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AMERICAN SMELTING AND REFINING COMPANY
Tucson Arizona
December 24, 1963

J. H. C.
JAN 14 1964

MEMORANDUM FOR J. H. COURTRIGHT:

STRATIGRAPHY - SUMMARY
Troy (Precambrian)-Bolsa (Cambrian)
Superior District, Arizona

Attached is a summary report on the Troy and Bolsa Quartzites of Central Arizona. Information for this summary was secured in the vicinity of Superior, Arizona and personal communications with D. W. Peterson, A. F. Shride, and M. E. Krieger, all of the U.S.G.S.

The Troy Quartzite and the underlying Apache Group has been intruded by the large diabase masses in Central Arizona. Age determinations assign a Precambrian age to the diabase. Subsequently all Precambrian units were beveled by the Cambrian seas as sedimentation again became dominant in Central Arizona.

The break between Precambrian and Cambrian time, and the assignment of formational units, has long been a speculated problem in Central and Southern Arizona. Krieger in her paper was the first to separate the Troy (Precambrian) and Bolsa (Cambrian) Quartzites with the new evidence now mapped and deciphered. Krieger and Shride, with additions by Cooper and Peterson, are scheduled to write a summary paper on the Precambrian-Cambrian problem. Last report indicated little had been written although the report was started more than two years ago.

Separation of the Precambrian and Cambrian quartzites and the assigning of the large intrusive diabase masses to the Precambrian helps clarify many structural complexities. Among these is the confirmation of Precambrian as well as post-Paleozoic deformation along the same northeast trending fault zone located north of Superior, Arizona, which essentially is the northern limit of Nels Petersons mineral belt of the Globe-Miami-Superior area.

James D. Sell
JAMES D. SELL

JDS/jk

Troy (Precambrian) - Bolsa (Cambrian) Problem

TABLE OF CONTENTS

1. Early History of the Troy-Bolsa Quartzite Problem.

2. Diabase Problem.

3. Unraveling of the Quartzite Problem by the U.S.G.S.

4. Field Work and Description of the Troy and Bolsa(?) Quartzites in the Superior Area.

5. References.

1. Early History of the Troy-Bolsa Quartzite Problem

Pioneering stratigraphic studies and geologic mapping by Ransome (5, 6, 7, 8, 9) and Darton (1) established the nomenclature of the Precambrian and Paleozoic formations south of the Colorado Plateau in Arizona.

Ransome (5) in his early work in the Globe area placed all units below the fossiliferous Paleozoic limestone into the Apache Group and assigned a Cambrian(?) age to the group. The Apache Group units above the older Precambrian Pinal Schist were (in ascending order): Scanlan Conglomerate, Pioneer Shale, Barnes Conglomerate, and Dripping Spring Quartzite.

In the Bisbee area the formational exposures are clearer and more easily resolved than at Globe. At Bisbee Ransome (6) found and named the following Paleozoic units above the Pinal Schist: Bolsa Quartzite, Cambrian (unfossiliferous); Abrigo Limestone, Cambrian (fossiliferous); Martin Limestone, Devonian; Escabrosa Limestone, Mississippian; and Naco Limestone, Pennsylvanian.

Returning to the Ray-Globe region, Ransome (7, 8, 9) was able to redefine much of his early work in the Globe area and extend part of the formational names from the Bisbee area. Several new units were noted in the Ray area (Ransome 7, 9) and the redefined sequence above the Pinal Schist was recorded as: Apache Group, Cambrian(?); Martin Limestone, Devonian; and Tornado Limestone, Carboniferous. The Apache Group, in ascending order, included: Scanlan Conglomerate, Pioneer Shale, Barnes Conglomerate, Dripping Spring Quartzite, Mescal Limestone, vesicular basalt flows, and Troy Quartzite. The Troy Quartzite of Central Arizona and the Bolsa Quartzite of the Bisbee area were somewhat similar but direct correlation could not be established and separate formation names were assigned.

Darton (1) in his work questioned the Cambrian(?) age of the Apache Group when he recognized a long time-interval between some of the units within the Troy Quartzite. Southeast of Globe Darton noted an upper Cambrian fossiliferous sandstone overlying the lower, unfossiliferous, sandstone and quartzite. Further, this fossiliferous unit of the Troy was found to be unconformably on the Mescal Limestone and Dripping Spring Quartzite as the unit was traced southeastward from Globe. Darton suggested that the upper Troy units were equivalent to the Bolsa Quartzite of the Bisbee area.

Darton (2), and later Stoyanow (14), removed the Troy from the Apache Group and dropped the group status to Precambrian while retaining the Troy in the Cambrian.

Students of Arizona geology have since speculated on the Troy and Bolsa Quartzites in regard to nomenclature and stratigraphic relationships.

2. Diabase Problem

The great mass of diabase found extensively in Central Arizona has also been a subject of much discussion, primarily as to its age and mode of emplacement.

Darton (1) believed the large sills were Precambrian in age with small bodies being post-Pennsylvanian. Ransome (9) favored a late Paleozoic or early Mesozoic

age for all the diabase. Subsequent writers have confirmed one or the other of the above observations. A brief review and summary were given by Sell (10) on the age and mode of emplacement of the diabase in the Superior area.

In the study (10) of a few exposures of diabase and quartzite in the east end of the Magma Mine in Superior, the results indicated that the diabase was an intrusive magma but had not assimilated any of the quartzite in which it was emplaced. Later, at Magma, additional exposures of diabase and quartzite were observed in the underground workings. In one exposure an unconformity within the quartzite (designated as Cambrian Troy) was noted and the diabase intruded the lower quartzite of this sequence. In another exposure a rubble layer of diabase was noted at the contact of the massive diabase and the quartzite. As the quartzite was thought to be Troy in each case, the observations help to confuse the issue on the mode of emplacement of the diabase. The knowledge allowed the possibility of (1) two ages of quartzite (pre- and post-diabase) or (2) two ages of diabase intrusive activity.

3. Unraveling of the Quartzite Problem by the U.S.G.S.

During the past several years workers in the U.S.G.S. have been mapping quadrangles in Central Arizona and interest in the stratigraphic correlations problems has been renewed.

Shride, working in the asbestos region north of Globe, was primarily interested in the diabase, Apache Group, and the lower Paleozoic formations. Shride (11) renewed the question of the relationship between the nonfossiliferous Troy Quartzite of his area and the fossiliferous Cambrian sandstones, also referred to as Troy, which were found in the southern part of the region. He suggested a Precambrian age for the nonfossiliferous units with a separation of them from the fossiliferous Cambrian units.

Krieger (3), mapping the Holy Joe Quadrangle south of Globe, found the two units in contact and established the stratigraphic and age relationship of the Troy and Bolsa Quartzites. Continued work by Shride (12) established similar relationships for the quartzites and established the position of the diabase in relationship to the quartzite. The diabase intrudes the unfossiliferous Troy and in turn is overlain by the Bolsa. Age determinations by Silver (13), on differentiates of the diabase sills north of Globe, places a Precambrian age on the diabase, Apache Group, and the Troy Quartzite of the region.

In November 1960 twelve geologists of the U.S.G.S. met in Arizona for a field symposium on the stratigraphic problems of the younger Precambrian and Cambrian units. Most of these geologists were conducting geologic mapping in specific areas of southeastern Arizona. Also included in the group were authorities in paleontology, stratigraphy, and structural geology. Areas were visited in the Little Dragoon Mountains, Santa Catalina Mountains, Galiuro Mountains, areas near Winkelman, Superior, Globe, Christmas, and in the Sierra Ancha Mountains.

The group's major conclusions were:

(1) The Troy Quartzite is Precambrian, based on (a) the intrusion of the Troy by diabase, (b) the time interval represented by the erosional cycle for the complete removal of large areas of the formation, and (c) the deep weathering of the exposed diabase prior to the deposition of the Bolsa.

(2) The Troy is separated from the Apache Group by a distinct disconformity and is therefore not included in the Apache Group.

(3) Younger quartzite (Bolsa) and other sedimentary rocks (Abrigo) are separated from the Troy and the diabase by a major unconformity. These younger rocks in some places contain fossils diagnostic of Cambrian age and other organic remains -- vertical scolithus tubes, fucoid markings (horizontal burrows), and phosphatic linguloid brachiopods.

When the group visited the Superior area, under the direction of Don Peterson, they suggested that both Precambrian Troy Quartzite and one of the Cambrian formations were probably present. Subsequent mapping by Peterson confirmed this suggestion although the nomenclature for the Cambrian formation has yet to be clarified. Diabase was found to intrude the redefined Troy Quartzite, and several good exposures were found showing the Cambrian formation overlying weathered diabase. In some places up to 700 feet of Troy lay below the Cambrian formation; and in other places deformation and erosion prior to Cambrian deposition has completely removed the Troy. Further study by Peterson showed subtle but distinct and consistent lithologic differences between the quartzites of the Troy and those of the Cambrian formation.

Peterson's report on the geology of the Superior quadrangle is being processed by the U.S.G.S. The western half of the quadrangle has been released in preliminary form as U.S.G.S. map MF-253 (Peterson, 4). On this sheet the Cambrian rocks have the symbol for Bolsa, but the explanation lists them as "Cambrian rocks" without a unit name. Although the unit is essentially a quartzite, Shride and Krieger (personal communication, 1962) favor correlating the Cambrian quartzite at Superior with the Abrigo formation in the Bisbee-Tombstone area. Peterson (personal communication, 1962) favors the Bolsa nomenclature. The uncertainty of correlating the Cambrian quartzites of the Superior area with formations further south makes it advisable to use the designation Bolsa(?) for the formation at this time.

A report on the regional problem as expressed by the U.S.G.S. field symposium is being prepared by Shride and Krieger. A brief summary of the problem has been presented by Krieger (3).

4. Field Work and Description of the Troy and Bolsa(?) Quartzites in the Superior Area

The field work in the Superior area during October 1961 was primarily directed toward gaining an insight into differentiating the Troy and Bolsa(?) Quartzites. The work was undertaken with the guidance and helpfulness of Don Peterson of the U.S.G.S. Several sections typical of parts of the Troy and Bolsa(?) were studied and specimens from the various units were collected.

The Troy has been divided by Peterson (personal communication, 1962) into an upper and lower member in the Superior area based on a very marked visual change in the formation. Shride (personal communication, 1962) has divided the Troy into three members in the Sierra Ancha region and has established the following nomenclature in descending order:

quartzite member
Chediski member
arkose member

The arkose member is locally missing north of the Salt River and is missing everywhere south of the Salt River. In the Superior area Shride would place his

quartzite member equivalent to Peterson's upper member and the Chediski member equivalent to the lower member. The term "arkose member" would be reserved for the lowest member found north of the Salt River.

At Superior the lowest member generally has a basal conglomerate. The conglomerate consists of granules, pebbles, and cobbles of quartzite, quartz, and fragments of Pinal Schist and the Apache Group in a coarse-grained, poorly sorted, arkosic sandstone matrix. Overlying the conglomerate is a highly variable sequence of sandstone, arkose, quartzite, siltsone, and gritty and conglomeratic beds. Certain beds locally pinch and swell, and many are lenticular. The channeling and irregular bedding are characteristic of Shride's Chediski member of the Troy. Color varies through shades of brown, gray, yellow, purple, and maroon, with purple-black liesegang bands occurring in some beds. The lower member is generally very feldspathic (pink feldspar is found only in the lower member) with abundant interstitial feldspar and clay spotting on the weathered surfaces. Hematite grains and various types of pebble bands are found throughout. The weathered surface is generally vitreous and the shapes of the blocks and faces are variable, with the rock breaking across the quartz grains for the most part. The over-all color characteristic of the exposures is grayish.

At Superior, Peterson's upper member of the Troy shows a marked change. It is generally finer grained with only occasional pebble and grit beds and is medium- to thick-bedded with distinct bedding planes, and weathering with a blocky aspect. The upper member is generally better sorted, cleaner, and is a quartz sand quartzite with less feldspar and clay content than the lower member. Two features are very characteristic of the upper Troy at Superior: (1) A "plum" conglomerate layer of pebbles which are found at the top of a bed rather than at the base of the bed, and (2) pebble zones composed of dead-white quartz pebbles. The dead-white quartz pebbles are not found elsewhere either in the lower Troy or the Bolsa(?) Quartzites. The weathering characteristic shows the over-all grayish coloration of the Troy, but the angular blockly outline of the outcrop is different from the variable outline exhibited in the lower member.

Although the Troy may be readily separated into upper and lower members by the visual change in the formation at Superior, Shride (personal communication, 1962) believes that the actual contact should be placed somewhere in Peterson's upper member. Shride points out that the "plum" conglomerate (usually more than one and sometimes as many as twenty) are characteristic of the upper one-third of the Chediski member (i.e., lower member at Superior) from north of Globe to the Mogollon Rim. Also, the quartzite member of Shride (upper member at Superior) has only rare pebble and grit beds and rare feldspar and clay content.

In the Troy the lithology of the formation is laterally consistent. Although the lower member is quite variable in lithology and grain size, the variability persists laterally from one place to another. Likewise, the lithology of the upper Troy is laterally consistent.

The Bolsa(?) Quartzite is not as consistent in its appearance and changes are found throughout the Superior district. The base of the Bolsa(?) is variable in lithology and thickness and generally depends upon the underlying rock type. Where it rests on diabase the basal unit is composed of weathered diabase debris intermixed with feldspar grains, quartz grains(?), and in a few places it is composed entirely of diabasic material with a distinctive crossbedded structure. Few distinct diabase fragments, however, have been recognized.

The basal unit of the Bolsa(?) Quartzite is generally dirty, poorly sorted, contains angular fragments, coarse to fine particles, with silts and muds. The remainder of the Bolsa(?) is essentially a sequence of regularly bedded sandstones and quartzites. The rock is even-grained with coarse-grained sections containing scattered grit or pebble streaks. Over-all the sequence grades upward into finer-grained, thinner-bedded quartzites. Banding and crossbedding are abundant and complete, generally sharp, with distinctive color bands of yellow, orange, red, and white occurring widespread laterally and increasing in the upper units. In the Superior area interstitial feldspar is less in the Bolsa(?) than in the Troy, and feldspar (clay) spotting on the exposed surface of the rocks is lacking for the most part. Fracturing and blocky outlines are not as sharp nor as consistent in the Bolsa(?). The coloration of weathered surfaces is a decided yellowish color and the rock tends to break on the sandstone side with free grains exposed rather than across the grains.

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JDS/jk

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r. J.H. Courtright
file : Stratigraphy

CORRELATION OF SOME POST-LARAMIDE TERTIARY UNITS GLOBE (GILA COUNTY) TO GILA BEND (MARICOPA COUNTY), ARIZONA

By

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GENERAL STATEMENT

Integration of field mapping by various geologists has resulted in the identification of some correlative Tertiary units along a zone 130 miles in length. The zone extends from the Globe-Miami area across the alluvial basin at Casa Grande into the Gila Bend area. The rock units are correlated on the basis of rock type, structural involvement, and sequence, but they are not necessarily exact time equivalents. This paper does not propose that any rock unit completely covered the region from Globe to Gila Bend, nor that similar appearing units in the various areas are necessarily from the same source. The units are post-Laramide (post-early Tertiary) in age.

I wish to thank ASARCO geologists for their written and verbal comments and, along with M. E. Cooley, for field checks. American Smelting and Refining Company (ASARCO) kindly permitted permission for publication of the paper.

DIVISIONS

The late Cretaceous-early Tertiary sequence of selected localities was reported in a paper by Richard and Courtright (1960). Summaries of the numerous problems of Late Mesozoic-Tertiary events involving sequence and correlations are given by Cooley and Davidson (1963), and Heindl (1962).

The post-Laramide Tertiary units rest on a widespread erosion surface termed the San Xavier surface (Heindl, 1962, p. 13). In this paper the following six divisions are proposed for this portion of the Tertiary sequence.

VI	Younger basalts	) Late (?) Miocene-early Pliocene
V	Tuffs and ignimbrites	) Late Eocene (?) to Middle Miocene (?)
IV	Younger conglomerates	)
III	Older volcanics	)
II	Andesitic volcanics	)
I	Older conglomerates	)

All divisions are not represented in each area discussed; however, the stratigraphic-structural break representing these divisions has been noted and commented on by various workers in Cenozoic geology. Field relationships of the rock units and their structural complexities indicate that a sequence of depositional-readjustment and volcanic activity was continuous for the entire time span as covered in this paper. The relation of structure to deposition, volcanism, and erosion is widely covered in the papers by Cooley and Davidson (1963), and Heindl (1962). Because of these complexities any of the Tertiary units may be in depositional contact with any Laramide or pre-Laramide sequence.

Unit names in this paper (generally in quotes) are those given in the various reports and thus are of local usage only. Widespread correlation with named units elsewhere in Arizona is speculative at this time, and work is continuing in correlating the Tertiary sequence of the Basin and Range Province in Arizona.

Division Description

I. *Older conglomerates.* The older conglomerates are generally tuffaceous and contain large quantities of locally derived debris but do not contain fragments of extrusive volcanic rocks. The gravels range from pebble to boulder size, angular to rounded, unsorted to poorly sorted. In the eastern area (Superior-Globe-Miami), the conglomerates appear to occupy restricted basins whereas westward in the Table Top-Sand Tank area they were deposited in more widespread sheets. A major unconformity separates the older conglomerates from the overlying units.

II. *Andesitic volcanics.* The lower flows of the andesitic volcanics may interfinger with the underlying conglomerates but the change occurs rapidly from dominantly sedimentary rock to dominantly volcanic rock. At the base of the andesitic volcanics are beds, often exhibiting waterlain characteristics, of brown to red-brown cinder and ash beds, and locally in the western area a white pumice bed. Overlying the cinders are non-vesicular light to medium grey andesite flows characterized by abundant red specks which are probably iddingsite derived from olivine.

The characteristic cinder and ash beds have been mapped from the Superior area to the Gila Bend area and constitute a very good marker bed even though they are thin and not present in all outcrops of andesitic volcanics.

III. *Older volcanics.* A dark gray, to black vesicular basalt lies disconformably on the underlying volcanic rocks, predominantly andesitic, in the western part of the report area. Associated with the basalt is a complex sequence of andesitic, rhyolitic, and latitic flows and vents. In the Superior-Globe-Miami area, the Division III unit is a complex of trachyte, rhyolite, glassy lavas, and other flows, which, in Arnett Creek is known to overlie the "red speckled" andesite and the red-brown cinder-ash beds of Division II. A major unconformity occurs at the top of the complex Division III.

IV. *Younger conglomerates.* The younger conglomerates appear to occupy very restricted basins and are primarily composed of material from the eroding and reworking of the nearby older volcanic-conglomerate sequence. Especially characteristic is the abundant debris derived from the older volcanics of diverse types. With the conglomerates are abundant tuffaceous sandstones, and some mudstones.

V. *Tuffs and ignimbrites.* A vast amount of ash material, ranging in composition from rhyolitic to dacitic, and of pastel colors, make up the units of this division. The material is characteristically a welded tuff or ignimbrite which often has a dense black vitrophyre layer near the base. The structural complexities of the ignimbrites are minor compared to the underlying units (especially the older volcanic rocks) although the ignimbrites are cut by faulting. A minor unconformity separates the units from the overlying younger basalts.

VI. *Younger basalts.* Dense, black basalts overlie the ignimbrite forming material. The basalts are found as isolated "caps" throughout the region, but are also found as widespread, though dissected, sheets.

DESCRIPTION OF AREAS

Five areas, from Globe to Gila Bend, and their sequence of post-Laramide rock units are discussed in this section. Figure 1 shows the geographical relationship of the areas. Figure 2 is the proposed correlation between the six divisions previously described.

Globe-Miami

In the Globe-Miami area the older conglomerate unit of Division I is represented by the Whitetail Conglomerate which may rest on any of the older rocks. The conglomerate is composed of coarse, bouldery diabase detritus with subordinate amounts of Pinal Schist, Apache Group, and Paleozoic limestones. N.P. Peterson (1962, p. 37) writes: ". . . . the lower part is wholly unsorted and unstratified. Higher in the section crude stratification can be recognized, and lenses of poorly sorted gravel occur that undoubtedly represent temporary stream channels. Approximately the upper 50 feet of the formation is well stratified and is composed of layers of dark sand and gravel interbedded with layers of white tuffaceous sand."

The andesitic volcanics, Division II, are not represented in the Globe-Miami area and the older volcanics of the complex Division III rest directly on the Whitetail. The correlation of N. P. Peterson's "Earlier Volcanics" with Division III is based on Blucher's (1958) and D. W. Peterson's (1962) work in the Superior area.

The Division III unit is a complex assemblage of bedded tuffs (some of which are waterlain), felsitic and glassy lavas, and perlitic glass. These volcanics are separated from the overlying volcanics by an "interval during which some erosion of the rocks of the first eruption occurred" (N. P. Peterson, 1962, p. 37).

This interval of erosion undoubtedly is the interval represented by Division IV, younger conglomerates, but no remnants of any conglomerate have been reported.

The Division V, tuffs and ignimbrites, ("Later Volcanics" of N. P. Peterson, 1962) have a base of white to gray crystal-tuff which grades upward into a black vitrophyre, which in turn is overlain by the massive welded tuffs or dacite which have a slightly variable light brownish-gray-orange color.

Superior

The Whitetail Conglomerate (Division 1, older conglomerates) crops out in the Superior quadrangle in several places and in Queen Creek within the Thompson Arboretum area of the Picketpost quadrangle. The Whitetail Conglomerate, as described by D. W. Peterson (1962) is ". . . . fluvial deposits composed of angular to subangular fragments derived from all older rocks, mainly from underlying or nearby rocks. Most fragments are pebble size, some larger. Matrix is coarse-grained, poorly sorted arkosic to lithic sandstone, moderately well cemented; bedding planes poorly defined or absent."

Overlying the Whitetail Conglomerate north of Picketpost Mountain is the distinctive brown to red-brown ash bed which in turn is overlain by a massive blue-black andesite ("Blue Basalt" of Blucher, 1958) with altered red crystals - probably iddingsite after olivine. These volcanic units represent Division II, andesitic volcanics, of this paper. In Arnett Creek the ash beds rest directly on either Pinal Schist or Laramide granite,

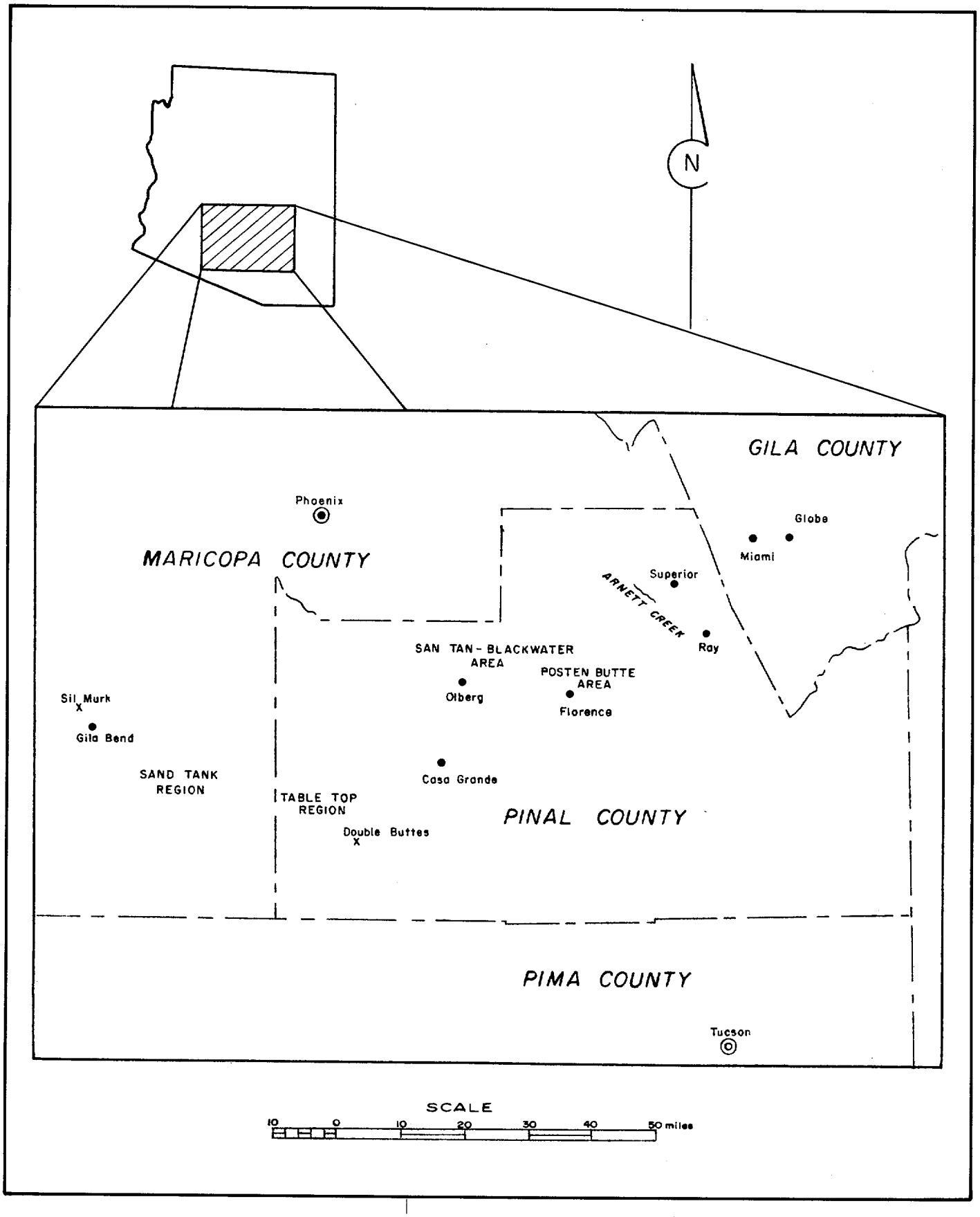

Figure 1 — Location map of south-central Arizona

while in the road cuts west of the Arboretum they rest on Pinal Schist and poorly preserved conglomerates.

Blucher and Kinnison in 1960 (Personal Communication) recognized a disconformity separating the Division II red ash and "Blue Basalt" units from the overlying complex (Division III) of tuff, spheroidal agglomerate with perlite, and rhyolite of the Arboretum area. Eastward the units are apparently part of the sequence which D. W. Peterson (1962) describes as: "Rhyolite: Lava flows composed of rhyolite and perlitic obsidian. Light to medium-gray rhyolite. . . .generally prominent flow laminations, locally contorted. Perlitic obsidian generally forms top or bottom of rhyolite flows. . . . Includes minor deposits of tuff, tuff breccia, and flows of andesite and trachyte."

D. W. Peterson (1966) suggests that the tuffs and rhyolites on Picketpost Mountain are younger than the dacite; however previously (1962), he maps and describes the thick rhyolite which underlies the dacite northeast of Picketpost.

A break suggesting an "unrecognized erosion cycle" (Blucher, Personal Communication) separates the complex sequence of Division III from the overlying dacite and welded dacite tuff of Division V. As in the Globe district, this interval is represented by Division IV.

The dacite of Division V is described by D. W. Peterson (1962) as ". . .ash-flow sheets; non-welded tuff at the base grades upward to densely welded black vitrophyre that is overlain by densely welded tuff with cryptocrystalline groundmass. Progressively upward from the vitrophyre the welding gradually decreases, the amount of crystallization in the groundmass increases and the color changes from light brown to moderate red to very light grey."

Blackwater-San Tan

ASARCO geologists Blucher and Kinnison conducted the bulk of the mapping in this area and the following descriptions are from their reports.

The lowest post-Laramide unit found was termed the "Yellow Peak conglomerate" for its excellent exposure on Yellow Peak northeast of Olberg. This Division I, older conglomerate, is equivalent in position to the Whitetail Conglomerate of the Globe-Superior region. The "Yellow Peak" (as reported by Blucher) ". . . .is a poorly sorted, poorly indurated, fluvial deposit. . . .made up principally of pebbles, cobbles, and boulders of Coolidge granite in a silty matrix." The Coolidge granite is the report term for the Laramide granite of the area.

The basal unit of Division II, not everywhere present, is red-brown cinders and ash beds ("Olberg Beds" of Blucher and Kinnison) which rest directly upon the "Yellow Peak conglomerate" as well as the Laramide granite. Overlying the red-brown cinders and ash beds is Blucher's "Blue Basalt" which is seldom amydaloidal or vesicular. The basalt weathers to a soft bluish-gray surface. This sequence of cinders and basalt is directly correlated with the Division II sequence at the Arboretum, Superior, Arizona.

Units composing the complex group of Division III, older volcanics are not exposed in the areas mapped by Blucher and Kinnison, but they may be present in the volcanic complex of the Malpais Hills to the north and west.

Overlying the "Blue Basalt" is the "Rock Peak conglomerate" which is assigned to the younger conglomerates of Division IV. This unit is composed of ". . . . tuffaceous sandstone, siltstone, and conglomerate which weathers to a light tan pock-marked surface" (Blucher, private company report).

The tuffs and ignimbrites of Division V cap Rock Peak and Yellow Peak and are exposed in most of the cliffs west of the peaks. This thick sequence of dacitic volcanic rocks is correlated with the dacites to the east and consists of tan dacite tuff, welded tuff, or tuff agglomerate with a brown to black vitrophyre near the base of the series.

The younger basalts (Division VI) cap many of the isolated buttes in the region. They were named the "Walter Butte basalt" by Blucher for exposures on the butte.

Table Top-Sand Tank

Throughout this region are numerous exposures of the older conglomerate - here termed the "Antelope Peak conglomerate" for its excellent exposure on that peak in the Antelope Peak quadrangle west of Casa Grande. The Division I conglomerate rests on Precambrian granite at Antelope Peak, on Apache Group rocks on Table Top Mountain, on Pinal Schist throughout the area, and on Paleozoic limestones and Laramide granite south of Freeman Underpass on the Casa Grande-Gila Bend Freeway. Mapping in this area was conducted by the author. The "Antelope Peak conglomerate" has a sandy-silty-tuffaceous matrix, often with waterlaid biotite tuff lenses and contains pebbles and boulders of Laramide and older rocks. Some volcanic porphyry-type pebbles are present in minor amounts but none resemble the overlying volcanics. Boulders of conglomerate similar to the Glance Conglomerate (Cretaceous) of the Vekol Mountains are also present.

Division II, andesitic volcanics unit, is composed of two distinct units. The lower member, the "Freeman beds" (exposed in the roadcuts at Freeman Underpass)

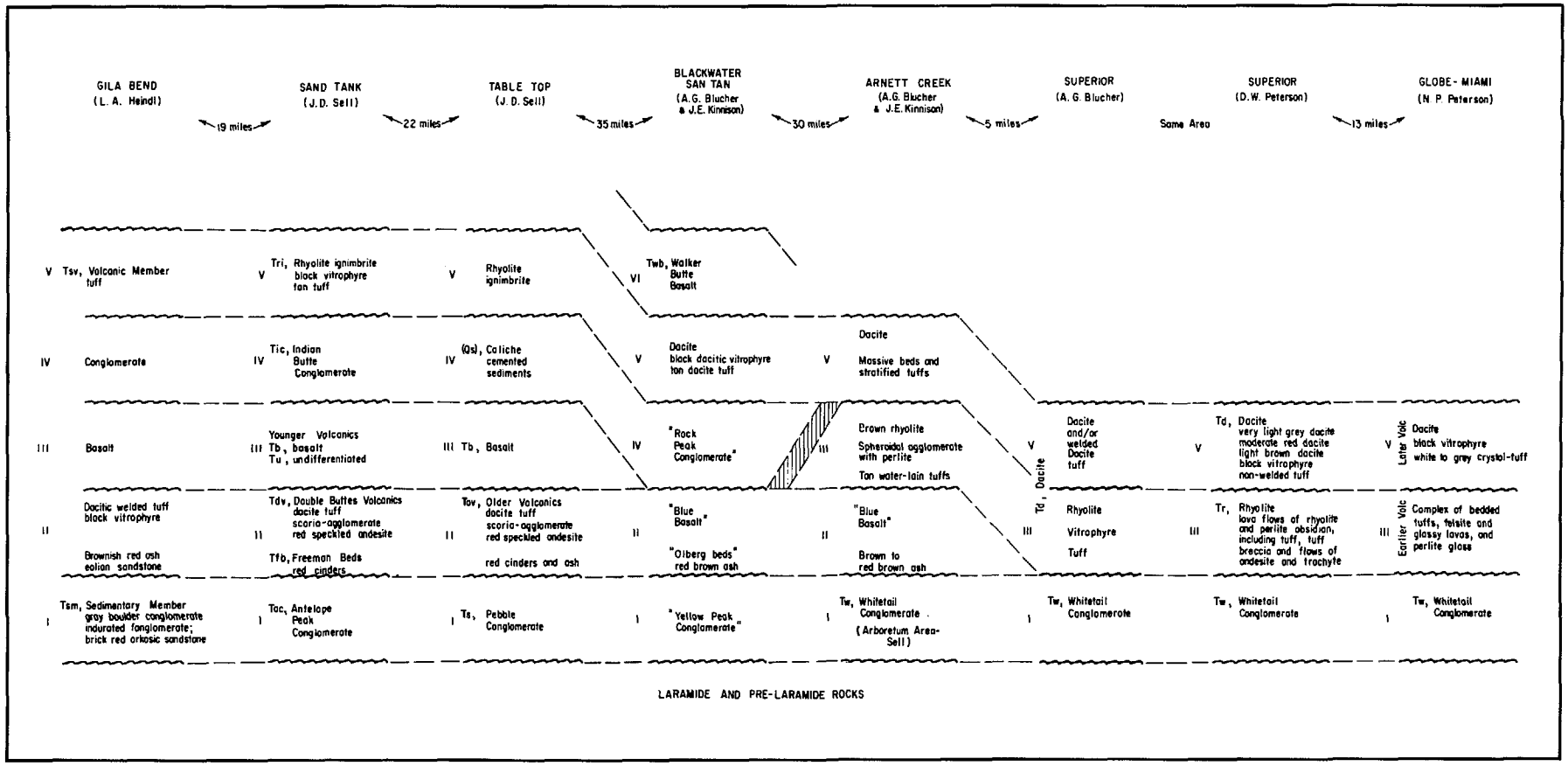

Figure 2 – Proposed correlation of post-Laramide units in central Arizona

is composed of brown-red cinders and ash with white pumice. The upper member, "Double Buttes volcanics" (named for the exposures in the Table Top quadrangle), is composed of purple-gray andesite containing the characteristic altered red crystals, lava scoria, cinders, agglomerate, and sometimes local units of dacitic tuff.

In the Sand Tank region, the volcanics of Division II are mapped as the Sauceda volcanics of Cretaceous age by Wilson et al (1957). As the volcanics overlie the older conglomerates which contain fragments of Laramide-type rocks, the volcanics must be younger than Cretaceous.

The interfingering of the lower conglomerate type unit with the first phases of extrusive volcanic action of the Division II units is well demonstrated in exposures in the region. However, it is not known whether the interfingered conglomerates are merely the result of erosion and reworking of the main conglomerate units or whether it reflects the continued inflow from the conglomerate source areas. The exposures show, however, that the change from dominantly sedimentary processes to dominantly volcanic processes is sharp and complete.

Overlying the andesitic volcanics are units of Division III. In the Table Top area, Division III is a basalt sequence of dark glassy basalt and dark andesitic basalt; whereas, to the west in the Sand Tank area the basalt is associated with a complex of andesitic, latitic, and basaltic volcanics interbedded with minor tuffaceous units.

The younger conglomerates of Division IV are poorly exposed throughout the region but scattered outcrops of conglomerate containing fragments of all previous volcanic types in the area can be found. One exposure is at Indian Butte (Table Top quadrangle) where a tuffaceous, often caliche-cemented, conglomerate contains numerous fragments of the older volcanics and basalts. Northwest of the Table Top Mountains an outcrop of conglomerate containing all types of volcanics is found underlying a rhyolite ignimbrite.

Capping many isolated buttes, especially north of the Freeman Underpass, is a distinctive pinkish rhyolite ignimbrite which generally has a basal tan tuff and black vitrophyre. The tuff, vitrophyre, and rhyolite ignimbrite are assigned to Division V. An unconformity separates Division V units from the underlying units, and the upper units have been subjected to only minor faulting and tilting.

No dense black basalt of the Division VI type was found in the area mapped.

Southeastern Gila Bend Mountains

The work of Heindl and Armstrong (1963), following the previous work of Babcock and others (1948), was a rapid reconnaissance of a small part of the south end of the Gila Bend Mountains. Heindl defined and described the "Sil Murk Formation" in this report and, although additional work is needed to definitely establish the correlation, the sequence of units they describe in this formation resembles the sequence of units in the Tertiary section farther east.

The Division I conglomerates are mapped over much of the Gila Bend area and were named the "Sedimentary Member" of the Sil Murk Formation.

The "Volcanic Member" overlies an angular unconformity cut on the conglomerate and is sequence in which Heindl lists the following, ascending, types: Eolian tuffaceous sandstone, brownish-red ash, black vitrophyre, and dacitic welded tuff (all Division II); a fine-grained black basalt (Division III); a conglomerate containing both gneissic and volcanic rocks (Division IV); and a lavender tuff, possibly dacitic (Division V).

Also found on the northwest side of the area (but not mentioned by Heindl) is the distinctive pink rhyolite ignimbrite of Division V, which is underlain by conglomerates having volcanic material and belonging to Division IV.

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GEOLOGY OF THE BISBEE AREA

Abstract

The geologic formations outcropping in the Mule Mountains in the Bisbee area consist of the Precambrian Pinal schist basement overlain by 1,200 feet of Cambrian Bolsa quartzite and Abrigo limestone, 300 feet to 375 feet of Devonian Martin limestone, 600 feet to 800 feet of Mississippian Escabrosa limestone, and 3,000 feet of Pennsylvanian-Permian Naco group. During late Triassic or early Jurassic time, the Juniper Flat granite with associated dikes and the Sacramento Stock were intruded into these formations, accompanied by complex faulting and brecciation. Peneplanation north of the Dividend fault was followed by the deposition of 5,000 feet of the lower Cretaceous Bisbee group. Post-Cretaceous tilting, faulting and erosion gave rise to the present surface.

STRUCTURAL CONTROL OF THE SULFIDE REPLACEMENT DEPOSITS AT BISBEE

Abstract

Orebodies around and adjacent to the Sacramento stock south of the Dividend fault were probably of a pyrometasomatic origin. Their configuration was influenced largely by the bedding of the limestone host and to some extent by fracturing. Orebodies lying away from the stock tend to occur in groups or clusters. The placement of these clusters was influenced largely by steeply-dipping north-south trending fracture zones which occur between branches of northeast-southwest trending faults. A prerequisite of the host rock was its ability to fracture under stress. This prerequisite is met in the thinly-bedded Abrigo formation, the Parting quartzite overlying the Abrigo, the impure and brittle Martin limestone, and the chert zones in the lower portion of the Escabrosa limestone. Post-Cretaceous movements along many of these northeast-southwest faults have displaced the ore-bearing fracture zones along with the Cretaceous sediments, and further displaced the Paleozoic formations.

UNDERGROUND GRAVITY SURVEYS AT BISBEE, ARIZONA

BY ROBERT N. SCHNEPFE

Abstract

Twelve thousand gravity stations have been occupied in 160 miles of crosscut underground at Bisbee. All of these values are referenced to a base network, permitting direct comparison of the data. Latitude, free air, Bouguer, terrain, and regional corrections are made to the raw data. The resulting residual gravity data presented in the form of contour maps.

The density of the country rock is remarkably uniform and averages 2.70 g/cc. A density contrast of 1.00 g/cc between the massive sulfide mineralization and the country rock is generally assumed in making theoretical calculations.

Limited station distribution precludes the use of mathematical interpretational aids. Non-sulfide disturbing influences are solution caverns, mine workings, epidote skarn, dolomitic limestone, gossan, and some copper oxide mineralization.

Five examples of gravity anomalies in various portions of the mine are shown. These illustrate a number of the problems encountered in the interpretation of the results, as well as the size and magnitude of the anomalies to be expected. One example of a vertical section showing the relation of the apparent density to the gravity contours is given.

Eighty percent of the recommended holes that have been drilled have cut sufficient sulfide mineralization to account for the anomaly they were investigating. The gravity data is also used in planning exploration crosscuts.

HC. Mum chuckles
Nice to remember
you & your old School.
Please return for your
dearest some day.
J. Bl

Bonbright

COMBINED METALS, Pioche, Nevada.

GEOLOGY

No. 1 Shaft at Pioche - Castleton Shaft over summit - about 1 mile apart. Ore body in "C.M." lime bed in Pioche shale near base - Prospect Mt. quartzite below. C.M. bed 30' thick - Mineralized portions 3'-5' thick - 2 to 3 horizons of ore. Average grade, Au. .03 - Ag. 6 oz. 6% Lead, 16% Zn., 17-19 Fe - Sulphide ore. Mineralization follows E.W. fissures - N.W. faults - drop W block down as much as 2--'-300'. Numerous porphyry dikes.

BRISTOL SILVER MINE - Bristol Range N of Pioche
Paul Gemmill, geologist - J. H. Buehler, Mgr.

GEOLOGY

Elevation at collar 7200 - Mine has been worked to 1700' on 75 deg. incline shaft. Ore occurs in fissure fillings and replacements along E-W S dipping normal fault. Upper formations are Highland Peak limestone and dolomite - lower, Burrows dolomite, Muav & Chisholm shale? Ore is nearly all secondary - Iron carbonates and sulphates and oxides - $PbCO_3$, SO_4 - $ZnCO_3$ - Typical assay - 25 oz. Ag, 15% Pb, 5% Z Zn, Au. .03 oz. Large "Caves" containing soft ore occur - platy dolomite beds act as dams rich ore above. Leads are iron oxide stringers lamphrophyric dikes in lower levels - water table at 1720 - serves as domestic supply - raised by 3-cylinder plunger pump. Mine produces 60 tons per day. Some contain high grade Cuprite and Melanconite

CONSOLIDATED COPPERMINES CORPORATION
E.N.Pennebaker, Chief Geologist

GEOLOGY

Formations * Ore porphyry - altered monzonite - intruded into Paleozoic sediments - well fractured - occurs in anticlinal structure 2 miles to east chalcopyrite in seams and fractures - also phlogopite mica and molybdenite. Later "peanut porphyry - less altered seldom carries ore values - Tertiary rhyolite - some breccia carries fragments of high grade copper - indicating possibility of ore below.

Erosion just entering top of primary ore small amounts of secondary have been mined (chalcocite).

Rough zoning in district - copper, gold, silver, lead, zinc, manganese Mineralization in E-W break in N-S structures. Foot wall reverse fault controlling factor in ore deposition - ore in hanging only - movement pre-porphyry to post-rhyolite. Both por. are sills.

RUTH MINE - NEVADA CONSOLIDATED. Paul Hett, Sup't.

GEOLOGY

Gradual gradation from ore to pre-porphyry - do not recognize 2 different intrusives - bottom of high grade (chalcocite) ore chutes contain turquoise and rounded white nodules - talcose - called "cannon balls".

NORTHUMBERLAND MINE - 80 mi. NE of Tonopah - J.C.Perkins, Sup't.

GEOLOGY

Granodiorite intruding shale and quartzite. Lower pit - carbonaceous shale and quartzite and granite are mineralized - latter is soft altered. Average value $6.00 Au - some scorodite. Gold is extremely fine - does not pan. Anderson - Caltech., made thin section of $8.75 ore - showed no free gold at 10,000 M Extraction 80-85%.

BELMONT MINE

GEOLOGY

Early silver camp - steep-dipping quartz veins in limestone and shale - veins parallel to bedding in most cases worked to 500' - majority of ore values in chlorides near the surface.

COPPER CANYON MINE - SW of Battle Mountain.

GEOLOGY

Breccia pipe in quartzite conglomerate cut by numerous fissures - latter were stoped in early days for gold and copper - soft oxidized ore. Mine developed to 500' - primary chalcopyrite and pyrite in breccia - 500,000 tons blocked out 1-2% Cu, .1 Au, No gold associated with chalcopyrite. Monzonite plug on ridge above mine. Diorite and porphyry dikes in ore body. Some pyrrhotite.

INDEPENDENCE MINE - Wilson & Brogle - west of Copper Canyon near Greenan Placers.

GEOLOGY

Steep-dipping fracture zone - average width 5' - irregular bodies of soft oxidized gold silver ore - country rock - shale, quartzite and silicified shale. Shaft down 200' - have shipped 9 cars of ore - average $42.00. Silver-gold ration about 2 to 1- values erratic - ore does not pan free gold - contains as much as 15% As.- some Bismuth - small pockets of primary arsenopyrites occur. Apparently post mineral fracturing and faulting has allowed free circulation of surface waters creating open spaces or caves - partly filled with extremely soft residual ore enriched by removal of valueless material.

TURQUOISE MINE - located in Copper Basin 7 mi. from Battle Mountain

GEOLOGY

Narrow seams in fracture zone - vertical altitude vertical - wall rock is leached - light grey - altered quartzite or partially metamorphosed sandstone subsequently altered by solutions - Ore is hand sorted and cobbed - shipped to gem cutters in Los Angeles - owners - Mineralized zone 15'-20' wide, grades into hard quartzite on each side - Material of good quality - hard, dark blue - worth about $6.00 per lb. - last year mine produced three quarters of the U. S. supply - deposit appears to be worked out.

GOLCONDA TUNGSTEN PLANT - "Pi" Warren, mill sup't.
8/21/41 Now with U. S. Vanadium in Colorado.

GEOLOGY

Flat lying neds 3' to 30' thick in alluvium at base of mountain east of Golconda. Ore is composed of calcareous material - mainly travertine, clay and iron oxide - In places beds of manganese oxide, psilomelane and pyrolucite occur. Apparently a hot springs deposition in shallow lake WO_3 in solid solution? Beds 3' to 8' thick will be mined room and pillar - overburden is but few feet thick but hanging stands well. 30' bed will be stripped and mined by power shovel. Ore is soft. In present development drifts blasting holes driven with hammer and bull prick. Prospecting by churn drill.

GEOLOGY NOTES FROM G.S.A. BULLETIN
"Tungsten bearing Manganese Deposits at Golconda, Nevada", by Paul F. Kerr.

Blanket-like deposit of manganiferous and ocherous clay lies on truncated tilted Triassic sediments. Overlain by calcareous tufa - Beneath are veins of similar mineralization - may be source of ores - ~~tungstic acid adsorbed into psilomelane and limonite~~ Ore minerals are colloidal in origin - tungstic acid adsorbed into psilomelane and limonite while both were gels. Ore minerals and tufa of hot spring origin. Mineralization started with chertification - silicification - followed by precipitation of WO_3, Mn, Fe and tufa.

CROWN MINE - Jay Shoemaker, Sup't.
15 mi. S of Golconda.

GEOLOGY

Fracture zone 10'-60' wide in quartzite - average $5.00 in Au and Ag - values are irregular - assay walls in part.

WEST COAST MINE - NW of Winnemucca - Roscoe Smith, U.C.

GEOLOGY

Fissure vein in metamorphosed sedimentaries - quartzites and phyllites - Triassic in age? Diorite stock near deposit - dikes occur - premineral - where vein cuts diorite little difference in mineralization noted. S & NS dip 65 degrees E. Two stages of mineralization - earlier white quartz - contains As and Fe sulphides - little Au or Ag. Later dark quartz fills brecciated spaces - contains arsenopyrite (predominand) pyrite, galena and zinc blende as latest mineral. Some specimens show replacement by solution of earlier quartz. Numerous strike slips displace ore a few feet - Slips are discontinuous - apparently caused by settling of numerous fault blocks.

MOUNT TOBIN QUICKSILVER MINE
Mike Gould, President
William Jenkins, Sup't.

GEOLOGY

Located 50 mi. south of Winnemucca - Cinnabar occurs mainly as "paint" thin seams in tuffaceous quartzitic breccia - apparently tuffaceous clays acted as barriers to solution - deposit may have originated in nearby hot springs - laves show intense leaching due to hydrothermal alteration - characteristic of areas contain mercury deposits in the district E of Lovelock.

NEVADA MASSACHUSETTS CO. Ott F. Heizer, Manager.

GEOLOGY

Located 9 mi. W of Mill City in Eugene Range. Contact metamorphic type deposit - thin beds limestone (3' to 8') in triassic shales have been replaced by quartz, garnet, epidote, pyrite and scheelite. Beds str. roughly N-S and dip 75 W. Granodiorite intrudes sedimentaries metamorphosing shale to hornfels. In Stank Mine beds terminate to N against grd.

MANGANESE PROPERTY - Located in Pumpernickel Valley, 21 mi. S of Golconda - Pat Divine, owner.

GEOLOGY

Ore occurs in lens 30' thick several hundred feet in diameter - near top of spur on west side of valley. Deposit contains 30% Mn - lower grade material on outer margins - Considerable siliceous rock associated - jasper and cherts - few veins, quartz. Ore mineral is psilomelane - small amounts of manganite and pyrolucite noted. Deposit lies on schistose igneous rock possibly andesite - May have originated as replacement of sedimentary beds. 200,000 tons 30% ore blocked out, 20,000 tons shipped to date. Mining open cut - hand mucked - crushed to minus 3" - jaw crusher - trucking to Golconda $1.25 - freight to Provo, Utah, $3.25 at 30¢ per unit - Columbia Steel pays $9.00 per ton. At present 5 cars being loaded for U. S. Government at Boulder. SiO_2 content 50-55%.

GETCHELL PLANT - Fred Wise, General Manager
Bob Spitzer, Mine Foreman
C. W. Wark, Mill Superintendent

GEOLOGY

Mineralization occurs in and adjacent to basin range fault zone - Str. N-S dip E 40 - extend several miles. Paleozoic sediments shale and limestone intruded by grd. - latter makes ore where vein cuts dikes or tongues. Ore shoots vary from 500 to 2000 ft. in length - average width 55 ft. - prospected by incline shaft and drift to 800 level - Hanging black clay gouge - assay wall - foot wall portion siliceous - 85% brecciated shale and limestone. Oxidized zone down 400' on dip in main pit - 10' capping hard siliceous breccia over oxide ore - cap assays .03 or .04 - ore is comparatively soft beneath. Gold is extremely fine - does not pan - concentrations of pyrites do not show higher values - Average assay $7.00. Later realgar and orpiment have been introduced - fault shows movement subsequent to all mineralization fault characterized by series of springs. Clay gouge hanging acted as dam for ore solutions. Contact silicates - wallastonite and tremolite occur on foot wall - no values. Vein apparently splits to north - eroded down to sulphide zone. Small amounts cinnabar in dog tooth spar in sulphide zone - crosscut on main haulage drift.

Sulphide ore is roasted to drive off sulphur and remove coating (?) from gold particles - 90% extraction on oxide less on sulphide ore.

STANDARD MINE. D. Ross Frazer, Sup't.

GEOLOGY

Open cut 100' deep - walls nearly vertical - mineralization occurs in fractured limestone - assay wall in limestone on East - shale contact on West. Ore shows some iron oxide - numerous calcite stringers - bottomed by flat-dipping fault - .04 cut off

Cross-section of deposit

Grade is higher just above fault - some local faulting in ore body - later 2½ to 1 str. ratio.

CHAMPION SILLIMANITE CO. Oreana.

GEOLOGY

Dumortierite deposit in keratophyre - albitic ? or albitized trachyte. A flow rock in Koipate limestone and shale. Rock is light colored schistose - Formation strikes N-S dips steeply - Dumortierite occurs in lenses 2' - 3' thick in platy schist - intercalated sediments or zone of shearing - cost of production $20.00 per ton - ore is sorted and hand-cobbed. Andalusite and corundum are found in canyon East.

GYPSUM - Pacific Portland Cement Co.

GEOLOGY

Steep-dipping bedded deposit - in Triassic sediments - 90% pure. Anhydrite at bottom - $CaCO_3$ & SiO_2 form impurities. 16 cu. ft. in place per ton.

SIXTEEN TO ONE MINE - Alleghany, California.
Dick Bennett, Superintendent
Van Doren, Foreman
Bill Fuller, Geologist

GEOLOGY

35 degree reverse fault in serpentine and Tightener formation - chlorite, talc and amphibole schist - later thrusts cut vein. Quartz stage - pyrite and arsenopyrite contemp. with and slightly earlier - both in wall and vein - replacement and stringers - Carbonate stage - replacement of wall rock ankerite, sericite, mariposite, talc and chlorite. Last state - calcite, marcasite, pyrite coatings and veinlets. Earlier quartz milky, micro-brecciated - later quartz clear opaline - mineralization in earlier. Au always associated with arsenopyrite - never less than $1.00 per lb. concentrates. Paragenesis - quartz, pyrite, arsenopyrite high intensity minerals chalcopyrite, galena, gold lower intensity also sphalerite and tetrahedrite. Ore shoot on 1557 - 45' long 75' on dip - 3' width - produced $500,000 in one place 60 ft. drift - 300,000 at $20.00 gold, $14,000,000 total production. Average mill ore $4.50 - 85% redovery, 65% brought out by specimen boss.

BROWNS VALLEY - EMPIRE COMPANY
Ellsworth Bennett, Manager
Berger, Mill Superintendent

GEOLOGY

Flat dipping fissure in metaandesites, diabase, gabbro, etc. - vein describes right angle turn serpentine formation in bend - due no doubt to relatively plastic nature of serpentine - vein is pinched - no quartz or values in serpentine. May have acted as a dam to solutions as values are higher where vein goes into serpentine. Postmineral faulting in plane of vein - causes irregular thickness of quartz - Later normal faulting causes displacement of 10' or 15'. Earlier faulting reverse?. Minerals - galena usually associated with gold values - also pyrite - and chalcopyrite - some rutile. Pennsylvania Shaft on N-S east dipping branch - Dannebrough Shaft - (18 degree average dip) on E-W vein.

LAVA CAP MINE

Otto Schiffner, Manager
J. W. Chandler, Mine Superintendent

GEOLOGY

Ore in reverse fault fissure in metamorphosed carbonaceous shales and argillite slates. Average dip 51 degrees - width of vein average 3-5 feet. Metamorphism effected by gr. intrusion has not been sufficiently intense to form hornfels at this distance from contact. Wall rock is grey to black, dense blocky fracture - slaty cleavage not very apparent. Pre-fissure (?) latite dikes offset showing displacement (reverse) 42'. Post mineral faulting - horizontal movement - steep dip. "Mullions", large striations or curves in vein - rake to north - where vein splits enrichment occurs - As split becomes wider included wall rock is waste. Paragenesis - pyrite, sphalerite, galena, tetrahedrite (friebergite) gold. Ratiom gold to silver 10 to 1.

AMERICAN SMELTING AND REFINING COMPANY
Tucson Arizona
February 18, 1963

FILE MEMORANDUM

PORPHYRY COPPER DEPOSITS - ARIZONA & NEW MEXICO

A general review of porphyry copper exploration in the Southwest was contained in my memorandum of October 4, 1950. Since that time considerable exploratory work has been carried out by various companies, and several new mines have been put into production. The purpose here is to bring the picture up to date and to re-examine the gambling odds involved in porphyry copper exploration.

In the following tabulation porphyry copper occurrences are divided into 5 different categories: (1) Productive Deposits, (2) Marginal Deposits (undeveloped), (3) Deposits Currently Under Exploration, (4) Prospects which have been Tested and Proven Sub-Marginal, and (5) Untested Prospects.

1) Productive Deposits

Over 100 Million Tons*	Under 100 Million Tons*
Morenci	Bagdad
Santa Rita	Copper Cities
San Manuel	Silver Bell
Miami-Inspiration	Esperanza
Ray	Christmas
Ajo	Mineral Park (under development)
Cananea (Sonora, Mex.)	Castle Dome (mined out)
Bisbee	
Mission-Pima	

* Production plus potential

2) Marginal Deposits (Undeveloped)

Tyrone..... Reportedly plus 400 million tons @ .70% Cu, chiefly chalcocite. Owned by Phelps Dodge.

Lone Star..... Reportedly 800 million tons @ .55% Cu, mixed sulphides and oxides. Kennecott.

San Juan..... "Large ore body too deep for open pit mining." Owned by Phelps Dodge.

Helvetia ..... 14 million tons .80% Cu. Mixed sulphides and oxides. Controlled by Banner.

File Memo February 18, 1963

3) Deposits Currently under Exploration

Sacaton	Asarco
McGee (NW of Esperanza)	Bear Creek
Saginaw Hill (So. Tucson Mtns.)	Anaconda
Red Mt. (Patagonia)	Kerr-McGee
Twin Buttes	Banner
Four Metals	Noranda
Johnson Camp	Cyprus
Chilito	Bear Creek

4) Sub-Marginal Deposits
Proven either too small or too low grade

	Drilled By
Kelvin	Con Coppermines
Copper Creek	Bear Creek & others
Sunnyside	ASARCO
Turquoise	ASARCO, Bear Creek
Red Hills (Texas)	ASARCO, Bear Creek(?)
Poston Butte	ASARCO
Lake Shore	USBM, Shattuck-Denn & Trans Arizona
Pioneer Group	Duval Sulphur & others
Blackwater	Magma Copper
Cerrillos	Bear Creek
Hiltscher	Bear Creek
Steeple Rock	Bear Creek
Madera	Miami Copper
Cactus	Miami Copper
Three R	Con Coppermines (property recently acquired by Anaconda)
Copper Basin	Phelps Dodge

5) Porphyry Copper Prospects - Untested

Rock House (No. of Superior)	Outcrops indicate minor chalcocite enrichment below, but zone too small in size.
Border Pipe (So. of Patagonia)	Mineralized breccia pipe ± 500' in diameter. Outcrops indicate original disseminated pyrite with minor enrichment. Deposit too small to warrant drilling.
Tyndall District (So. Santa Rita Mts.)	Zone of strong quartz-sericite-pyrite alteration several square miles in extent. General character of leached outcrops, plus occasional exposure of sulphides in old adits, indicate little more than traces of either primary or secondary copper.

File Memo February 18, 1963

5) Con't

Tombstone	Zone of alteration one mile or more in diameter lies southwest of this old silver mining district. Outcrops do not appear too promising, but total extent of zone has not been determined. Further reconnaissance planned.
Organ District (Organ Mts.,NM)	Zone of alteration ½ mile wide extends about one mile northwesterly where it passes beneath valley alluvium. Mineralization in exposed portion of zone not sufficiently attractive to warrant exploration. Possibilities under cover highly speculative. A possible application of geophysics was considered at one time; however, the area is now partly within the White Sands Testing Range.

The Productive Deposits listed above (see attached map for location) range in size from 18 million tons (Castle Dome) to a plus one billion tons (Morenci), if future potential is added to past production. With the exception of Castle Dome, which is mined out, nearly all of the mines listed here have a future life of at least 10 years, and at least 50% of them a future life of over 20 years.

Tyrone is included in the group of marginal deposits; however, under different ownership this deposit would likely be in production. Phelps Dodge spent several years in drilling and evaluating and then placed it on the shelf --- presumably because they possess ample resources of lower cost copper elsewhere. Tyrone, with a relatively large tonnage and a grade of .70% copper, would be at least equally profitable, if not more so, than either of Duval Sulphur's two deposits, Esperanza and Mineral Park.

Among the Deposits Currently under Exploration, Saginaw Hill and the Four Metals are noteworthy simply because both are relatively small deposits which have undergone repeated unsuccessful exploration attempts by various companies in the past. Anaconda is now drilling a 3000' hole on Saginaw Hill and Noranda is preparing to drill the Four Metals.

Reportedly Bear Creek ("McGee" Prospect) has been finding .4 to .5% primary copper in diorite and andesite in ground adjacent to the Experanza.

Red Mt., Patagonia, lies within a large alteration zone which includes the Sunnyside breccia pipe (drilled by Asarco in 1950). Kerr-McGee recently completed driving an incline on the east side, encountering low grade (± .05% Cu) primary mineralization. Reportedly, they plan drilling higher on the mountain.

Chilito produced 91,000 tons of 1.4% Cu. This ore, which consisted of disseminated copper in quartzite, was shipped to Hayden as siliceous flux. Kennecott acquired the property last year.

Banner recently drilled several holes in a gravel covered area southeast of

Twin Buttes. This is the area generally considered to be the probable location of the "roots" of the Mission-Pima zone of mineralization. According to a local contractor, Banner recently cancelled plans for an additional 90,000 feet of diamond drilling at Twin Buttes. The area may still hold exploration possibilities.

Most of the copper ore mined at Johnson Camp came from more or less massive sulphide lenses in the Cambrian Abrigo formation. Disseminated copper occurs, however, in the Cambrian quartzite and in the lowermost part of the overlying limy shale of the Abrigo. During the past few years, 150,000 tons or more of oxidized copper-bearing rock has been mined open pit and shipped to the Douglas, El Paso and Hayden smelters for siliceous flux; and recently, Cyprus completed a series of drill holes in this disseminated copper horizon, reportedly indicating a zone 150' thick and 2000' long of .75% Cu. No intrusive rocks of the porphyry copper type have been found in the area; however, the deposit resembles a porphyry type occurrence in other respects, and an intrusive center of relatively strong alteration-mineralization could exist under the alluvial covered valley east of the mine.

Brief comments on the Untested Porphyry Copper Prospects are included in the foregoing list.

Referring to the attached map, it is to be noted that with the exception of Christmas, mines developed within the past 12 years --- Mineral Park, Mission, Pima, and Esperanza --- all fall within a northwest-trending belt which includes Bagdad, Sacaton, Silver Bell and Cananea. In his report on the discovery of the Sacaton Prospect (Feb. 13, 1961), Mr. Kinnison referred to the aforementioned belt as the Silver Bell zone, and pointed out that the Sacaton area was situated at the intersection of this zone and two cross-trending zones which he labeled "Miami" and "Poston Butte". Since that time, drilling at Sacaton has demonstrated the existence of a major-sized porphyry copper deposit, the full extent of which has yet to be determined. This, and other new discoveries, tend to emphasize certain trends along which the exploration chances may be better; but we must still depend on finding a lead, such as an altered outcrop with evidence of leached sulphide mineralization, or altered boulders derived from a now-buried outcrop, wherever it be located --- on trend, or off.

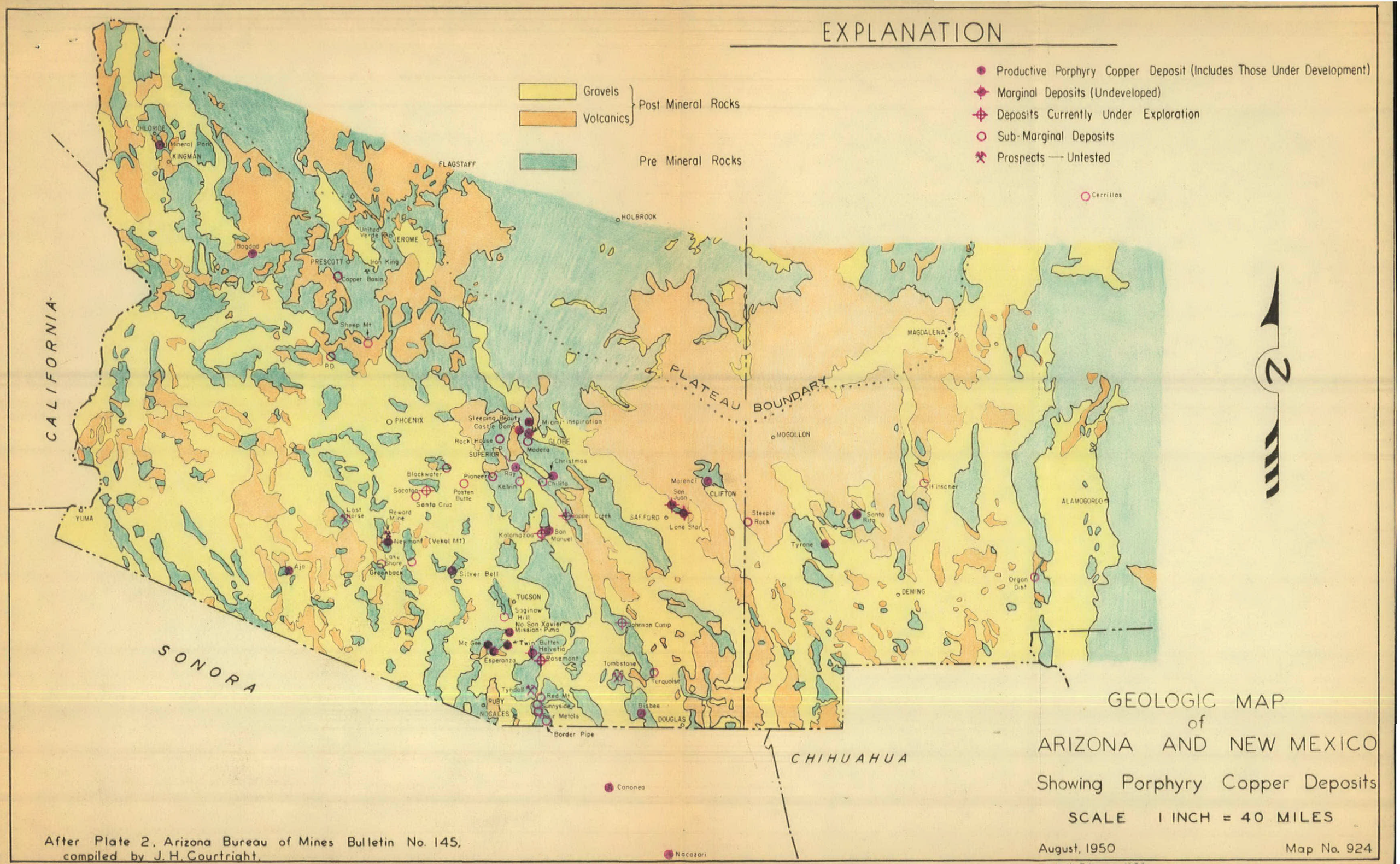
In 1950 (above mentioned memo of Oct. 4, 1950) there were 12 "commercial" deposits (excluding Tyrone and Pilares) and 10 deposits regarded as either "non-commercial" or as "prospects" with unknown potential. The ratio has changed some in the past 12 years, but the odds still appear very favorable. Today there are 17 "commercial" deposits (including Tyrone), 3 marginal, 16 sub-marginal, 8 currently under exploration and 5 untested. Four of those currently under exploration, Saginaw Hill, Chilito, Red Mt., and Four Metals, should be regarded as sub-marginal on the basis of prior exploration results. Thus, we have a 20-25, or 4-to-5 ratio if the 3 marginal deposits are included with the 17 "commercial" deposits, and all 5 untested deposits are included with the sub-marginal deposits. This ratio has no bearing on the chances of finding a new porphyry copper prospect --- due to the great concentration of exploration personnel in the Southwest for many years, this chance must be regarded as very slim --- but it does suggest that if a new prospect

is found, and the zone of alteration-mineralization demonstrated to be of adequate size (say, a half mile or more in diameter), the odds should be roughly even that the zone will contain a "commercial" ore body.

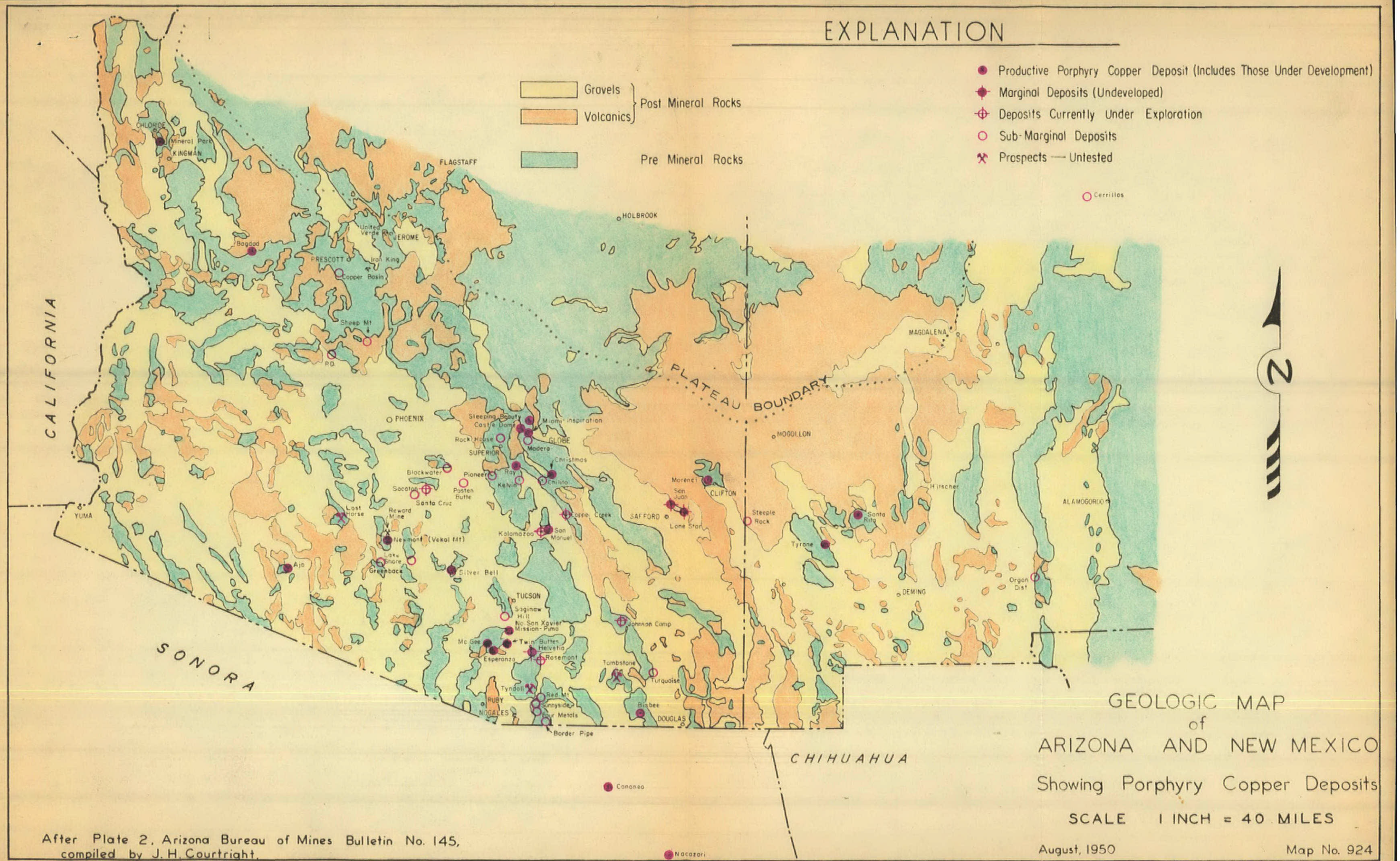
J. H. Courtright

J. H. COURTRIGHT

JHC/kw
Attachment - Map



After Plate 2, Arizona Bureau of Mines Bulletin No. 145, compiled by J. H. Courtright.



GEOLOGIC MAP
of
ARIZONA AND NEW MEXICO
Showing Porphyry Copper Deposits

SCALE 1 INCH = 40 MILES

August, 1950 Map No. 924

Revised February, 1968

After Plate 2, Arizona Bureau of Mines Bulletin No. 145, compiled by J. H. Courtright.

Geologic Map of Colorado

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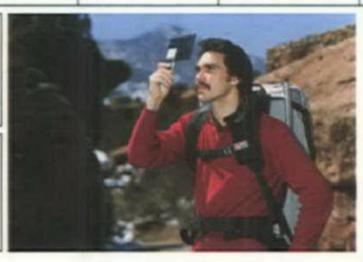

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