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NOTES ON THE IVANPAH REGION. SAN BERNARDINO COUNTY, CALIF.

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ILLUSTRATION

GEOLOGIC MAP OF IVANPAH REGION, scale 1:250,000
In pocket at end of report.

NOTES ON THE IVANPAH REGION, SAN BERNARDINO COUNTY, CALIF.

INTRODUCTION

In December, 1955, the writer submitted an office report on the copper deposits of eastern San Bernardino County. Since I had a few days available for field work in January-February, 1956, it was suggested that I take a look at some of the area, which I had not visited since I was superintendent of the Vanderbilt mine, near Ivanpah, in 1923-4.

The region is a large one, and I had to decide whether to look at the northern portion, via Highway 91-466, or the southern, via Highway 66. Not having a jeep I decided on the northern area, where company geologists were working. Unfortunately the company jeep pickup left for San Francisco the day I arrived in Baker. Inability to get far off improved roads greatly handicapped my inspection, and combined with lack of a guide rendered my attempt to reach the Copper World mine fruitless.

The following report describes what I did see, with further data from the literature. The accompanying map combines, for the first time, geology, modern roads, topography and ore deposits, and should be of use to the men in the field. Much of the geology is inaccurate; I have made a few corrections from field observation, but it is unfortunate that Hewett's Professional Paper on the Invanpah quadrangle is so slow in appearing.

Publications referred to are listed at end of report.

FIELD WORK

On January 28 the area of the Mountain Pass rare-earth mine was examined, including the Precambrian complex east of the Clark Mt. fault, the fault zone, and the Paleozoic sediments west of the fault. The Teutonia Peak granitic mass was also examined, along the section between Valley Wells and Cima, as well as the area of the Standard No. 2 and Copper King mines.

On January 29 an attempt was made to reach the intrusives of the New York Mountains, from the Ivanpah-Barnwell road, but I got stuck in a sandy wash and had to turn back. Driving to Cima I succeeded in seeing part of the larger intrusive at the Death Valley silver-lead mine.

On January 30 I tried to reach the Copper World mine, but had to leave the car near the Mohawk mine. Not being able to see the Copper World dumps from afar, I did not know in which direction to walk, so I spent half the day examining the Mohawk mine, a lead-zinc mine which produced some copper. In the afternoon I managed to find the East Camp possible porphyry copper now being mapped, and spent several hours there.

On January 31 I returned to the East Camp prospect with Mr. Rust, who was very helpful in showing me the principal features. In the afternoon I left for Berkeley.

GENERAL FEATURES OF THE IVANPAH REGION

The best descriptions are by Hewett (1954a, 1954b), and for the Clark Mt. area, by Olson et alii (1954). Although the site of heavy

sedimentary deposition in the Paleozoic, the entire Mojave block, which includes the Ivanpah quadrangle, was subjected to vigorous erosion from the late Mesozoic into the middle Tertiary. During this long period the block rose possibly 20,000 feet, although its surface never attained any such height, the rocks being removed as the block rose.

This tectonic history explains the abundant outcrops of Precambrian, and the fact that only remnant areas of Paleozoic sediments remain.

The Ivanpah region seems to have undergone three major periods of deformation since Precambrian times. (1). In the late Cretaceous, folding, thrusting, normal faulting and intrusion, with copper-lead-zinc metallization. The Clark Mt. fault, which is mineralized, cuts the Mescal thrust but is itself displaced by a thrust parallel to the Mescal, north of the map area. The Mescal thrust shoves Paleozoic rocks over volcanics which are probably of Cretaceous age. Hewett (1954a, p.12) states that the Teutonia Peak quartz monzonite invaded the Mescal thrust, being therefore, like the Clark Mt. normal fault, younger than the thrust.

Hewett (1954a, p.12) places this epoch of deformation, intrusion and metallization in the late Cretaceous "within the period of Laramide orogeny". Others, including the present writer, believe that at least one major orogeny preceded the true Laramide, occurring in Mid-Cretaceous time, and that it was most strongly developed along a belt containing Goodsprings, Pioche, Ely and probably Tintic. Southwest of Goodsprings

the orgenic-metallogenetic belt passes through the Mojave region and traverses Baja California.

It is probable that Butte, Bingham, Bagdad, Ray-Miami, San Manuel, Ajo, Morenci and Santa Rita were metallized with copper in the "true" Laramide period, i.e; latest Cretaceous -early Tertiary. But formation of porphyry copper deposits was not confined to that period: it is highly probable that the deposits at Ely are associated with the Mid-Cretaceous orogeny, and that at Yerington as well, although Yerington lies well west of the Mid-Cretaceous orogenic belt. It follows that the dating of the earlier Ivanpah orogeny, that just described, as Mid-Cretaceous, does not militate against the possibility of finding porphyry copper deposits there.

(2). The second major period of deformation in the Ivanpah region took place in the Pliocene, at which time major thrusting was active in a north-south belt extending down the east side of Death Valley and extending southward into the Ivanpah quadrangle. Hewett (1954b) shows many Klippen in the northwest portion of the Ivanpah quadrangle; these are patches of Precambrian, remnants of the upper plate of a great thrust which has shoved Precambrian over Tertiary and older rocks. The accompanying map shows only one of these, the isolated exposure of Archean west of Clark Mountain.

The East Camp, Middle Camp and West Camp turquoise-copper showings lie within the area of Pliocene thrusts. While the Mid-Cretaceous thrusts may have had influence on base-metal localization, the Pliocene thrusts did not; but their presence within the area of possible porphyry copper deposits now being mapped might invalidate the pros-

pective value of such a deposit. Formexample,what seemed to me the most promising portion of the area now being mapped seems to be made up of Precambrian rocks. If this showing is merely a thin plate lying above a Pliocene thrust,the main mass of the copper deposit from which the plate came may lie miles away,probably buried beneath desert wash. At least one thrust lies near the area in question,for Mr. Rust showed it to me,at a distance.

(3). The final major period of deformation was in the Pleistocene, and was characterized mainly by block-faulting. The Ivanpah fault dates from this period.

SUGGESTED EXPLORATION IN THE IVANPAH REGION

The major known copper and lead-zinc deposits lie in a northwest belt,of which the Clark Mountain premineral fault forms the northeast boundary. That fault,with the thrusts just west of it, appear to be important ore controls. My present opinion,however is that the deposits of this belt,mainly replacements in carbonate rocks,offer small chances of making large mines. Final judgment should be suspended until publication of Hewett's Professional Paper. When that appears,any possibilities suggested for base-metal exploration should be carefully appraised. Meanwhile,exploration should be centered,as at present,on possible porphyry copper deposits.

My field work was done mainly with that idea in mind. The intrusives examined are described below.

Teutonia Peak Intrusive.- Where exposed along the Valley Wells-Cima road the rock is medium-grained,with large quartz phenocrysts and looks like biotite granite. Hewett calls it quartz monzonite.

Where seen, this rock was unaffected by hydrothermal alteration and showed no trace of metallization. While the rest of the intrusive should be inspected, it seems to offer little promise of a porphyry type copper deposit, except, perhaps, at its northeast end. This part of the intrusion lies within the main mineral belt mentioned; it adjoins the premineral Mescal and Clark Mt. faults, and it is surrounded by small copper deposits in the intruded carbonate rocks.

New York Mountains Intrusive.- The major intrusive here was examined only at the Death Valley (now Dolly Varden) mine. This silver-lead mine is now being drilled by Irven Bates, who has it optioned. A diorite dike, about 100 ft. wide, strikes northeast and dips 45° southeast. Each wall of the dike carries a quartz-argentite-galena vein. The main shaft was sunk on the footwall vein, about 4 ft. wide; but at the 200 ft. level this vein steepened in dip; the shaft was continued straight, leaving the vein below it. At the 400 ft. level a crosscut was driven to the hanging wall vein, said by Bates to be 17 ft. wide but lower in grade than the footwall vein.

Although the footwall vein was stoped to the 200 ft. level, it remains unexplored below that level. Bates is testing it there by an inclined hole with collar about at the outcrop of the hanging wall vein. The mine gives promise of further production but is too small to be of interest.

The country rock invaded by the diorite dike is in part medium-grained biotite granite (quartz monzonite?) but an igneous complex seems to be involved, some of the rock being coarsely porphyritic, some nearly aphanitic. Hydrothermal alteration is slight or lacking, and

no signs of disseminated metallization were seen. Here again, however, the whole intrusive mass should be looked over, especially its northeast end, where it butts against the premineral Clark Mt. fault. The smaller intrusive near the Trio mine is marked Jurassic (?) but is probably of late Cretaceous age and should be examined.

Mohawk Mine.- The Mohawk lead-zinc mine occupies the western portion of the east-west Mohawk ridge, the Yucca Metals mine, the eastern part. The ridge is sharp and narrow; mine workings exist on both slopes.

Quartz monzonite intrudes moderately thick-bedded limestone and black dolomite, probably the Cambrian Goodsprings dolomite. The quartz monzonite, shown on the accompanying map, forms the lower half of the south slope of the ridge. The mass may extend southward, under alluvium, a considerable distance. The contact with the sediments strikes east-west and is intrusive, but is modified by faulting on transverse (roughly north-south) faults, and probably on longitudinal (east-west) faults as well.

Ore bodies occurred in the sediments, within a zone bordering the contact, half a mile or more in length, and perhaps 500 ft. wide, extending from the contact on the south slope of the ridge over the crest and part way down the north slope. Four or five small shafts were put down on this slope, and Yucca Metals drove an adit from that slope southwards.

One of the shafts was sunk on a small carbonate ore body striking east-west and dipping 56°S, probably conforming to the beds here. The ore body was localized along the intersection of the

ore bed with north-south vertical sheeting.

Farther west, another small ore body was localized by a roll in the dolomite beds, which strike north-south in this area, and dip west. The roll consists of a small anticline superimposed on the general structure and plunging southwest.

Another shaft on the north slope was sunk on an oxidized showing striking N20W and dipping vertically.

Several dumps on the north slope show ex-chalcopyrite limonite, as well as limonite derived from galena and sphalerite.

Three adits have been driven northward from the south slope of Mohawk ridge. The westernmost adit started on a well-defined oxide vein striking N20E and dipping 73E. At the portal the vein is four feet wide and consists mainly of limonite. The hanging wall is quartz monzonite porphyry, the footwall, marbleized limestone. The vein is along one of the transverse faults mentioned.

Undiscovered ore pods probably exist in the Mohawk and Yucca Metals mine, but there is nothing here to suggest a good-sized mine. The quartz monzonite porphyry may be big enough to contain a porphyry copper deposit, but it is generally fresh, and while showing in places ex-pyrite pits, nowhere suggests disseminated copper mineralization. However, as stated in my report of December 14, 1955 (p.20, under "Yucca Queen" (Yucca Metals) "Mine") Annex Tunnel No.6 was driven 200 feet in "diorite porphyry" (quartz monzonite porphyry) "with low copper values". This adit should be entered if possible and the copper-bearing porphyry examined. The porphyry exposure on the south slope of the ridge should be looked at with more care than I had time for.

East Camp.- This possible porphyry copper area is now being mapped in detail by Messrs. Rust and Maltzahn.

A large body of granitic rock lies north of a belt of Archean metasediments (see map). The metasediments have been intimately invaded by granite and diorite,probably also of Archean age (W.J. Miller,1946, p.499).Miller points out that near Halloran Spring and for several miles west of it the metasediments are nearly obliterated by diorite and granite,which he believes to be Archean. He points out that the state 1938 geologic map (from which my map xxx was made) shows this area as an early Tertiary granitic intrusion (as I show it). This point should be kept in mind by the men in the field,for copper deposits would presumably be associated only with late Cretaceous intrusions.

Miller states that the Archean igneous complex near Halloran Spring is cut sharply by aplitic granite dikes that may be late Mesozoic,and adds that there may be larger bodies of quartz monzonite northeast or east of Halloran Spring. Such a body is probably the large granitic mass now being mapped at East Camp.

The Archean complex south of this granitic intrusive resists erosion better than the granite,and stands up as a fairly high east-west ridge. High up on this ridge is the Yucca Grove talc mine of Pomona Tile Co. The complex here consists of limestone, mica schist and quartzite. The talc deposits conform to the metasediments, dipping steeply southwest.

The south contact of the Cretaceous(?) granite has been the site of turquoise mining,started in prehistoric times by Pueblo Indians from Arizona and New Mexico,and resumed,1898-1903,by

Americans. While many opencuts and small adits,presumably driven in search of turquoise,lie in the granitic mass north of the Archean complex,most of the turquoise seems to have come from the complex not far south of the granite.

The granitic intrusive contrasts strongly with the fresh and barren-looking Teutonia Peak and New York Mountains intrusives. Softened by alteration the East Camp intrusive weathers to subdued hillocks,except where protected by a flow of Pleistocene basalt on the west (see map). The granite is extensively bleached and iron-stained in various tints,from yellowish,ochery to brown and reddish brown. It is in many places intensely jointed,although the degree of jointing seems to vary considerably.

Casts representing former sulphides are not lacking,but they are far from universally distributed. While some are cubic,free from indigenous limonite and represent former pyrite,many are irregular in outline and contain dark brown indigenous limonite,suggestive of chalcocite or chalcopyrite.

Alteration is strong,obliterating most of the primary rock minerals in the hand specimen,except the quartz phenocrysts. It is mostly of the argillic type,forming various clay minerals,including probably alunite. Little sericite was seen,but sericite is often difficult to distinguish in the hand specimen.

South of the main granitic intrusive,and within the Archean complex,is a well-mineralized area where granitic material is intensely mixed in with metasediments,which include mica schist and quartzite. The igneous rocks are probably Precambrian in age, but the metallization is very likely associated with the Cretaceous (?) granite just north of the area. The mineralized area shows sericite and rather abundant casts filled with dark brown indigenous

limonite. Siliceous septa in these casts suggest to me former chalcocite.

Comparison of East Camp Prospect with Known Porphyry Copper Deposits.- Salient features of the East Camp prospect,so far as I could see them during my short inspection are: (1) locally intense but variable jointing;(2) dominantly agillic alteration; (3) extensive but variable limonitic staining;(4) presence of ex-sulphide casts,many with indigenous brown limonite;(5) all samples taken by Rust show at least a few tenths of a percent of copper, some giving as much as 1%;(6) presence of some chrysocolla and abundant turquoise; (7) the mineralized granitic area is only a portion of a much larger intrusive mass,and mineralization "spills over" into the adjacent Archean complex.

1. Intense jointing or "crackling" is typical of all porphyry copper deposits.

2. While sericitic alteration is associated with ore deposition in many porphyry coppers,the relationship is by no means universal. Thus at Santa Rita,New Mexico and Silver Bell,Arizona,the argillic stage of alteration is the most closely connected with the copper deposition (P.F.Kerr,1951,p.470.) The same holds for Castle Dome, Arizona (N.P.Peterson et alii,1946,p.820-Abstract).

3. Iron-staining is characteristic of the leached capping over all porphyry coppers.The following data are from Locke,1926,p.114:

Limonites over pyritic areas very low in copper are commonly bright red or brick red,or yellowish brown. Since limonite from highly pyritic deposits migrates far and fast,capping over such deposits is usually intensely colored.

Highly colored red outcrops may overlie pyritic material containing as much as 1% copper (North Hill. Miami,Arizona) but with higher grade chalcocite ore bodies the capping is much paler,with limonite mainly as inconspicuous,maroon-colored specks and veinlets.

The East Camp outcrop is not, in general, highly colored.It is in places yellowish brown,suggesting considerable pyrite below.But with enough tonnage,1% copper content might make ore,so that an outcrop indicative mainly of pyrite might be worth drilling.

4. Ex-sulphide casts,many filled with indigenous dark brown limonite,are fairly common,although less common than I should wish.

5. Capping over many porphyry coppers averages less than 0.1% copper,so that higher copper in the East Camp exposure is not discouraging.

6. Turquoise is a rare but perfectly legitimate oxidation product of copper deposits. At Tyrone, New Mexico, turquoise occurs in the Precambrian granitic complex just north of the quartz monzonite which contains the porphyry copper deposits. Paige (1912) believes the turquoise to have formed as a product of normal weathering of copper-bearing rock. At Tyrone,as at East Camp,turquoise gives out going down a short distance below the present surface.Both districts have been subjected to erosion for immensely long periods.

7. At Bingham the Utah Copper ore body is roughly coextensive with the Utah Copper stock, about 1 mile in diameter. The same holds for Santa Rita,where the stock is even smaller. But at Ajo the Cornelia quartz monzonite is at least 6 miles long and 2 miles wide,but the ore body at its southeast end is only 3000 feet by 2000 feet in area. At Miami porphyry copper deposits are associated

with the extreme northern lobe of the Schultze granite porphyry an irregular mass 6 miles by 6 miles in maximum dimensions; but most of the ore is in the adjoining Archean schist.

At Ray 90% of the disseminated ore is in the schist,and less than 10% in the Ray quartz monzonite porphyry stock.

There is nothing opposed,therefore, to a possible porphyry copper at East Camp,insofar as the rock formations and their distribution are concerned. Such a deposit may lie at the south end of the granitic intrusive,it may "spill over" into the Archean complex,or it may lie mainly in the latter.

There is nothing wrong,either,with the intrusive being(probably) granite instead of monzonite,with which so many porphyry coppers are associated. At Miami,the igneous rock related to ore deposition is granite porphyry;and while at Castle Dome,in the same region,much ore occurs in quartz monzonite,ore deposition is related in time,and largely in space, to granite porphyry.

Suggestions for Detail Study of East Camp Prospect.- I believe this area well worth the detail study now being given it. (The same may apply to Middle Camp and West Camp,where turquoise also occurs).

Geology is presently being mapped without a topographic base. This should be supplied,probably by aerial mapping,which at small additional expense might take in the Middle and West Camps as well. Full color aerial photos might be of aid in revealing alteration zones.

The following features should be mapped:

1. Major rock formations,major structures.

2. Degree and trends of jointing;relation to major faults,if any.

3. Hydrothermal alteration, by types. Much has been done lately on genetic relations between various types of hydrothermal alteration and metallization. East Camp alteration minerals should be identified. For the clay minerals,this is best done by differential thermal analysis and/or X-ray diffraction.

For an example of this type of mapping see Kerr,1950 (Santa Rita).Type of alteration may be shown by various colors,e.g. yellow for kaolinite,pink for alunite etc. Dots or stippling is used,intensity of alteration shown by intensity of the dot pattern.

4. Limonite and copper minerals. Distribution and intensity of limonite paint and general staining should be shown by some convention,and the same done for ex-sulphide casts,with or without indigenous limonite.

The best man living on the interpretation of leached outcrops is Roland Blanchard,153 South Hermosa Ave.,Sierra Madre,Calif. He is in delicate health and might not stand a field trip,but probably would be glad to inspect and report on a suite of specimens.

5. The company geochemical unit should be called in to make a survey. inasmuch as the East Camp terrain seems ideal for this method. Ralph Holmer of this organization has just sent me his program for the Geophysics Subdivision, AIME,sessions at the coming Annual Meeting. A paper by G.L.Sawyer,the abstract of which is given,describes a new rubeanic acid spot test for detection of trace amounts of copper in leached outcrops.The method is very fast and the field kit

contained in a box measuring 8" x4" x 4".

It is hoped that such a combined attack as that outlined above may furnish a convergence of evidence answering the questions (1) should the East Camp prospect be drilled at all;(2) if so, where' Ideally,it might be possible to delimit one or more areas which show maximum jointing,most intense hydrothermal alteration of a type probably related to metallization,greatest concentration of ex-sulphide casts and indigeneous limonite,in casts and veinlets,and highest concentration of copper shown by geochemical exploration. Such an area would naturally merit drilling.

If drilling is decided on, I suggest that use of a rotary rig, drilling dry with air under pressure,dust being recovered by a cyclone dust collecter,be considered. One such rig is the Mayhew 500 made in Dallas. The method is extremely fast and may be used down to water level;it is ideal for preliminary, wildcat holes.

CORRELATION STUDY OF PORPHYRY COPPER DEPOSITS

A critical correlation study of known porphyry copper deposits would be extremely valuable in a systematic exploration campaign such as that now being conducted by Bear Creek Mining Co. in the southwest.I have made a start along these lines,one result being the discovery of the importance of argillic alteration mentioned abov The study however should be much more thorough however and should include,not only analysis of the literature but field trips to known deposits,study of leached cappings and ore in the field,and by laboratory work on specimens.

E. W.

Berkeley,California
February 16, 1956

Edward Wisser

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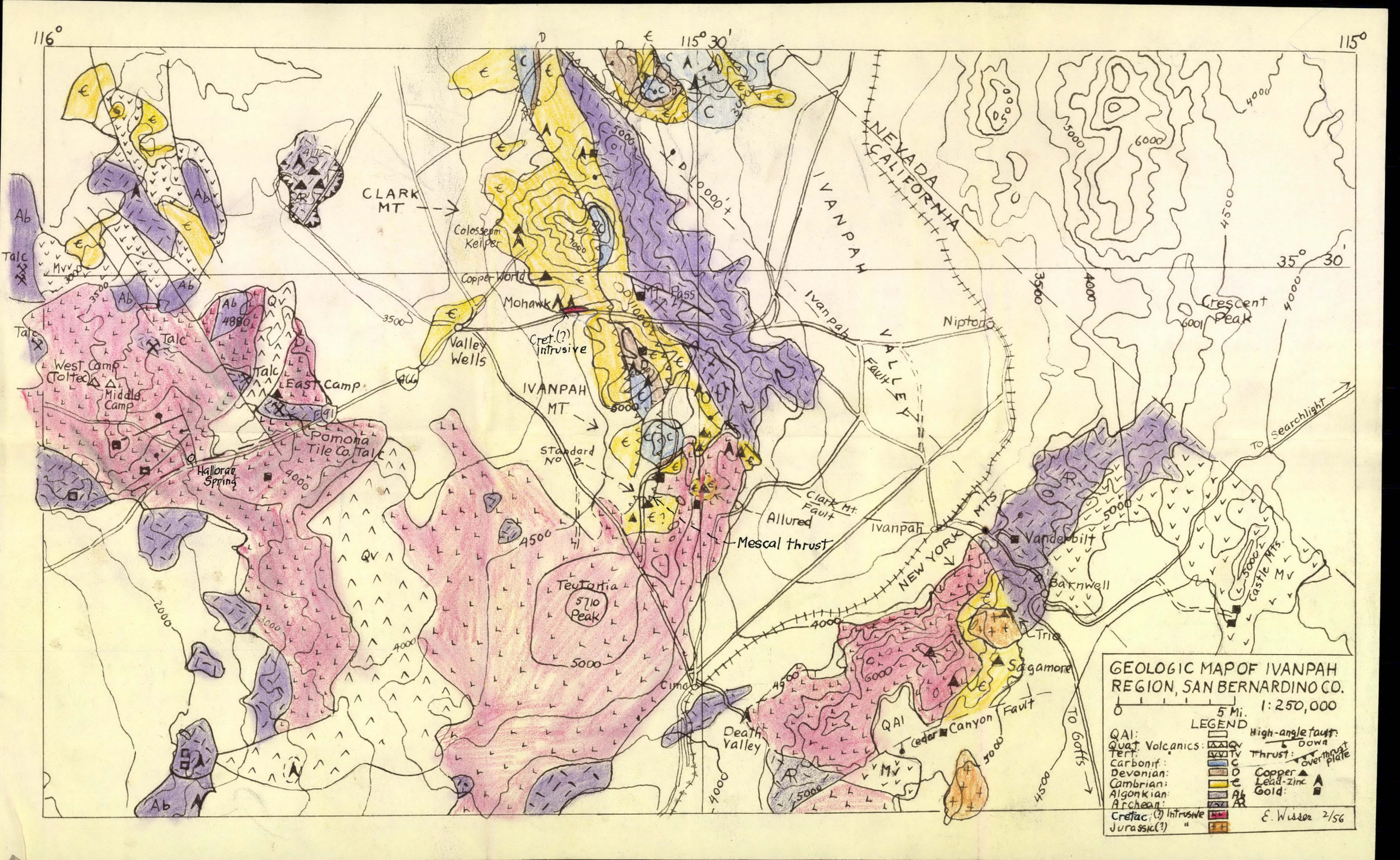
GEOLOGIC MAP OF IVANPAH REGION, SAN BERNARDINO CO.
0 5 Mi.
1:250,000
LEGEND
QAl: Alluvium
Quat. Volcanics: Qv
Tert.: Tv
Carbonif.: C
Devonian: D
Cambrian: Є
Algonkian: Ab
Archean: AR
Cretac.(?) Intrusive
Jurassic(?) "
High-angle fault: Down
Thrust: Overthrust plate
Copper
Lead-Zinc
Gold
E. Wisser 2/56
116°
115° 30'
115°
35° 30'
NEVADA
CALIFORNIA
CLARK MT
Colosseum Keilper
Copper World
Mohawk
Cret.(?) Intrusive
Valley Wells
IVANPAH MT
Standard No 2
Mt. Pass
Ivanpah Valley Fault
Nipton
Crescent Peak
To Searchlight
West Camp (Toltec)
Middle Camp
East Camp
Talc
Pomona Tile Co. Talc
Halloran Spring
Teutonia 5710 Peak
Cima
Death Valley
Allured
Clark Mt. Fault
Ivanpah
Mescal thrust
NEW YORK MTS
Vanderbilt
Barnwell
Castle Mts.
Trio
Sagamore
Cedar Canyon Fault
To Goffs

WISSER AND COX

CONSULTING GEOLOGISTS

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The best descriptions are by Hewett (1954a, 1954b), and for the Clark Mt. area, by Olson et alii (1954). Although the site of heavy

sedimentary deposition in the Paleozoic, the entire Mojave block, which includes the Ivanpah quadrangle, was subjected to vigorous erosion from the late Mesozoic into the middle Tertiary. During this long period the block rose possibly 20,000 feet, although its surface never attained any such height, the rocks being removed as the block rose.

This tectonic history explains the abundant outcrops of Precambrian, and the fact that only remnant areas of Paleozoic sediments remain.

The Ivanpah region seems to have undergone three major periods of deformation since Precambrian times. (1). In the late Cretaceous, folding, thrusting, normal faulting and intrusion, with copper-lead-zinc metallization. The Clark Mt. fault, which is mineralized, cuts the Mescal thrust but is itself displaced by a thrust parallel to the Mescal, north of the map area. The Mescal thrust shoves Paleozoic rocks over volcanics which are probably of Cretaceous age. Hewett (1954a, p.12) states that the Teutonia Peak quartz monzonite invaded the Mescal thrust, being therefore, like the Clark Mt. normal fault, younger than the thrust.

Hewett (1954a, p.12) places this epoch of deformation, intrusion and metallization in the late Cretaceous "within the period of Laramide orogeny". Others, including the present writer, believe that at least one major orogeny preceded the true Laramide, occurring in Mid-Cretaceous time, and that it was most strongly developed along a belt containing Goodsprings, Pioche, Ely and probably Tintic. Southwest of Goodsprings

the orogenic-metallogenetic belt passes through the Mojave region and traverses Baja California.

It is probable that Butte, Bingham, Bagdad, Ray-Miami, San Manuel, Ajo, Morenci and Santa Rita were metallized with copper in the "true" Laramide period, i.e; latest Cretaceous -early Tertiary. But formation of porphyry copper deposits was not confined to that period: it is highly probable that the deposits at Ely are associated with the Mid-Cretaceous orogeny, and that at Yerington as well, although Yerington lies well west of the Mid-Cretaceous orogenic belt. It follows that the dating of the earlier Ivanpah orogeny, that just described, as Mid-Cretaceous, does not militate against the possibility of finding porphyry copper deposits there.

(2). The second major period of deformation in the Ivanpah region took place in the Pliocene, at which time major thrusting was active in a north-south belt extending down the east side of Death Valley and extending southward into the Ivanpah quadrangle. Hewett (1954b) shows many Klippen in the northwest portion of the Ivanpah quadrangle; these are patches of Precambrian, remnants of the upper plate of a great thrust which has shoved Precambrian over Tertiary and older rocks. The accompanying map shows only one of these, the isolated exposure of Archean west of Clark Mountain.

The East Camp, Middle Camp and West Camp turquoise-copper showings lie within the area of Pliocene thrusts. While the Mid-Cretaceous thrusts may have had influence on base-metal localization, the Pliocene thrusts did not; but their presence within the area of possible porphyry copper deposits now being mapped might invalidate the pros-

pective value of such a deposit. Formexample,what seemed to me the most promising portion of the area now being mapped seems to be made up of Precambrian rocks. If this showing is merely a thin plate lying above a Pliocene thrust,the main mass of the copper deposit from which the plate came may lie miles away,probably buried beneath desert wash. At least one thrust lies near the area in question,for Mr. Rust showed it to me,at a distance.

(3). The final major period of deformation was in the Pleistocene, and was characterized mainly by block-faulting. The Ivanpah fault dates from this period.

SUGGESTED EXPLORATION IN THE IVANPAH REGION

The major known copper and lead-zinc deposits lie in a northwest belt,of which the Clark Mountain premineral fault forms the northeast boundary. That fault,with the thrusts just west of it, appear to be important ore controls. My present opinion,however is that the deposits of this belt,mainly replacements in carbonate rocks,offer small chances of making large mines. Final judgment should be suspended until publication of Hewett's Professional Paper. When that appears,any possibilities suggested for base-metal exploration should be carefully appraised. Meanwhile,exploration should be centered,as at present,on possible porphyry copper deposits.

My field work was done mainly with that idea in mind. The intrusives examined are described below.

Teutonia Peak Intrusive.- Where exposed along the Valley Wells-Cima road the rock is medium-grained,with large quartz phenocrysts and looks like biotite granite. Hewett calls it quartz monzonite.

Where seen, this rock was unaffected by hydrothermal alteration and showed no trace of metallization. While the rest of the intrusive should be inspected, it seems to offer little promise of a porphyry type copper deposit, except, perhaps, at its northeast end. This part of the intrusion lies within the main mineral belt mentioned; it adjoins the premineral Mescal and Clark Mt. faults, and it is surrounded by small copper deposits in the intruded carbonate rocks.

New York Mountains Intrusive.- The major intrusive here was examined only at the Death Valley (now Dolly Varden) mine. This silver-lead mine is now being drilled by Irven Bates, who has it optioned. A diorite dike, about 100 ft. wide, strikes northeast and dips 45° southeast. Each wall of the dike carries a quartz-argentite-galena vein. The main shaft was sunk on the footwall vein, about 4 ft. wide; but at the 200 ft. level this vein steepened in dip; the shaft was continued straight, leaving the vein below it. At the 400 ft. level a crosscut was driven to the hanging wall vein, said by Bates to be 17 ft. wide but lower in grade than the footwall vein.

Although the footwall vein was stoped to the 200 ft. level, it remains unexplored below that level. Bates is testing it there by an inclined hole with collar about at the outcrop of the hanging wall vein. The mine gives promise of further production but is too small to be of interest.

The country rock invaded by the diorite dike is in part medium-grained biotite granite (quartz monzonite?) but an igneous complex seems to be involved, some of the rock being coarsely porphyritic, some nearly aphanitic. Hydrothermal alteration is slight or lacking, and

no signs of disseminated metallization were seen. Here again, however, the whole intrusive mass should be looked over, especially its northeast end, where it butts against the premineral Clark Mt. fault. The smaller intrusive near the Trio mine is marked Jurassic (?) but is probably of late Cretaceous age and should be examined.

Mohawk Mine.- The Mohawk lead-zinc mine occupies the western portion of the east-west Mohawk ridge, the Yucca Metals mine, the eastern part. The ridge is sharp and narrow; mine workings exist on both slopes.

Quartz monzonite intrudes moderately thick-bedded limestone and black dolomite, probably the Cambrian Goodsprings dolomite. The quartz monzonite, shown on the accompanying map, forms the lower half of the south slope of the ridge. The mass may extend southward, under alluvium, a considerable distance. The contact with the sediments strikes east-west and is intrusive, but is modified by faulting on transverse (roughly north-south) faults, and probably on longitudinal (east-west) faults as well.

Ore bodies occurred in the sediments, within a zone bordering the contact, half a mile or more in length, and perhaps 500 ft. wide, extending from the contact on the south slope of the ridge over the crest and part way down the north slope. Four or five small shafts were put down on this slope, and Yucca Metals drove an adit from that slope southwards.

One of the shafts was sunk on a small carbonate ore body striking east-west and dipping 56°S, probably conforming to the beds here. The ore body was localized along the intersection of the

ore bed with north-south vertical sheeting.

Farther west, another small ore body was localized by a roll in the dolomite beds, which strike north-south in this area, and dip west. The roll consists of a small anticline superimposed on the general structure and plunging southwest.

Another shaft on the north slope was sunk on an oxidized showing striking N20W and dipping vertically.

Several dumps on the north slope show ex-chalcopyrite limonite, as well as limonite derived from galena and sphalerite.

Three adits have been driven northward from the south slope of Mohawk ridge. The westernmost adit started on a well-defined oxide vein striking N20E and dipping 73E. At the portal the vein is four feet wide and consists mainly of limonite. The hanging wall is quartz monzonite porphyry, the footwall, marbleized limestone. The vein is along one of the transverse faults mentioned.

Undiscovered ore pods probably exist in the Mohawk and Yucca Metals mine, but there is nothing here to suggest a good-sized mine. The quartz monzonite porphyry may be big enough to contain a porphyry copper deposit, but it is generally fresh, and while showing in places ex-pyrite pits, nowhere suggests disseminated copper mineralization. However, as stated in my report of December 14, 1955 (p.20, under "Yucca Queen" (Yucca Metals) "Mine") Annex Tunnel No.6 was driven 200 feet in "diorite porphyry" (quartz monzonite porphyry) "with low copper values". This adit should be entered if possible and the copper-bearing porphyry examined. The porphyry exposure on the south slope of the ridge should be looked at with more care than I had time for.

East Camp.- This possible porphyry copper area is now being mapped in detail by Messrs. Rust and Maltzahn.

A large body of granitic rock lies north of a belt of Archean metasediments (see map). The metasediments have been intimately invaded by granite and diorite, probably also of Archean age (W.J. Miller, 1946, p.499). Miller points out that near Halloran Spring and for several miles west of it the metasediments are nearly obliterated by diorite and granite, which he believes to be Archean. He points out that the state 1938 geologic map (from which my map xxx was made) shows this area as an early Tertiary granitic intrusion (as I show it). This point should be kept in mind by the men in the field, for copper deposits would presumably be associated only with late Cretaceous intrusions.

Miller states that the Archean igneous complex near Halloran Spring is cut sharply by aplitic granite dikes that may be late Mesozoic, and adds that there may be larger bodies of quartz monzonite northeast or east of Halloran Spring. Such a body is probably the large granitic mass now being mapped at East Camp.

The Archean complex south of this granitic intrusive resists erosion better than the granite, and stands up as a fairly high east-west ridge. High up on this ridge is the Yucca Grove talc mine of Pomona Tile Co. The complex here consists of limestone, mica schist and quartzite. The talc deposits conform to the metasediments, dipping steeply southwest.

The south contact of the Cretaceous(?) granite has been the site of turquoise mining, started in prehistoric times by Pueblo Indians from Arizona and New Mexico, and resumed, 1898-1903, by

Americans. While many opencuts and small adits,presumably driven in search of turquoise,lie in the granitic mass north of the Archean complex,most of the turquoise seems to have come from the complex not far south of the granite.

The granitic intrusive contrasts strongly with the fresh and barren-looking Teutonia Peak and New York Mountains intrusives. Softened by alteration the East Camp intrusive weathers to subdued hillocks,except where protected by a flow of Pleistocene basalt on the west (see map). The granite is extensively bleached and iron-stained in various tints,from yellowish,ochery to brown and reddish brown. It is in many places intensely jointed,although the degree of jointing seems to vary considerably.

Casts representing former sulphides are not lacking,but they are far from universally distributed. While some are cubic,free from indigenous limonite and represent former pyrite,many are irregular in outline and contain dark brown indigenous limonite,suggestive of chalcocite or chalcopyrite.

Alteration is strong,obliterating most of the primary rock minerals in the hand specimen,except the quartz phenocrysts. It is mostly of the argillic type,forming various clay minerals,including probably alunite. Little sericite was seen,but sericite is often difficult to distinguish in the hand specimen.

South of the main granitic intrusive,and within the Archean complex,is a well-mineralized area where granitic material is intensely mixed in with metasediments,which include mica schist and quartzite. The igneous rocks are probably Precambrian in age, but the metallization is very likely associated with the Cretaceous (?) granite just north of the area. The mineralized area shows sericite and rather abundant casts filled with dark brown indigenous

limonite. Siliceous septa in these casts suggest to me former chalcocite.

Comparison of East Camp Prospect with Known Porphyry Copper Deposits.- Salient features of the East Camp prospect,so far as I could see them during my short inspection are: (1) locally intense but variable jointing;(2) dominantly agillic alteration; (3) extensive but variable limonitic staining;(4) presence of ex-sulphide casts,many with indigenous brown limonite;(5) all samples taken by Rust show at least a few tenths of a percent of copper, some giving as much as 1%;(6) presence of some chrysocolla and abundant turquoise; (7) the mineralized granitic area is only a portion of a much larger intrusive mass,and mineralization "spills over" into the adjacent Archean complex.

1. Intense jointing or "crackling" is typical of all porphyry copper deposits.

2. While sericitic alteration is associated with ore deposition in many porphyry coppers,the relationship is by no means universal. Thus at Santa Rita,New Mexico and Silver Bell,Arizona,the argillic stage of alteration is the most closely connected with the copper deposition (P.F.Kerr,1951,p.470.) The same holds for Castle Dome, Arizona (N.P.Peterson et alii,1946,p.820-Abstract).

3. Iron-staining is characteristic of the leached capping over all porphyry coppers.The following data are from Locke,1926,p.114:

Limonites over pyritic areas very low in copper are commonly bright red or brick red,or yellowish brown. Since limonite from highly pyritic deposits migrates far and fast,capping over such deposits is usually intensely colored.

Highly colored red outcrops may overlie pyritic material containing as much as 1% copper (North Hill. Miami,Arizona) but with higher grade chalcocite ore bodies the capping is much paler,with limonite mainly as inconspicuous,maroon-colored specks and veinlets.

The East Camp outcrop is not, in general, highly colored.It is in places yellowish brown,suggesting considerable pyrite below.But with enough tonnage,1% copper content might make ore,so that an outcrop indicative mainly of pyrite might be worth drilling.

4. Ex-sulphide casts,many filled with indigenous dark brown limonite,are fairly common,although less common than I should wish.

5. Capping over many porphyry coppers averages less than 0.1% copper,so that higher copper in the East Camp exposure is not discouraging.

6. Turquoise is a rare but perfectly legitimate oxidation product of copper deposits. At Tyrone, New Mexico, turquoise occurs in the Precambrian granitic complex just north of the quartz monzonite which contains the porphyry copper deposits. Paige (1912) believes the turquoise to have formed as a product of normal weathering of copper-bearing rock. At Tyrone,as at East Camp,turquoise gives out going down a short distance below the present surface.Both districts have been subjected to erosion for immensely long periods.

7. At Bingham the Utah Copper ore body is roughly coextensive with the Utah Copper stock, about 1 mile in diameter. The same holds for Santa Rita,where the stock is even smaller. But at Ajo the Cornelia quartz monzonite is at least 6 miles long and 2 miles wide,but the ore body at its southeast end is only 3000 feet by 2000 feet in area. At Miami porphyry copper deposits are associated

with the extreme northern lobe of the Schultze granite porphyry an irregular mass 6 miles by 6 miles in maximum dimensions; but most of the ore is in the adjoining Archean schist.

At Ray 90% of the disseminated ore is in the schist,and less than 10% in the Ray quartz monzonite porphyry stock.

There is nothing opposed,therefore, to a possible porphyry copper at East Camp,insofar as the rock formations and their distribution are concerned. Such a deposit may lie at the south end of the granitic intrusive,it may "spill over" into the Archean complex,or it may lie mainly in the latter.

There is nothing wrong,either,with the intrusive being(probably) granite instead of monzonite,with which so many porphyry coppers are associated. At Miami,the igneous rock related to ore deposition is granite porphyry;and while at Castle Dome,in the same region,much ore occurs in quartz monzonite,ore deposition is related in time,and largely in space, to granite porphyry.

Suggestions for Detail Study of East Camp Prospect.- I believe this area well worth the detail study now being given it. (The same may apply to Middle Camp and West Camp,where turquoise also occurs).

Geology is presently being mapped without a topographic base. This should be supplied,probably by aerial mapping,which at small additional expense might take in the Middle and West Camps as well. Full color aerial photos might be of aid in revealing alteration zones.

The following features should be mapped:

1. Major rock formations,major structures.

2. Degree and trends of jointing;relation to major faults,if any.

3. Hydrothermal alteration, by types. Much has been done lately on genetic relations between various types of hydrothermal alteration and metallization. East Camp alteration minerals should be identified. For the clay minerals,this is best done by differential thermal analysis and/or X-ray diffraction.

For an example of this type of mapping see Kerr,1950 (Santa Rita).Type of alteration may be shown by various colors,e.g. yellow for kaolinite,pink for alunite etc. Dots or stippling is used,intensity of alteration shown by intensity of the dot pattern.

4. Limonite and copper minerals. Distribution and intensity of limonite paint and general staining should be shown by some convention,and the same done for ex-sulphide casts,with or without indigenous limonite.

The best man living on the interpretation of leached outcrops is Roland Blanchard,153 South Hermosa Ave.,Sierra Madre,Calif. He is in delicate health and might not stand a field trip,but probably would be glad to inspect and report on a suite of specimens.

5. The company geochemical unit should be called in to make a survey. inasmuch as the East Camp terrain seems ideal for this method. Ralph Holmer of this organization has just sent me his program for the Geophysics Subdivision, AIME,sessions at the coming Annual Meeting. A paper by G.L.Sawyer,the abstract of which is given,describes a new rubeanic acid spot test for detection of trace amounts of copper in leached outcrops.The method is very fast and the field kit

contained in a box measuring 8" x4" x 4".

It is hoped that such a combined attack as that outlined above may furnish a convergence of evidence answering the questions (1) should the East Camp prospect be drilled at all;(2) if so, where? Ideally,it might be possible to delimit one or more areas which show maximum jointing,most intense hydrothermal alteration of a type probably related to metallization,greatest concentration of ex-sulphide casts and indigeneous limonite,in casts and veinlets,and highest concentration of copper shown by geochemical exploration. Such an area would naturally merit drilling.

If drilling is decided on, I suggest that use of a rotary rig, drilling dry with air under pressure,dust being recovered by a cyclone dust collecter,be considered. One such rig is the Mayhew 500 made in Dallas. The method is extremely fast and may be used down to water level;it is ideal for preliminary, wildcat holes.

CORRELATION STUDY OF PORPHYRY COPPER DEPOSITS

A critical correlation study of known porphyry copper deposits would be extremely valuable in a systematic exploration campaign such as that now being conducted by Bear Creek Mining Co. in the southwest.I have made a start along these lines,one result being the discovery of the importance of argillic alteration mentioned above. The study however should be much more thorough however and should include,not only analysis of the literature but field trips to known deposits,study of leached cappings and ore in the field,and by laboratory work on specimens.

E. W.
Edward Wisser

Berkeley,California
February 16, 1956

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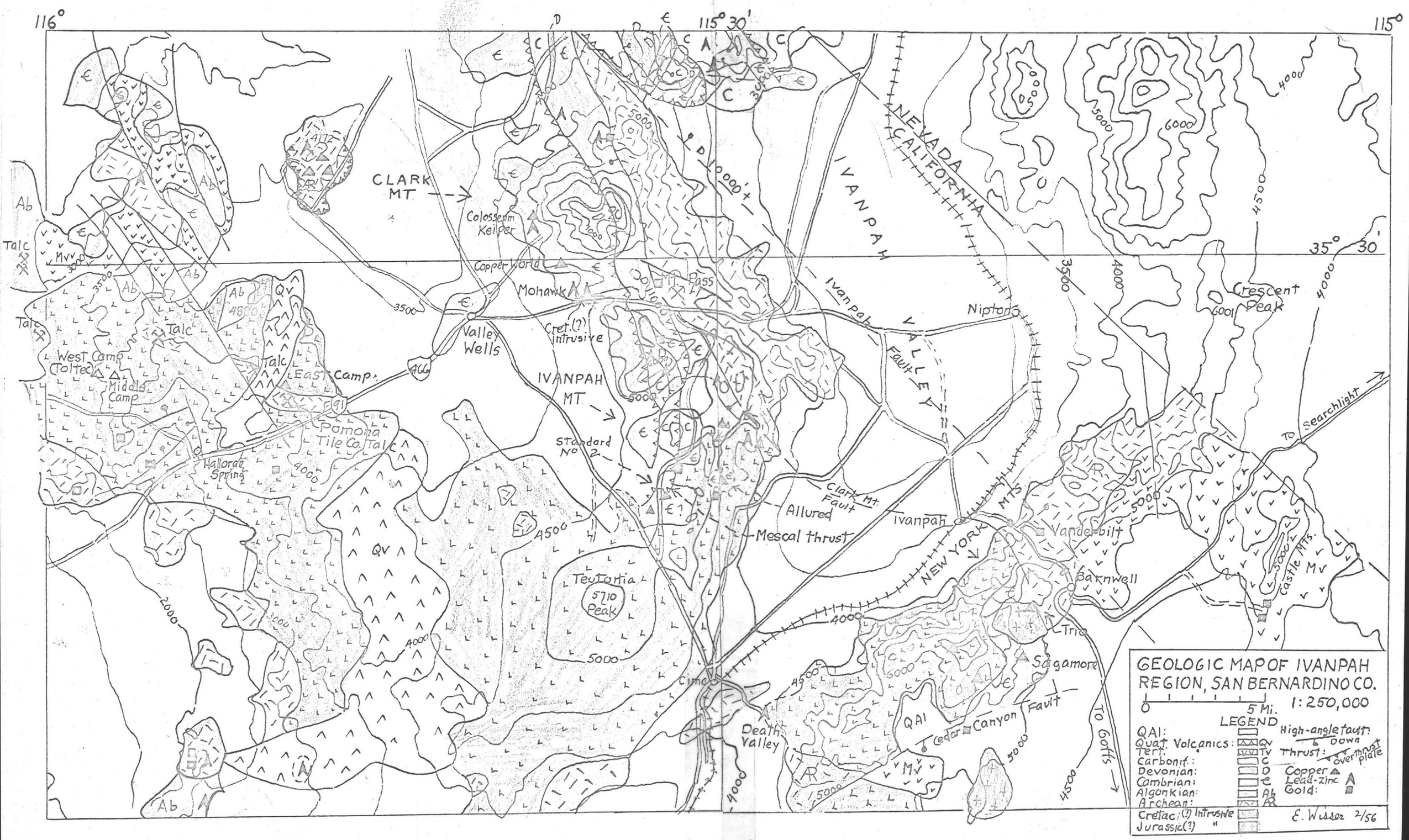
GEOLOGIC MAP OF IVANPAH REGION, SAN BERNARDINO CO.
0 5 Mi. 1:250,000
LEGEND
QAl: Quat. Volcanics: Qv
Tert.: Tv
Carbonif.: C
Devonian: D
Cambrian: Є
Algonkian: Ab
Archean: Ar
Cretac.(?) Intrusive
Jurassic(?) "
High-angle fault: Down
Thrust: overthrust plate
Copper
Lead-Zinc
Gold:
E. Wisser 2/56
116°
115° 30'
115°
35° 30'
CLARK MT
Colosseum Keilper
Copper World
Mohawk
Mt. Bass
Valley Wells
Cret.(?) intrusive
IVANPAH MT
Standard No 2
West Camp (Toltec)
Middle Camp
East Camp
Pomona Tile Co.
Halloran Spring
Teutonia 5710 Peak
Cima
Death Valley
Allured
Mescal thrust
Clark Mt. Fault
Ivanpah
Ivanpah Fault
IVANPAH VALLEY
NEVADA
CALIFORNIA
NEW YORK MTS
Vanderbilt
Barnwell
Trio
Sagamore
Cedar Canyon Fault
Nipton
Crescent Peak
Castle Mts.
To Searchlight
To Goffs