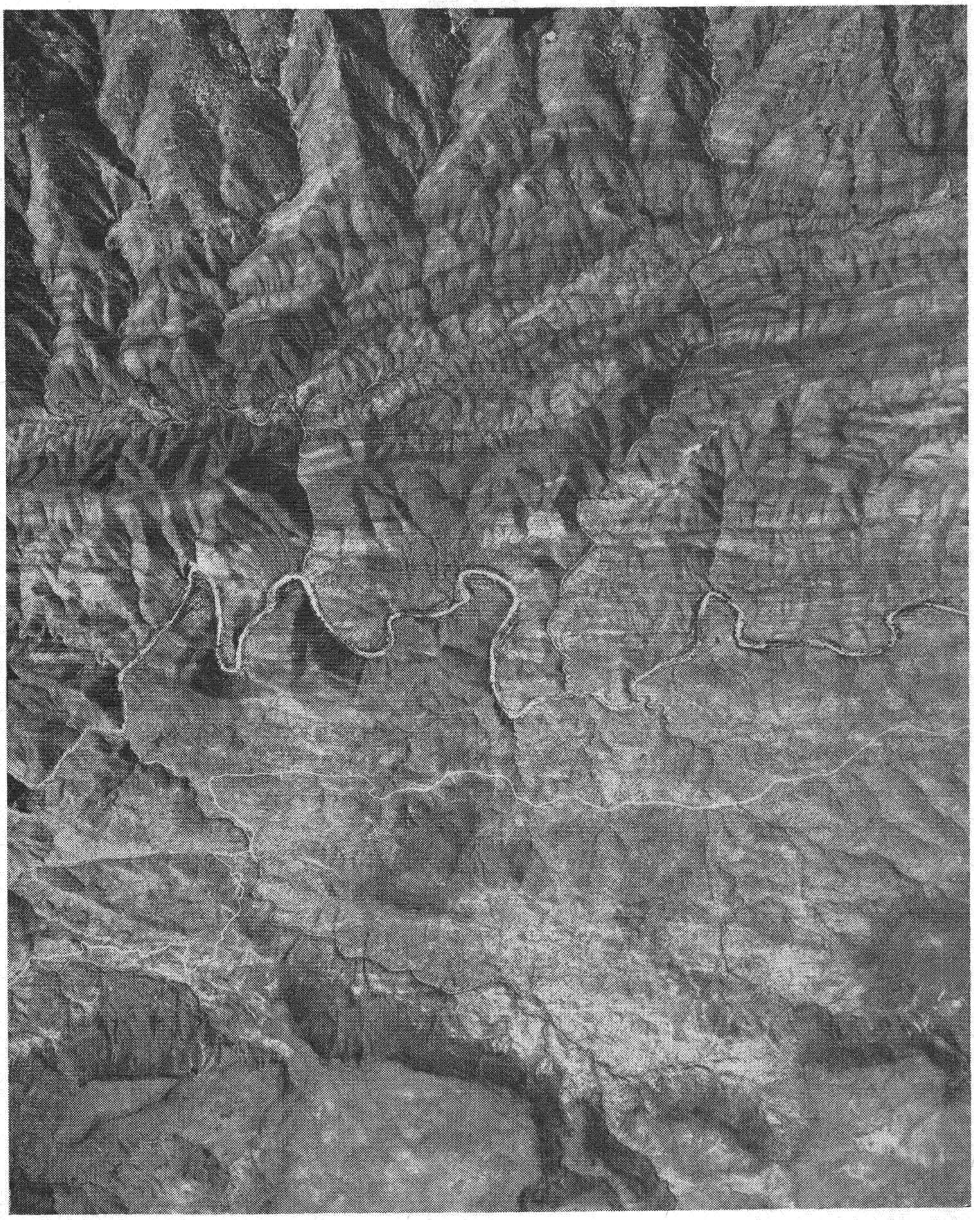

FIG. 5. An illustration of color banding and landform as they appear from the air. Color streaked sedimentaries at the top and dark colored basaltic flows at the bottom.

maps of these areas can be supplied to field geologists for use in ground investigation. (See Figures 7, 8 and 9.)

Research Needed

Of course, the airphoto method is not yet refined. Considerable research and experience are needed. This aspect must be emphasized because, in the author's opinion, well planned research is the key to the full utilization of the method.

For example, it is not yet possible using airphotos, to identify many of the

FIG. 6. An illustration of a possible vegetative "erratic." The dark-toned "moldy looking" areas in the upper right quadrant of the photograph indicate isolated areas of distinctive vegetation in an otherwise relatively barren area of rock (light-toned). The surrounding materials (darker-toned due to the "pepper pattern" of the vegetation) are different materials. A sheet-fracture pattern appears faintly at the right of the vegetative areas. There are numerous other small cracks. Dark-toned streams proceed to the upper left from the "moldy" areas. This area is included in the mosaic of Figure 8.

important igneous rocks such as syenite, monzonite, diorite, gabbro and dolerite. Yet these rocks are generally light or dark toned; they have typical colors; they occur in typical manners; and, because of differences in mineral and physical composition, they have different responses to weathering. Adequate research, based upon the examination of numerous deposits and supplemented by work with color, filters, and scale, would do much to facilitate their identification, just as it has succeeded in the rocks already described.

Research on scales is still needed. The largest scale is not usually the best one for mineral reconnaissance. Variations in rocks, environment, season and climate, as well as requirements based upon the detection of color and vegetation; all enter into the determination of optimum scale.

Filters provide a promising field, particularly in determining rock and vegetative types. Filters utilizing actual vegetable and mineral pigments can be constructed.[12] It is possible, therefore, to look for given indicator plants, rock types,

FIG. 7. Stress patterns (indicated by the numerous small dark lines of color and vegetation running from top to bottom) that may be related to the intrusion of igneous rock appearing in the upper right portion of the photo. This area, while possessing a somewhat different appearance due to vegetative and tonal differences, is most easily distinguished by its difference in land form. This is easily seen through a stereoscope though it is not at all apparent here.

and mineralization colors by taking photographs, and examining prints and negatives through filters that will emphasize the particular plant or rock colors desired. This technique would be of great value in arid areas. It might well be of tremendous value in forest-covered areas where prospecting by any means is difficult.

The field of plant-mineral associations in general is interesting. Little has been done to date. Airphoto research provides a rare tool for investigation on a large scale. Again, the results might be of particular value in forested areas.

Color photography has received little attention in mineral reconnaissance. Its use in detecting and examining outcrops, gossans and alteration halos would appear to be of tremendous value.

The relations between airphoto features and aeromagnetic patterns would

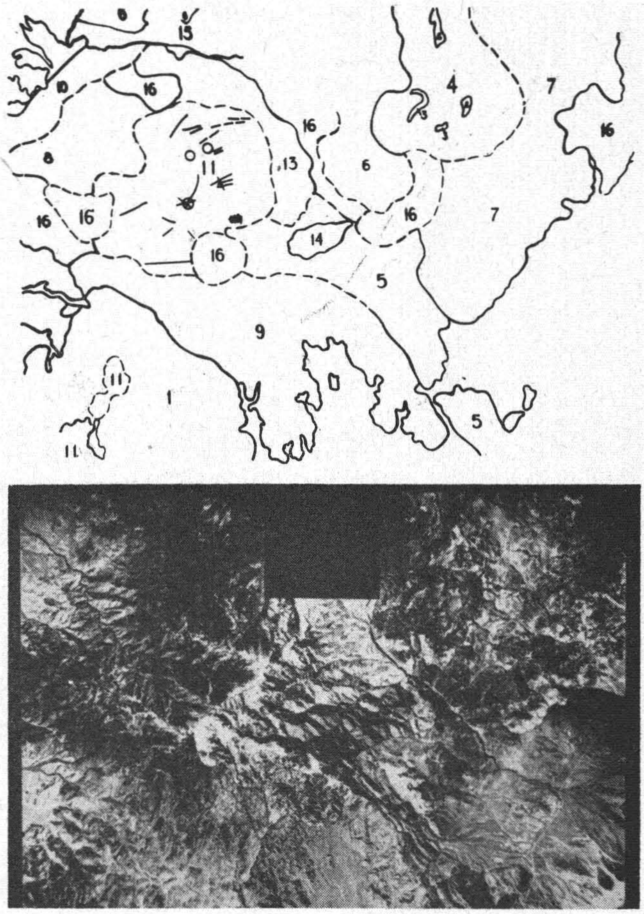

FIG. 8. A mosaic and overlay of a possible mineralized area. Drainage patterns are not included. The area shown in Figure 6 appears in the central portion of this mosaic (Number 11 on the overlay). Note the great variety of materials, many of which are favorable loci for mineralization.

most certainly prove interesting. Individual aeromagnetic anomalies assume importance only after geological environments are known.[13] Airphotos can aid in this respect. *More important is the correlation between certain significant airphoto details that have been observed to repeat themselves and aeromagnetic maps in the vicinity of such features.* This field is extremely enticing.

USES IN DEVELOPMENT

If space permitted, many phases of research could be discussed in more detail. However, in lieu of such additional discussion, it appears more desirable to devote a paragraph to the use of airphotos in mineral development. Some of the developmental uses are obvious. For example, the use of large-scale airphotos in the preparation of detailed property maps. Other uses, while they have proven their merit, have not yet beome well known. For example, it is possible, using airphotos to locate construction materials such as sand, gravel, clay and quarry rock.[14] It is possible to locate transportation routes and airfields, not only with regard to grade, cut and fill but also from the standpoint of construction and maintenance problems, road breakup, drainage conditions, depth to bedrock, and landslide potential.[15,16,17] It is possible, in many instances, to pre-

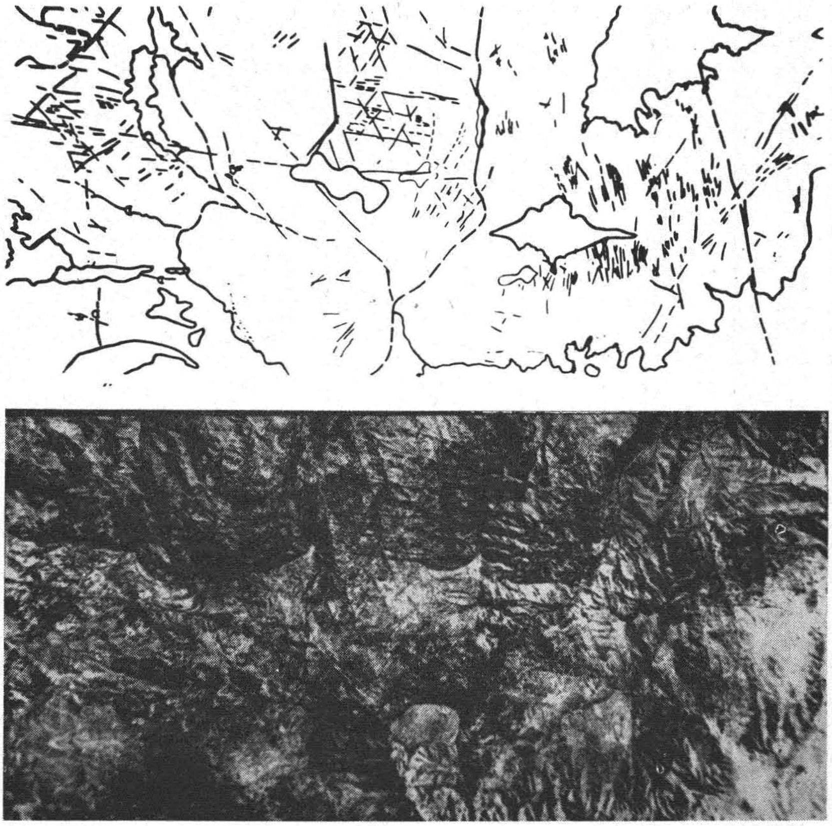

FIG. 9. A mosaic and overlay of another possible mineralized area. Drainage patterns are not included. The area shown in Figure 7 appears in the central left portion of this mosaic. A great variety of igneous and metamorphic rocks, combined with numerous faults, joints and dikes are easily plotted.

dict actual equipment needs. Pipeline conditions can be determined. In some areas, corrosion potential can be estimated. Groundwater, surface drainage, and runoff often can be evaluated. The possibilities are numerous and of obvious value in planning the development of relatively remote deposits. Again there is not space to describe them in detail.

Conclusion

Qualitative airphoto interpretation—and the word "qualitative" should be emphasized—*if backed by properly planned research, and utilized to its fullest extent*, provides an exceptionally valuable tool for mineral reconnaissance.

By its very nature, it is rapid. Consequently it is adapted to economical surveys of large areas as well as small.

Because of its discerning nature it is ideal for the detection of the less obvious deposits, as well as those with noticeable surface expressions.

If conducted by trained photo interpreters, backed by research results, it appears to be a most reasonable, practical basis for all mineral exploration whether it be aeromagnetic, geophysical, or field survey. Used properly, it enhances the prospect of discovering the many mineral deposits that still lie hidden in the vast, relatively unprospected areas of Canada, Alaska, and the United States.

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NEWS NOTE

NEW MODEL, KODAK PONY 135 CAMERA

A new model of the popular Kodak Pony 135 Camera, featuring a unique automatic take-up spool which eliminates the need for threading the film leader into the take-up mechanism, has been announced.

To load the new camera, one merely has to pull out a length of film leader to a predetermined position, drop the end of the leader over the take-up spool, close the camera, and wind the film. The end of the leader is then engaged by a small pin on the take-up spool. For easy removal of the film retort, a new spring has also been added to the storage cavity of the camera so that when the rewind knob is pulled out, the retort automatically pops out.

Known as the Kodak Pony 135 Camera, Model B, the camera will list for $36.75.