AIR PHOTO CRITERIA OF ORE LOCALIZATION IN THE CORBIN-WICKES MINING DISTRICT, JEFFERSON COUNTY, MONTANA*

W. S. Levings and K. S. Herness, Colorado School of Mines, Golden, Colorado

Introduction

THE purpose of this study which concerns one of the older and once productive mining districts of Montana is to illustrate the extent to which the study of air photographs can be helpful in supplying information concerning structures of other features and conditions that serve as clues to the location of orebodies. These guides range from those that are broad and general in nature, such as the topographic expression of veins or mineralized areas, to relatively minute structural details such as those showing flow fabric whose presence is reflected only by subtle variations in the color tone or texture of the photograph.

Location and History

The Corbin-Wickes mining district, at one time one of the largest producers of silver-lead ore in Montana, is situated about 35 miles northeast of Butte of world-wide fame. It comprises one of the many districts of the Helena mining region, an area of 1,300 square miles in the southwestern part of the state (Figure 1). Within the area are included the neighboring towns of Wickes, Corbin and Jefferson, along the Great Northern Railway.

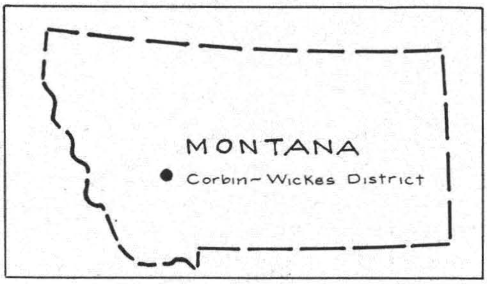

FIG. 1. Index map showing the location of the Corbin-Wickes district.

In common with so many of the old mining districts of the western United States, the discovery of the mineralized lodes in the Wickes area in 1866 followed closely upon the finding of rich gold placers, in this instance, those in and around the present site of Helena. These early-day mines, notably the Alta, located between Wickes and Corbin, were largely influential in establishing the lead smelting industry of the state at Wickes (later removed to East Helena), and the reputation of Montana as an important silver producing state.

The lack of an adequate transportation system together with high freight rates and expensive metallurgical treatment previous to 1883, were serious handicaps to mining operations in the region. The arrival of the Northern Pacific Railway in that year initiated a period of maximum production which persisted until the financial panic of the '90's. The steady decline in the price of silver, long delays in receiving returns on the bullion shipments to eastern refineries with the attendant loss due to the decline in price, resulted in a general suspension of operations throughout the district. Production suddenly and drastically declined. Since the turn of the century, small-scale production has been effected mainly by lessees who have been more or less successful in reworking the old company dumps and tailings and in the mining of small ore pockets either overlooked or bypassed by the companies. The good grade of

* Paper read at the Nineteenth Annual Meeting of the Society, Hotel Shoreham, Washington, D. C., January 14 to 16, 1953. This paper was a part of the Report by the Photo-Interpretation Committee.

ore, however, in conjunction with favorable geological indications are suggestive of important ore reserves that remain to be discovered.

Production

Production data for the Wickes district previous to 1904 are not accurately determinable. A good index of its magnitude, however, is afforded by the early production data available for the Alta mine, by far the dominant producer in the district:

"The production of the mine previous to 1893 is stated to have been 1,250,000 tons of ore, aggregating $32,000,000, mainly in lead and silver, and up to that time, only the highest grade ore had been shipped."[1]

From 1893 to 1919 the dollar value of the Alta is reported to have reached the imposing total of $40,000,000.[2]

A summary of the production statistics for the Corbin-Wickes district from 1904 to 1919 follows.[3]

Gold	Fine ounces	10,453.47 or $365,855
Silver	Fine ounces	2,802,603
Lead	Pounds	21,689,672
Copper	Pounds	3,429,280
Zinc	Pounds	8,542,355

Total tonnage—548,903 (includes ore, tailings, concentrate and slag).

Physical Features

The area under consideration is in the Northern Rocky Mountain Province, east of the Continental Divide. On its south and southeast borders it is hemmed in by the Boulder and Elkhorn Mountains, respectively. Although, the relief is considerable and in many places abrupt, the topography is characterized by the broad, rounded summits of the hills and the rolling configuration of the intervening lowlands. Alta Mountain, a conspicuous feature of the landscape, rises about 1,000 feet above the valley floor of Woodchute Creek, one of the principal drainage courses of the districts.

The area is drained toward the northeast into the Missouri River by the tributaries of Prickly Pear Creek, the largest stream in the district.

General Geologic Setting

The Corbin-Wickes district is geologically located within the confines of a mass of granitic rock which forms the northern extension of a great intrusion in southwestern Montana known as the Boulder batholith.

Although the area under consideration was covered by Cordilleran seas, no sedimentary rocks of pre-Quaternary age are known. Sedimentary rocks of Paleozoic and Mesozoic age, however, crop out in the Elkhorn Mountains 12 miles southeast of Wickes.

The igneous rocks of the district may be classified as pre-batholithic, batholithic and post-batholithic. The sole representatives of the pre-batholithic rocks are late Cretaceous andesites aggregating perhaps 4,000 feet in thickness which were extruded upon a warped and broken terrain resulting from the Laramide orogeny. Subsequent invasion and in places, doming of the andesite flows, tuffs and breccias by quartz monzonite magma in late Cretaceous-early Eocene time

[1] Knopf, Adolph, "Ore Deposits of the Helena Mining Region, Montana," *U. S. Geol. Survey Bull.* 527, p. 109, 1913.

[2] Ropes, L. S., Personal Communication.

[3] Compiled from Mineral Resources of the U. S., U. S. Geological Survey.

was followed by the formation of ore deposits around the margin of the monzonite, but chiefly in the roof rocks overlying it. An exceptionally large erosional remnant of these rocks forms a roughly rectangular "roof pendant" about 25 square miles in area, west and north of Wickes.

In many places the andesites display pronounced flow banding (Plate 1); consequently, the attitudes of these rocks are much more readily determined than otherwise would be possible. Although the dips are generally flat, steep dips ranging from 45° to the vertical are not uncommon (Plate 2). Whereas, strike lines generally have a northeast trend, significant deviations and even opposite trends point toward recurrent warpings and dislocation.

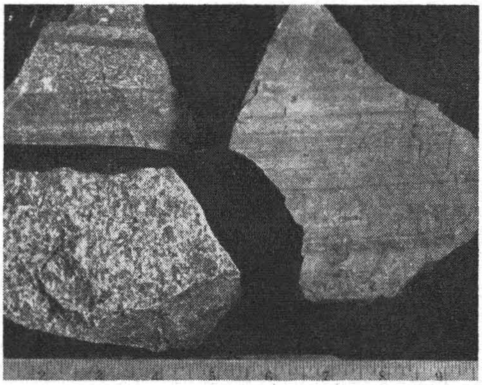

PLATE 1. Specimens of andesite porphyry from the Bluebird area; well-defined flow banding shown at the top and to the right.

The early Tertiary batholithic rocks are mainly quartz monzonite, but many aplitic and pegmatitic facies are present either as residual differentiation masses and schlieren or as injection dikes in the quartz monzonite (Figure 2).

Late Tertiary post-batholithic rocks are represented by a thick series of light-colored flows and sub-parallel dikes of dacite porphyry (Plate 11). These dikes served as feed channels for the flows. The dacites overlay or intrude the andesites in a north-south trending zone about six square miles in extent north and west of Wickes. Elsewhere, dacite dikes cut the quartz monzonite thus proving the younger age of the dacite. Flow structure in the dacites, in common with the andesites, is conspicuous in many places.

The principal structural features include veins, faults, dikes and primary flow structures in addition to the quartz-monzonite cupola intrusives. A pronounced vein system which exhibits a predominant eastward trend—almost due east in the area covered by andesites and northeast in the granitic rocks—dips northward. In the Mt. Washington mine the dips of the veins approach the vertical ranging from 80 degrees to 85 degrees in contrast to the relatively flatter dips of the Alta and Minah mines which range from 45 degrees to 50 degrees.

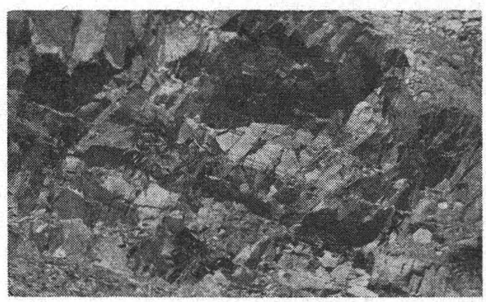

PLATE 2. Flow banding in unaltered andesites.

The veins, which are a final manifestation of batholithic igneous activity in the area represent the filling or replacement of fractures produced by continued compressional deformation after the top portion of the magma had solidified. That, in general, the andesites were deformed prior to the mineralization is evident where the veins cut masses of andesite of different attitudes.

A series of parallel, normal, post-mineral faults showing maximum development in the dacite area between the Minah and Alta mines trend south-southwest and dip steeply westward. These faults are relaxational in nature, consequent upon the release of post-intrusive compressional forces.

Primary igneous flow structure developed at the time of the magma emplacement is indicated by the parallel orientation of minerals, clots, and inclusions and by compositional banding. The recognition and mapping of such flow structure are significant in the determination of hydrothermal solution source areas or cupolas because there can be no mineralization in any area where hydrothermal solutions are lacking. Flow structures, moreover, are significant in the delineation of areas and vertical depth expectancies of favorable igneous host rocks.

Ore shoots or rich aggregations of ore within veins, in many places, are localized where lithologies favorable for ore deposition are present. The spacial projection of such lithologies is facilitated by knowledge of flow structure or of rock fabric orientation. By projecting flow layers or rock fabric on vein planes, reliable criteria for the prediction of ore shoot rake may be obtained with resultant savings in the cost of mine development.

Structural criteria for the localization of ore deposits likewise may be obtained from rock fabric studies. For example, ore shoots tend to "make" only where the rock fabric forms obtuse angles with the vein.

Post-mineral intrusives and extrusives are common in many mineralized areas and present a problem in ore shoot prediction. Where dikes transect the veins, ore necessarily is missing as a result of the displacement of the vein by the dike, either by dilation or by the assimilation of the dike material. It is therefore important to know what portions of an intrusive-extrusive complex is dike material and what portion is flow cover, as ore may be present beneath the extrusive flows. Steeply inclined flow banding is indicative of dike areas; where the flow banding is flat lying, flows are suggested.

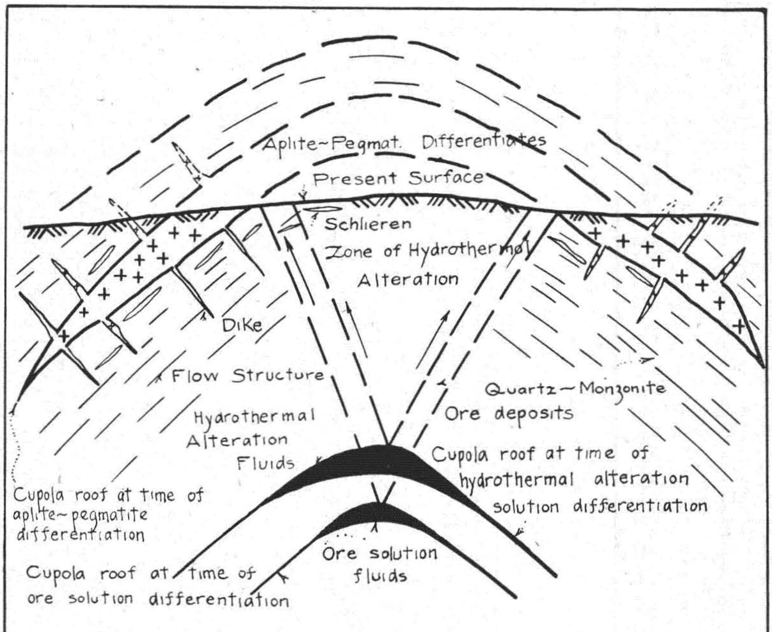

FIG. 2. Idealized cross section showing the relationship between igneous source and mineralized zones.

Ore Deposits

The ore deposits of the Corbin-Wickes district have formed primarily as the result of the differentiation of the Boulder batholith magma.[4] Evidence for this belief is seen in the localization of the orebodies within or near the quartz monzonite. Ascending hot solutions from the cooling magma not only have given rise to mineralized veins by filling and replacement along fissures, but also have drastically altered the country rock. In certain portions of the area this alteration is of blanket type and the entire area is bleached and tourmalinized; in other portions the alteration is confined to the fissure or vein walls. Figure 2, which shows an idealized relationship between the igneous source and mineralized zones is self-explanatory. Dikes emerging from the zone of aplite-pegmatite differentiates suggest that this portion of the igneous mass remained mobile after its surroundings had cooled and hardened and that subsequent compressive deformation squeezed the fluids into the adjacent country rock.

Chemical as well as physical control in ore deposition in the district is shown by the selectivity of the ore-bearing solutions for the andesites as a host in preference to the granitic rocks.

Sulphide ore minerals predominate in the veins wherever andesites comprise the host rocks; in contrast, mineralization in the quartz monzonite areas is marked by greater amounts of quartz and pyrite. The ore minerals include sphalerite, galena, tetrahedrite and some free gold and silver. Gangue minerals are quartz, carbonates and tourmaline.

Air Photo Criteria of Ore Localization

In order to evaluate properly the mineral potentialities of a given district it is necessary to determine the character, arrangement and distribution of the various rock masses of which it is composed. Such a task, in time not far removed, usually involved many arduous hours in the field. With the development and effective use of air photos, however, not only was there effected a very great saving in time and physical exertion on the part of the geologist, but in addition, he was provided with a most comprehensive viewpoint of the terrain, enabling him to quickly classify basic geologic relationships. Of even greater importance was the demonstrated ability to detect features invisible on the ground, but which could be seen readily in the air view.

The use of air photos is especially helpful to the mining geologist because the photos, combined with field-work to make them strategically effective, serve as usable guides in the search for new ore bodies or extensions of those already known. Such guides fall in the categories of (1) physiographic guides, including the topographic expression of ore bodies; (2) mineralogical guides, such as alteration effects; (3) stratigraphic and lithologic guides, for example, favorable host rocks; and (4) structural guides among which may be included contacts, fracture patterns and flow structures.

To facilitate the discussion of the criteria of ore localization as determined from selected air photos of the Corbin-Wickes district, attention is directed firstly toward the broader district relationships. In this district as well as in other exploited mining districts, empirical patterns of the deformation, lithology and mineralization become established and constitute basic data in the search for areas favorable for ore occurrence. In the Corbin-Wickes district, for example, almost the entire economic production has come from veins in areas of local high relief within highly altered andesitic rocks.

[4] Knopf, Adolph, "Ore Deposits of the Helena Mining Region," *U. S. Geol. Survey Bull.* 527, p. 9, 1913.

The almost invariable association of ore with areas of high relief can be traced to the alteration effects of hydrothermal solutions on the country rock they traverse. End products which are chemically stable and hence resistant to weathering and erosion have been thus produced. Conspicuous examples of differing elevations resulting from this process appear in Plates 4, 5, and 6. Strong contrast between bleached and unbleached hand specimens of quartz monzonite are shown in Plate 3. This difference between altered and unaltered areas as caught by the air camera lens is fairly obvious in Plate 7, where the larger areas of darker color tone represent unaltered quartz monzonite. Similarly, reference to Plate 5 shows the summit areas of Alta Mountain, the most highly metallized zone in the district to be characterized by a light-gray color tone. Stereoscopic examination of matched pairs of photos, needless to say, readily makes local differences in elevation apparent.

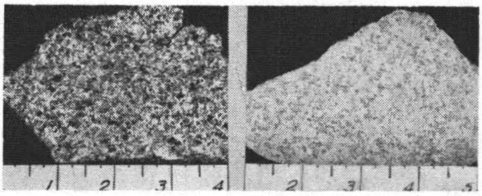

PLATE 3-A. Unaltered quartz monzonite.
PLATE 3-B. Altered quartz monzonite.

Hydrothermal alteration controlled by fissures is well exemplified in Plates 6 and 7; here hot, watery solutions from the underlying magma have altered the wall rocks to form a resistant sheath which may or may not have served as host rocks to metallic deposits and/or aplite-pegmatite dikes. Most of the aplites, however, are schlieren masses in the granite (Figure 2) although some occur as tension joint dikelets extending outward from the schlieren masses (Plate 7, Location A). Plate 8, by way of contrast, is illustrative of an area where the andesites, which were in existence before the ore was deposited and which served to localized it, were affected by blanket-type alteration. Where alteration of the blanket type has prevailed, the topography tends to be rounded in contrast to the decided ruggedness of the unaltered granitic areas. Moreover, within the areas of altered rocks, timber is commonly restricted to the northern slopes (Plate 9). In unaltered and hence unmineralized areas heavy growth of timber covers the terrain (Plate 10).

Alteration, which is photographically expressed in terms of topographic expression, slight but perceptible differences in color tone and areal distribution of vegetation, therefore, not only calls attention to the possibility of ore in the

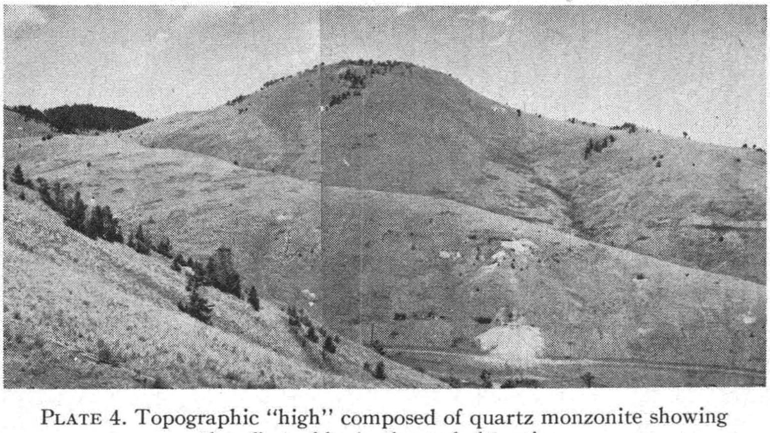

PLATE 4. Topographic "high" composed of quartz monzonite showing the effect of hydrothermal alteration.

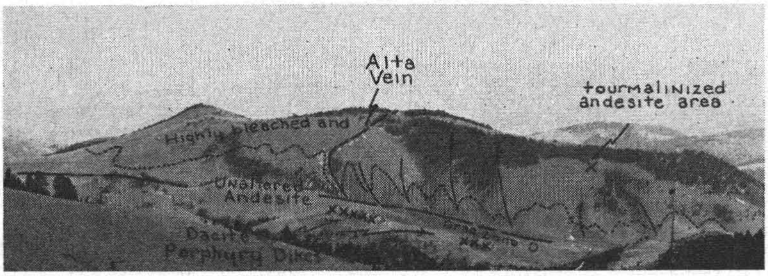

PLATE 5. Panorama of Alta Mountain showing the Alta vein, altered andesites, fault zone and dacite porphyry dikes. View is eastward.

Corbin-Wickes district as a whole but also may serve to locate outcropping veins.

In view of the fact that the andesites constitute the highly favorable host rocks to the ore-bringing solutions in the district under discussion, it is pertinent to inquire as to their distinguishing characteristics, if any, as seen on the air photos. In this connection should be mentioned the flow banding and streaking referred to in the introductory portion of this paper. Although easily visible on the ground at many localities these structural features are expressed on the air photos in the form of delicate swirls or streakiness which becomes apparent only after close inspection preferably stereoptically. A definite impression of "swirling" from the ground viewpoint is gained by scrutinizing the area slightly to the left of center of Plate 5 which shows the west face of Alta Mountain. Referring to Plate 8, Location A, the air counterpart is seen to be not so obvious. The western portion of Plate 8, however, is more satisfactory in this respect. A clean-cut example of flow banding visible to the unaided eye on the glossy original of this plate appears at Location B.

Unfortunately, this feature is not confined to the andesitic rocks. Flow structure fabric is seen to be present in abundance in the area of granitic rocks in the upper left portion of Plate 7. This type of structure, in general, is of material assistance in delineating flow closures or cupola areas which are the focal zone of ore-bearing solutions. The ore solutions tend to accumulate in the cupola closure in much the same manner as petroleum migrates into the higher parts of domed structures.

As might be anticipated, "swirling" and streakiness in the post-mineral dacites also are photographically expressed. No distinction between the andesites and dacites appears possible on the basis solely of tonal or textural variations. Unaltered quartz monzonite, however, expresses a decided preference for

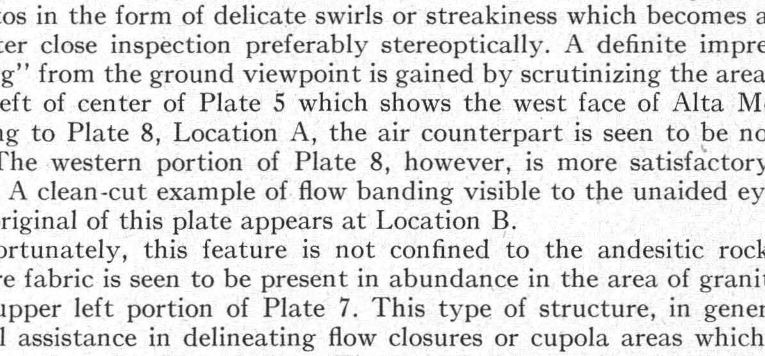

PLATE 6. Altered pegmatite-aplite veins in altered quartz monzonite.

heavy timber growth, is characterized by rock slides and in general is somewhat darker in tone than the extrusives (Plate 10; left portion of Plate 8).

Criteria indicating more detailed ore targets such as individual veins[5] are evident on air photos and in many places it is possible to trace clearly the position and lateral continuity of veins. Where mine and prospect development have occurred, the continuity may be traced easily by noting the position of waste dumps which occur preponderantly in alignments. Moreover, an impression may be gained of the amount of development that has taken place by noting the size of the dumps (see the Alta, Gregory, and Minah veins, Plate 9). The dump trends are much more readily discernible from an inspection of air

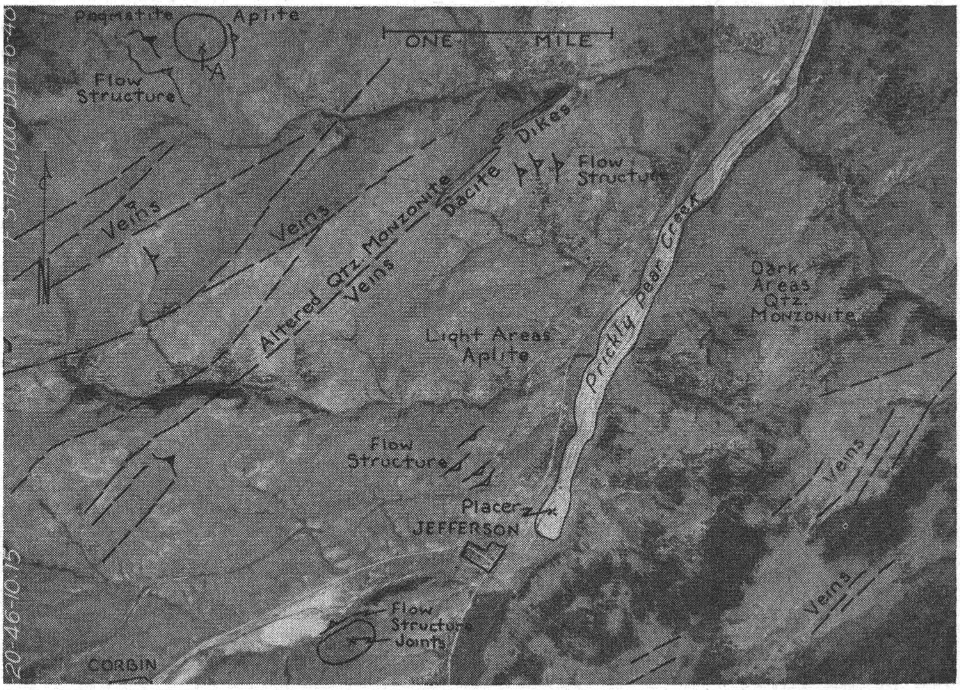

PLATE 7. Air view of the Jefferson-Corbin area showing veins, flow structure, dikes and joints.

photos than from the corresponding map implying a considerable saving in time in reconnaissance mining evaluation where time is "of the essence" in the selection or rejection of prospective mineral lands.

In undeveloped areas of the Corbin-Wickes district, the veins show on air photos as well-defined ridges reflecting the associated hydrothermal alteration. Veins of this type are conspicuously portrayed in Plates 6 and 7. A graphic expression of masses and dikelets of aplite-pegmatite typified by a very light color tone and highly irregular outlines appear in the upper left corner of Plate 7. Of incidental interest is the pictorial expression of placer tailings along Prickly Pear Creek (Plate 7), which would lead one to infer correctly the presence of outcrops of gold-bearing veins in this portion of the district.

Plate 8, Location C, shows an area where vein outcrops are covered with post-vein dacite flows (Plate 11) which were fed by a system of generally north-

[5] "Vein" as herein used denotes a fissure with or without filling but with hydrothermal alteration effects localized by the fissure. Hence a vein may be economically productive or barren.

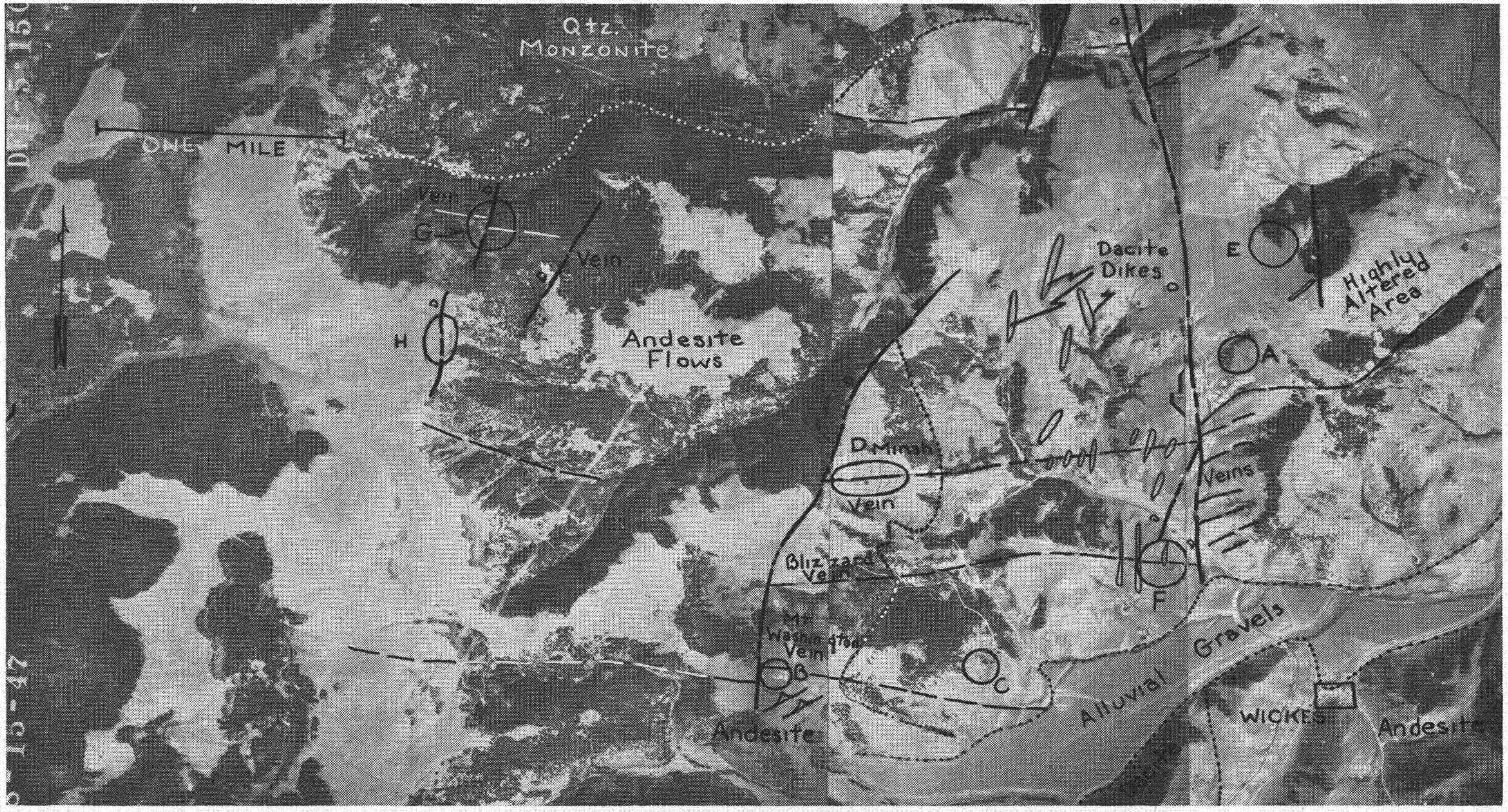

PLATE 8. Air view of the Wickes area showing blanket alteration, veins, dikes and faults.

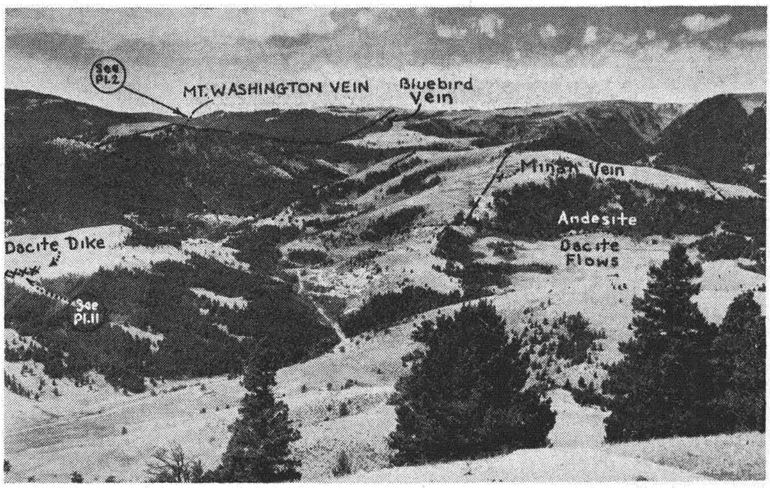

PLATE 9. Minah, Bluebird and Mt. Washington veins. View is westward from the summit of Alta Mountain.

PLATE 10. Unmineralized area in rugged terrain. The heavy growth of timber and talus deposits are characteristic of unaltered quartz monzonite areas.

south trending dikes. For the evaluation of sub-flow possibilities it is important to know what portions of the flow-covered veins either terminate against or are cut out by dikes. Air photos, by showing the location, widths and extent of the dikes are helpful in arriving at decisions concerning the extent of remaining vein segments. Such a situation exists along the Minah,[6] Blizzard, and Mt. Washington veins (Plate 9). Here also an intimate relationship between the dikes and assumed extensions of the veins is indicated which finds explanation in the fact that subsequent compressive deformation of the pre-mineral fracture systems reopened the east-west veins and post-mineral north-south faults which then served as dike conduits. There exists therefore, a tendency for a series of north-south dikes to be aligned along an east-west axis which is located immediately above the sub-flow vein apex. Such dike groupings within the dacite flow area are regarded as significant in the delineation of the sub-flow vein trends.

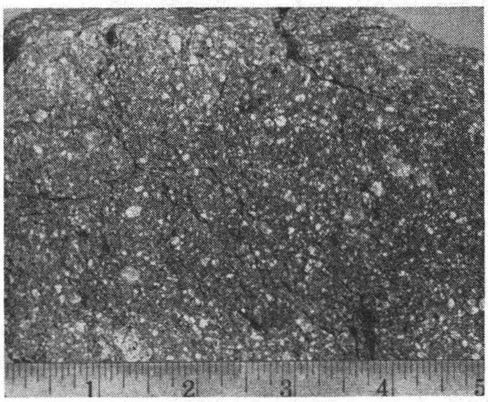

PLATE 11. Dike rock composed of dacite porphyry.

The identification and mapping of faults[7] in the district have proved helpful in the location and correlation of displaced veins. Interpretative criteria mostly relate to differences in soil color and vegetation. Reference to Plate 8, Location E makes such differences apparent. Topographic differences also, in places emphasized by the presence of north-south trending dacite dikes (Plate 8, Location F), which utilized post-mineral zones of weakness, are evidence of faults. A pronounced and persistent fault zone suggested by the topography, as an example, extends from Wickes to Gregory. Northward-dipping veins on Alta Mountain and elsewhere have been curved and cut by faults downthrown toward the west (Plate 8). Other topographic anomalies denoting faults are fairly obvious as seen in Plate 8, Locations G and H.

Photographic criteria of ore shoots involve various intersecting loci. A plausible explanation to account for the demonstrated past productivity of the Alta vein would perforce, recognize the fortuitous association of three different types of loci, topographic, lithologic and structural. Significant also in this regard is evidence of vein intersections at obtuse angles with the country rock fabric. Flow fabric, hence, may be of local as well as of broader significance. This case is clearly illustrated in the Mt. Washington area where the obtuse angle relationship is pronounced and definite (Plate 8, Location B). Not only does the flow fabric strike at an obtuse angle to the trend of the vein, but the visibility of the air photo permitted the dip of the flow fabric to be estimated as 40 degrees. This estimated dip checked with the dip observed in the field. Knowing the attitudes of both flow fabric and vein it is a simple matter to predict the rake[8] of the ore shoot within the vein. A large ore shoot was mined at this point the rake of which was 40 degrees to the west.

[6] The system of narrow, white scars along the west portion of the Minah vein (Pl. 8, Location D) represent bull-dozer trenches.

[7] The term "fault" as used in this paper signifies a fissure unaffected by hydrothermal alteration along which displacement has occurred.

[8] "Rake" is herein used as denoting the acute angle, measured in the plane of the vein, between the trend of the ore shoot and the strike of the vein.