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GEOLOGIC REPORT

on the

JABA, INC. PROPERTIES

in the

TOMBSTONE MINING DISTRICT,

COCHISE COUNTY, ARIZONA

Submitted to

Vancouver Stock Exchange

By

John M. Guilbert
Professor Emeritus of Economic Geology
University of Arizona
Tombstone, Arizona 85821

February 5, 1993

CERTIFICATION

I, John M. Guilbert of Tucson, Arizona, do hereby state:

1. I am a Consulting Geologist and am 62 years of age. I graduated from the University of North Carolina in 1953 with a B.S. in Geology, the University of Wisconsin in 1955 with an M.S., and the University of Wisconsin in 1962 with a Ph.D. in Economic Geology.

2. My address is 740 West Las Lomitas Road, Tucson, Arizona 85704.

3. I am a member in good standing of the Society of Economic Geologists in which I have held executive positions. I am also a Fellow of the Geological Society of America, Arizona Geological Society, Society of the Genesis of Ore Deposits, a Fellow of the Mineralogical Society of America, Geologic Society of South Africa, International Association on the Genesis of Ore Deposits, Canadian Mineralogical Association, and Geological Society of Chile. I am the senior author of the advanced text book, Geology of Ore Deposits, used as a text throughout the world in teaching the study of ore deposits.

4. I am Professor Emeritus of Economic Geology in the Department of Geosciences, University of Arizona, Tucson, Arizona, where I have been a Professor for 27 years.

5. Since graduation, I have practiced geology for 35 years, on a world-wide basis., specializing in porphyry copper deposits.

6. My report is based on numerous visits to the Tombstone Mining District over the last 20 years. My most recent work in the Tombstone Mining District culminated in October, 1992, with the dissertation defense of one of my students on remote sensing aspects of the Tombstone area.

7. JABA, Inc. has given permission to use the data they acquired in this evaluation and report.

8. This report entitled "Geologic Report on the JABA, Inc. Properties in the Tombstone Mining District, Cochise County, Arizona", February 4, 1993, may be used by Excellon Resources USA, Inc. in a public financing.

9. I, myself, have no direct or indirect interest in any of the Tombstone District properties discussed in this report or in Excellon Resources USA, Inc.

Dated at Tucson, Arizona, the 4th day of February, 1993.

John M Guilbert

Dr. John M. Guilbert
Professor Emeritus Economic Geology
University of Arizona
Tucson, Arizona

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ATTACHMENT IN POCKET

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INTRODUCTION

The report that follows has been brought together from many sources, chiefly by and through the sustained involvement in the district of James A. Briscoe of JABA, Inc., Tucson. My involvement has been through interest in Tombstone geology sparked by boyhood visits in 1944, through my professional involvement in 'porphyry copper', Arizona, and Tombstone geology as a Professor at the University of Arizona, from 1965 to the present, and through use of the Tombstone District as an ongoing investigative lab project for graduate students in Economic Geology since 1985. It is herewith acknowledged that Briscoe has joined the ranks of Butler, Ransome, and Wilson as a contributor to and synthesizer of geologic information on the Tombstone District. Most of the data to follow results from his efforts, and the credit for recent progress and many of the points made in this report belongs to him.

SUMMARY

Tombstone, discovered in 1877, has produced approximately 1/3 of a billion dollars, at modern metal prices, in gold, silver, lead, zinc, copper, and manganese. Previously thought to be a mid-Tertiary aged epithermal silver-lead-zinc district of limited size and potential, more recent work shows it to be of Laramide age. Mineralization is associated with volcanism and related caldera formation, and alteration assemblages are characteristic of porphyry copper deposits. Five such potential porphyry copper centers identified by Briscoe have been acquired by JABA Inc.

Potential in the district is for carbonate-hosted replacement-type porphyry copper mineralization at intermediate to moderate depth and perhaps great depth; shallow chalcocite blanket porphyry type mineralization; stratigraphically and structurally controlled carbonate replacement lead-zinc-silver mineralization; similarly controlled gold of low grade to high grade; volcanic-hosted disseminated precious metal mineralization; supergene enriched volcanic and sediment hosted intermediate to high grade precious metal mineralization; and porphyry-copper-associated distal sediment or volcanic hosted gold mineralization.

An exploration program for each of the 5 blocks owned by JABA Inc. has been designed to test these targets. Various industry accepted exploration tools will be used in the exploration program to define drill targets, culminating in each case with exploration drilling using reverse circulation.

The estimated exploration expenditures for each block are:

Block 1	$227,120
Block 2	$120,445
Block 3	$100,036
Block 4	$139,250

Block 5	<u>$108,103</u>
Total for the entire program	$694,954

This would include 10,000m feet of drilling. The program cost would average $22.79 per foot of drilled hole.

HISTORY

The Tombstone Mining District, then in Arizona Territory, was discovered in 1877 in outcrops near the present Lucky Cuss mine, by Edward L. Schieffelin, a prospector and son of California 49ers. Tombstone, isolated and subject to marauding Indians and outlaws in its early days, was affected by world events through their effect on silver prices. During the 38 year period from 1877 to 1915, when most of the ore was produced at Tombstone, declining silver prices, financial panics, and the removal of the United States currency from the silver standard, had immeasurably more effect on the mines than the Earp/Clanton feud, Apaches, bandits, or underground waters.

The district has generally been divided into the main (eastern) portion and the western portion - the State of Maine & Charleston sub-district.

In 1911, silver prices of $0.55 per ounce (less than half that in effect when Schieffelin discovered Tombstone) brought the demise of efforts to un-water the mines and the bankruptcy of the Development Corporation of America and its Tombstone Consolidated Mines subsidiary. The Phelps Dodge Corporation, a creditor, took over the mines and operated them in a desultory fashion from 1914 through 1933. The Pittman Act, supporting the price of silver at $1 per ounce between 1920 and 1923, stimulated some production in the main part of the district, primarily in the Bunker Hill mine, and small production in the western part. With the repeal of the Pittman Act in 1923, the price of silver plummeted (Fig. 18) and the mines closed.

The higher gold price instituted by Franklin Roosevelt in 1932 stimulated some development, particularly in exploration in the main part of the district. During World War II, there was some study of the manganese deposits in the district in relation to the war effort. Also during World War II, in late 1940, a controlling interest in the surviving Tombstone Development Company was acquired by the Newmont Mining Company. After holding the property until late 1950, Newmont's controlling interest was sold to the current owners, a group of investors from Grand Island, Nebraska, under the name Tombstone Development Company. Exploration work in late 1950 by the Eagle Picher Company in the northeastern part of the main district showed values in lead and zinc (Burton DeVere, Billiton Exploration, 1983, pers. comm.). In 1965, the Duval Corporation drilled several rotary holes in the main part of the district probing for porphyry-copper-type mineralization. Not much is known of the results of this exploration, though data is thought to be in the files of the Tombstone Development Company. In the period of 1972 to 1973, the American Smelting & Refining Company (ASARCO) obtained a lease on the Horne claims around the Robbers' Roost breccia pipe. They drilled three holes to a maximum depth of 1700m (5,000 ft) on a porphyry copper alteration zone in the vicinity of the breccia pipes. These holes intersected extensive but low-grade mineralization, grading vertically downward from a lead-zinc phase of mineralization into porphyry copper type mineralization, including disseminated pyrite, chalcopyrite, and molybdenite, as well as secondary K-feldspar and purple anhydrite. The Uncle Sam tuff was penetrated, intersecting Bisbee Formation, and at about 1700m, the Bisbee was penetrated and the drill entered the Naco Limestone. Poor copper prices at the time and since have discouraged further exploration for copper at this depth. It is noteworthy that scientific progress in this period led to the recognition that (1) the age of mineralization at Tombstone is of Laramide age, not mid-Tertiary, as had been surmised, and (2) the mineralization is of 'porphyry copper' affinity and therefore of large scale, not of epithermal style and local. Both realizations substantially enlarge exploration perspectives in the district.

In 1973, a limited Partnership headed by Hewlett, Stevenson, and Bishop optioned holdings in the western part of the district, and later the lands belonging to the Tombstone Development Company, Inc. In the spring of 1973, geologist James A. Briscoe was hired by Richard Hewlett to prepare a report on the State of Maine area. A topographic and geologic map of the State of Maine area was prepared at a scale of 1" = 200'. Previously unrecognized windows exposing sediments beneath the Uncle Sam tuff, as well as isoclinal folding in the sediments, were mapped. A comprehensive exploration program was planned and recommended. Also, in October of 1973, just before completion of the detailed report on the State of Maine area, the entire Tombstone District was flown in color aerial photography at a scale of 1" = 2,000' along north-south flight lines. The Partnership also consolidated all of the old mine dumps in the main district on Tombstone Development Company land into one large heap leach pad, which was operated until 1977, when the Tombstone Development Company lease was relinquished. None of the exploration program recommended to the Partnership by Briscoe was carried out.

At about the same time, Newell was completing a Stanford PhD dissertation covering the area. Newell's maps cover the district as far west as the San Pedro River and as far south as the Bronco Hills at a scale of 1:31,250 and 1:12,000 (Newell, 1974, Plates 1 & 2), and are the most detailed and complete geologic coverage to date. Newell also presented geochemical data from regional sampling of mine dumps (Figs. 3 through 17, and Newell, 1974, p. 13-23), which suggest that mineralization in the district is related to a series of porphyry copper centers.

In 1980, Tombstone Exploration, Inc. obtained a lease on patented Tombstone Development Company lands in the main part of the district. Between 1980 and 1985, Tombstone Exploration, Inc. operated an open pit mine on the Contention vein, and produced up to 3,000 tons per day of ore averaging in the range of 1.25 ounces silver and 0.02 ounces gold. Approximately 40% of the silver and 60% of the gold was recovered by cyanide leaching. Graves (1985) reports that 2 million ounces of silver and 10,000 ounces of gold were produced in the period from 1970 to 1985, mostly from the Tombstone Exploration, Inc. open pit operation, and in a small part by the Partnership mine dump consolidation. No exploration drilling was ever done, and no ore reserves of significance were measured ahead of mining. Lowered silver and gold prices, poor management, and a lack of reserves forced T.E.I. into bankruptcy in 1985, and its assets were liquidated.

A regional map covering southeastern Arizona, compiled by Harald Drewes of the United States Geological Survey, was published in 1980. In 1982, J. A. Briscoe and T. E. Waldrip, Jr. compiled data and maps from the work of Newell, Drewes, and others (Figs. 3 through 17). It was concluded from these various data that the volcanic geology and structure in the Tombstone area is related to a district-scale Laramide caldera. Mineralization in the district is also related to the caldera and attendant hydrothermal fluid migration.

Tombstone has primarily been a silver camp, although substantial gold and lead, and subordinate copper, zinc, and manganese have also been produced. The silver to gold ratio for documented production between 1877 and 1937 is 126 to 1. Production has come mainly from mineralized vein fractures cutting folded Lower Cretaceous limestones and basal conglomerate of the Bisbee group within the Tombstone Basin (main part of the district). Ninety-five percent or more of the production is from the surface to 200m, and is primarily from oxide ore minerals.

Unpublished figures and estimates compiled by Tenney from old company reports and other sources (Butler, p. 48), indicate that $28,400,000 was produced between 1879 and 1907. Unfortunately, this compilation is based only on value; it is assumed this production was primarily gold and silver. From 1908 through 1936, Briscoe has estimated that 1.25 million tons of ore was produced from the Tombstone district. Using this estimated tonnage and the recorded metal production, average grade for ore produced was 26 ounces silver, 0.21 ounces gold, 2.6% lead, and 0.10% copper, with smaller amounts of zinc and manganese. Not included in these figures are the substantial amounts produced between 1980 and 1985 by Tombstone Exploration, Inc. from its open pit mining operation along the Contention vein, nor from the dump leaching done by the Partnership between 1974 and 1977.

Total production at Tombstone, not including that of the Partnership or Tombstone Exploration, Inc., in terms of $400 gold and $10 silver, $.50 lead, $1.00 copper, and $.40 zinc, is approximately $463 million (Fig. 21). Over a quarter million ounces of gold (262,500) are included in that figure, and the viability of gold exploration in the district is heightened by the fact that gold was a geochemical accompaniment but secondary economic target through virtually the entire district production life.

TOPOGRAPHY, VEGETATION, CULTURE & ACCESS

The Tombstone Mining District (Fig. 1) is located in southeastern Arizona, 40 Km north of the international boundary with Mexico, and 100 Km southeast of Tucson (Figs. 1&2). It is in western Cochise County, and is on the Tombstone USGS 15-minute quadrangle, which is bounded by meridians 110^0 15 minutes, and 110^0, and parallels 31^0 30 minutes, and 31^0 45 minutes. These boundaries are shown on Figures 1 and 2, and Figures 3 through 17.

Tombstone is the only town in the quadrangle, but Sierra Vista, which services the Army Electronic Proving Ground at Ft. Huachuca, lies just west of the quadrangle 25 Km from Tombstone via the Charleston Road. Tombstone is well serviced by paved all-weather highways, including U.S. Highway 80, which goes through the center of town, and Arizona State Highways 82 and 90. Many mining supplies are available in Tombstone, and most types of supplies are available in Sierra Vista, with 30,000 inhabitants and the fastest growing city in Cochise County. Semi-skilled to skilled labor is available in Tombstone and Sierra Vista. The old mining camp of Bisbee lies about 50 Km southwest of Tombstone, where underground and open-pit copper mines, operated for about 100 years by Phelps Dodge, were shut down in 1982. The newly defined open pit chalcocite blanket ore body - the Cochise Mine - is scheduled for start-up in a year or so. A core work force of skilled underground miners is probably available in Bisbee. The second largest city in Arizona, Tucson, is

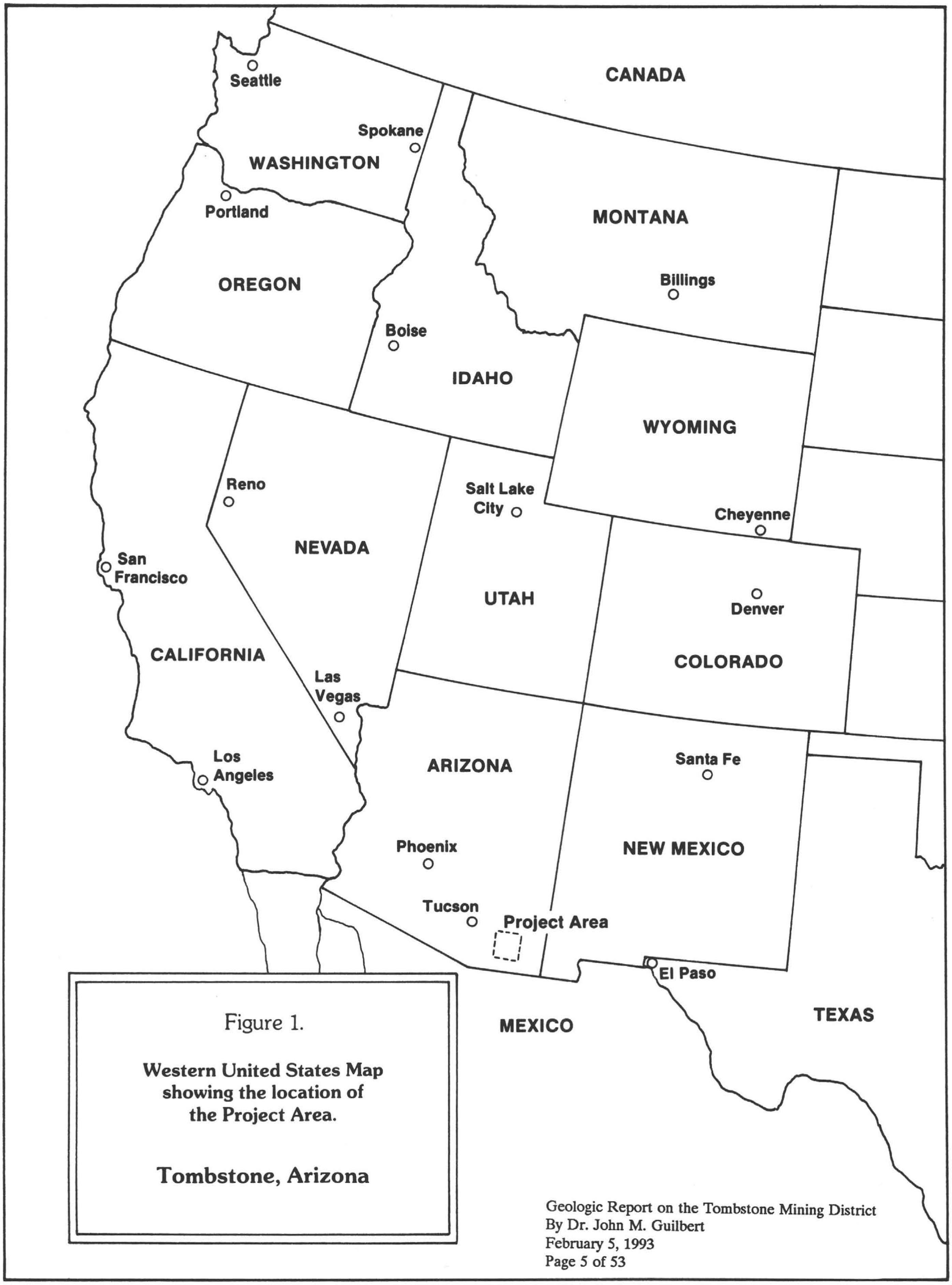


Figure 1.

Western United States Map showing the location of the Project Area.

Tombstone, Arizona

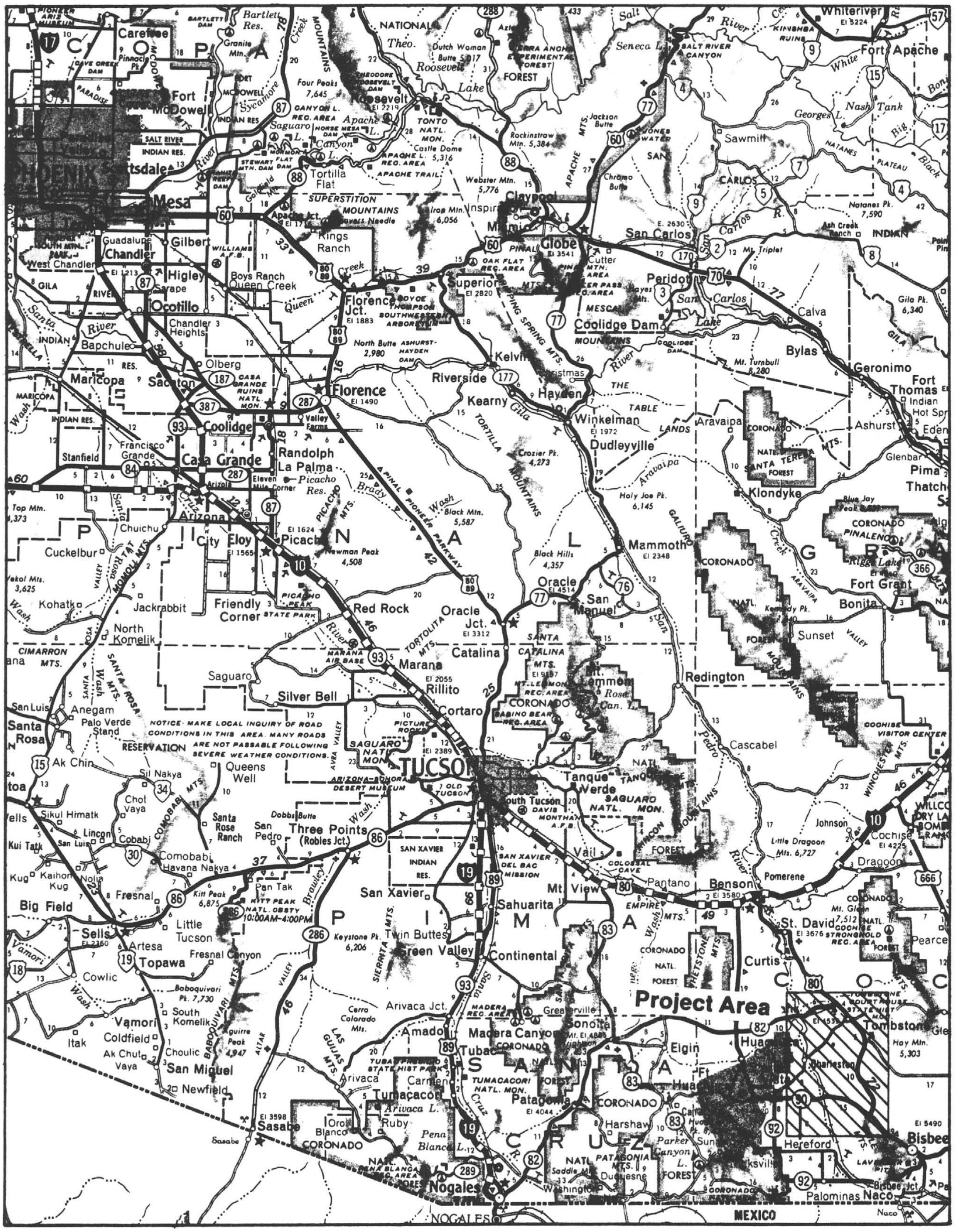


Figure 2. Highway map showing the location of the Project Area in relation to Tucson and Phoenix, Arizona

Explanation

Geology

Symbol	Description
QTgu	OLDER OR UNDIFFERENTIATED SURFICAL DEPOSITS (HOLOCENE TO OLIGOCENE):—Gravel, sand, and silt (Pleistocene and Pliocene—Mainly alluvium of basins; includes some colluvium and landslide deposits. Generally light-pinkish gray, weakly indurated, and with poorly rounded clasts; locally well indurated. Thickness several meters to hundreds of meters.
QTb	Basalt (Pleistocene to Pliocene)—Lava flows, pyroclastic rocks, and some intercalated gravel. Thickness several meters to a few hundred meters in most places. Radiometrically dated at 0.25, 1.0, and 3.2 m.y. old
Tva	Extensive andesite and dacite (Miocene and Upper Oligocene)—Lava flows, pyroclastic rocks, some intercalated epiclastic rocks, and dikes. Mostly gray, fine-grained, porphyritic rocks; includes some very coarse feldspar porphyry andesite (Turkey track porphyry, an informal term of Cooper, 1961). Thickness mostly several meters to several tens of meters. Dated at 24, 25, 27, 33, and 39 m.y.
Tv	Extrusive rhyolite and rhyodacite (Miocene and Upper Oligocene—Lava flows, welded tuff, pyroclastic rocks, and some intercalated epiclastic rocks. Light-gray to grayish-pink, vitric to fine-grained, porphyritic. Commonly a few tens to a few thousand of meters thick. Dated at 23, 24, 25, 26, 26, 26, and 27 m.y. An additional date of 47 m.y., if substantiated, may indicate the presence of Eocene rocks in the lower member of the S O Volcanics of Cochise Co.
Tlc	Lower conglomerate, gravel, and sand (Oligocene and Eocene?)—Alluvium; commonly grayish-red deposits of small, well rounded, nonvolcanic clasts. Mostly several meters to a few tens of meters thick.
Tlv	UPPER CORDILLERAN (LARAMIDE) IGNEOUS ROCKS (LOWER PALEOCENE):—Lower volcanic rocks—Rhyolite to andesite lava flows, pyroclastic rocks, and some intercalated epiclastic rocks. Dated at 57 m.y. Possibly younger age to east.
TKp	MAIN CORDILLERAN (LARAMIDE) IGNEOUS ROCKS:—Porphyritic and aplitic intrusive rocks (Paleocene and Upper Cretaceous)—Mostly latitic porphyry to dacitic porphyry in small stocks and plugs and aplitic bodies not associated with other granitoid stocks. Dated at 61, 63, 63, 64, and 65 m.y.
Kib	Fluidized intrusive breccia—exact age unknown, but penetrates, and thus younger than Uncle Sam porphyry.
Kr	Rhyodacite tuff and welded tuff.—Includes parts of Salero Formation, Sugarloaf Quartz Latite, and Bronco Volcanics, and all of Red Bay Rhyolite, Cat Mountain Rhyolite of Brown (1939) and Uncle Sam Prophyry. Includes local intrusive bodies and locally contains fragments of exotic rocks. Thickness commonly several tens of meters to several hundreds of meters. Dated at 66(?), 70, 72, 73, and 73 m.y. The Uncle Sam, in the Tombstone area, is dated 72 m.y.
Ka	Andesitic to dacitic volcanic breccia.—Includes parts of Solero Formation, Sugarloaf Quartz Latite, and Bronco Volcanics, and all of Demetrie Volcanics and Silverbell Formation of Courtright (1958). Commonly contains large blocks of exotic rocks and locally includes some sedimentary rocks and intrusive rocks. Several tens of meters to several hundreds of meters thick in most places.
Klq	Lower quartz monzonite and graodiorite—Includes some quartz diorite; appears in small stocks. Locally associated with mineralization. Dated at 70, 71, 72, 73, 74, 74, 74, and 76 m.y. The Schiefflin granodorite at Tombstone is 72 m.y.
Kb	BISBEE FORMATION OR GROUP, UNDIFFERENTIATED (LOWER CRETACEOUS):—Upper part of Bisbee Formation or Group, undifferentiated, and related rocks.—Includes upper part of Bisbee Formation, Mural Limestone, Morita, Cintura, Willow Canyon, Apache Canyon, Shellenberger Canyon and Turney Ranch Formations (not listed in stratigraphic sequence) of the Bisbee Group, Amole Arkose of Bryant and Kinnison (1954), and Angelic Arkose. Consists of brownish- to reddish-arkose, gray siltstone, sandstone, conglomerate, and some fossiliferous gray limestone. Commonly several hundred meters thick
Jg	GRANITE AND QUARTZ MONZONITE (JURASSIC)—Stocks of pinkish-gray coarse-grained rock. Locally associated with mineralization. Dated at 140, 148, 149, 149, 150, 153, 160, 161, 167, 178, 185 m.y.
PlPs	Sedimentary rocks (Lower Permian and Upper Pennsylvanian)—consists of Epitaph Dolomite (Lower Permian), Colina Limestone (Lower Permian), and Earp Formation (Lower Permian and Upper Pennsylvanian), undifferentiated. Epitaph Dolomite is a dark- to light-gray slightly cherty dolomite, limestone, marl, siltstone, and gypsum, 120-280 meters thick. Colina Limestone is a medium gray, thick-bedded, sparsely cherty, and sparsely fossiliferous limestone 120-280 meters thick. Earp Formation is a pale-red siltstone, mudstone, shale, and limestone, 120-240 meters thick.
IPh	Horquilla Limestone (Upper and Middle Pennsylvanian)—Light-pinkish-gray, thick- to thin-bedded, cherty, fossiliferous limestone and intercalated pale-brown to pale-reddish-gray siltstone that increases in abundance upward. Typically 300-490 meters thick.
MDs	SEDIMENTARY ROCKS (MISSISSIPPIAN AND DEVONIAN)—Consists mainly of Escabrosa Limestone (Mississippian)—locally (Armstrong and Silberman, 1974) called Escabrosa Group—and Martin Formation (Upper Devonian), undifferentiated. In part of the Chiricahua Mountains also includes Paradise Formation (Upper Mississippian) and Portal Formation of Sabins, 1957a (Upper Devonian). In the Little Dragoon Mountains and some adjacent hills also includes Black Prince Limestone, whose fauna and correlation show strongest affinities with Mississippian rocks but which may include some Pennsylvanian rocks. Escabrosa Limestone is a medium-gray, massive to thick-bedded, commonly crinoidal, cherty, fossiliferous limestone 90-310 meters thick. Martin Formation is thick- to thin-bedded, gray to brown dolomite, gray sparsely fossiliferous, and some siltstone and sandstone, 90-120 meters thick. Paradise Formation is a brown, fossiliferous, shaly limestone. Portal Formation is a black shale and limestone 6-105 meters thick. Black Prince Limestone is pinkish-gray limestone with a basal shale and chert conglomerate, as much as 52 meters thick.
OCs	SEDIMENTARY ROCKS (LOWER ORDOVICIAN TO MIDDLE CAMBRIAN):—El Paso Limestone (Lower Ordovician and Upper Cambrian), Abrigo Formation (Upper and Middle Cambrian), and Bolsa Quartz (Middle Cambrian), undifferentiated.—El Paso Limestone is a gray, thin-bedded cherty limestone and dolomite 90 meters to about 220 meters thick. Abrigo Formation is a brown, thin-bedded fossiliferous limestone, sandstone, quartzite, and shale, 210-240 meters thick. Bolsa Quartzite is a brown to white or purplish-gray, thick-bedded, coarse-grained quartzite and sandstone with a basal conglomerate, 90-180 meters thick. To the east, equivalents of part of the Abrigo Formation and Bolsa Quartzite are known as the Coronado Sandstone.
Cs	Sedimentary rocks (Upper and Middle Cambrian)—Abrigo Formation (Upper and Middle Cambrian), and Bolsa Quartzite (Middle Cambrian), undifferentiated.
Yg	GRANITOID ROCKS (PRECAMBRIAN Y):—Mainly granodiorite and quartz monsonite, unfoliated to foliated, in part metamorphosed. Generally in stocks, which ahve been little studied.
Xp	PINAL SCHIST (PRECAMBRIAN X)—Chlorite schist, phyllite, and some metavolcanic rocks, metavolcanic rocks, metaquartzite, metaquartzite conglomerate, and gneiss. One metavolcanic rock dated at 1715 m.y.

CONTACT—Dotted where concealed.

MARKER HORIZON—Dotted where concealed.

DIKES—Showing dip.

70 FAULTS—Showing dip. Dotted where concealed or intruded; ball and bar on downthrown side.

45 Normal

45 Reverse

Strike-slip—Arrow couple shows relative displacement. Single arrow shows movement of active block.

Major thrust fault—Sawteeth on upper plate.

Thrust fault—Sawteeth on upper plate.

Anticline.

Syncline.

30 Inclined strike and dip of beds.

EXOTIC-BLOCK BRECCIA—Rock contains chip or block inclusions of rock different from those of host or other blocks nearby. Typically of volcanic-tectonic or sedimentary-tectonic origin; excludes Tertiary megabreccia deposits.

(QTgu) 157 — Site of well or generalized site of several wells, showing unit penetrated, if known, and depth of well, in feet. 100 feet equals 30.5 meters.

72x — COLLECTION SITE—Radiogenically dated rock showing age in millions of years. Query before symbol where precise location uncertain.

Roads and Highways

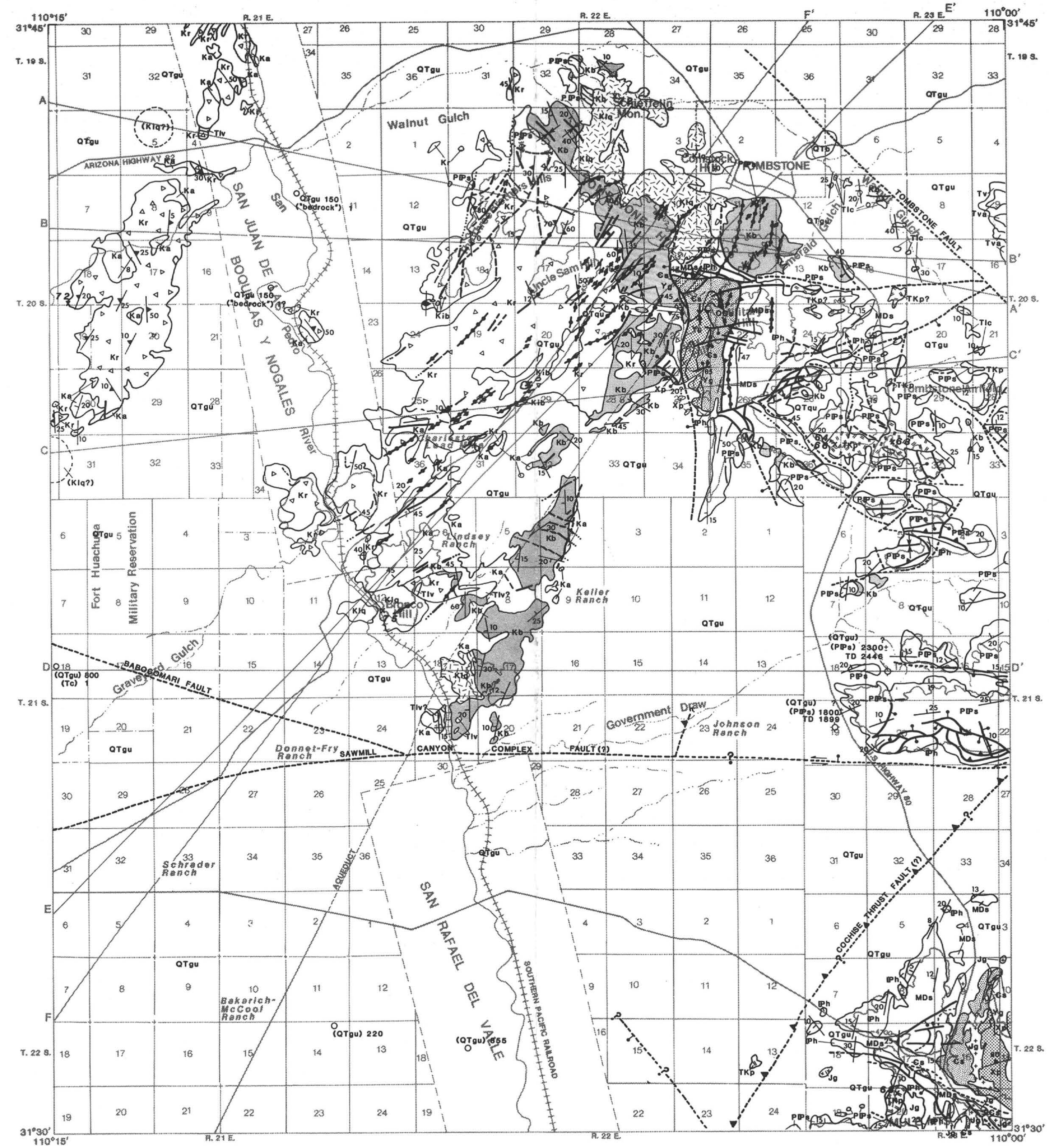
Dry wash

Southern Pacific Railroad

Government Reservation Boundary

Aqueduct

A——A' Cross section line



Tombstone Development Company, Inc.
Tombstone, Arizona

Geology adopted from Drewes, Harold, 1980, and Newell, R.A., 1973.

Figure 3. Generalized geological and structural map on screened topographic base.

By James A. Briscoe
James A. Briscoe and Associates
Tucson, Arizona

Explanation

Land Status

Public Domain - Mineral and Surface owned by Federal Government.

State Domain - Mineral and Surface owned by State of Arizona.

Public Domain Mineral and Surface. Mineral owned by Federal Government; Surface owned by State of Arizona.

Fee Simple - Mineral and Surface privately owned.

Fee Simple Surface and Public Domain Mineral Private Surface ownership Mineral owned by Federal Government.

Spanish Land Grants - Fee Simple. Mineral and Surface privately owned; Reservation of Gold, Silver and Mercury to Federal Government.

Military Reservation - Restricted Mineral Entry. Not open to Mining.

Water & Power Resource Service & Various other Withdrawals - Not open to Mineral Entry or Mining.

Mineral and Surface owned by Federal Government. Mineral Rights privately claimed.

Mineral and Surface owned by State of Arizona. Mineral leases, prospecting permits or applications privately held.

Public Domain Mineral and State of Arizona Surface. Mineral rights privately claimed.

Public Domain Mineral and Fee Simple Surface. Mineral rights privately claimed.

Roads and Highways

Dry wash

Southern Pacific Railroad

Government Reservation Boundary

Aqueduct

A——A′ Cross section line

Tombstone Development Company, Inc. Lands

Public Domain Mineral and Surface. Mineral rights claimed by Tombstone Development Company, Inc.

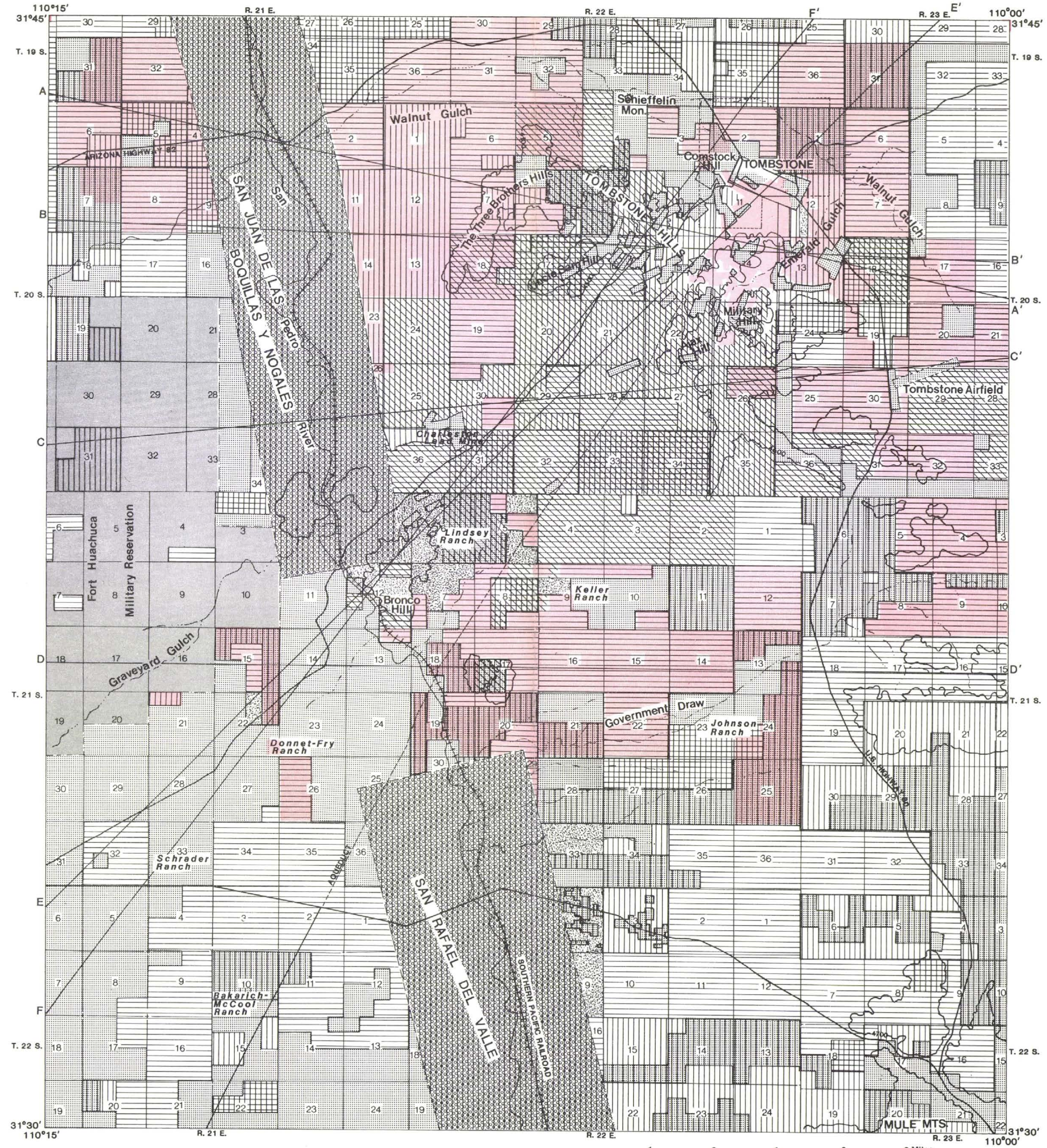
Mineral and Surface owned by State of Arizona. Prospecting permits or applications held by Tombstone Development Company.

Public Domain Mineral and Surface owned by State of Arizona. Mineral rights claimed by Tombstone Development Company, Inc.

Patented Mining Claims owned by Tombstone Development Company, Inc.

Public Domain Mineral and Fee Simple Surface. Mineral rights claimed by Tombstone Development Company, Inc.

Fee Simple Surface and State of Arizona Mineral. Prospecting Permit held by Tombstone Development Company, Inc.



Tombstone Development Company, Inc.

Tombstone, Arizona

Land Status Map, Tombstone
15 min. Quadrangle

By Thomas E. Waldrip, Jr.
James A. Briscoe and Associates
Tucson, Arizona

Figure 5. Property map showing ownership of major holdings of mineral rights in the Tombstone area. Red overprint shows state, federal and private land and lands with mineral rights held by the Tombstone Development Company as of October 15, 1981.

Explanation

Geology

QTgu — OLDER OR UNDIFFERENTIATED SURFICAL DEPOSITS (HOLOCENE TO OLIGOCENE):—Gravel, sand, and silt (Pleistocene and Pliocene—Mainly alluvium of basins; includes some colluvium and landslide deposits. Generally light-pinkish gray, weakly indurated, and with poorly rounded clasts; locally well indurated. Thickness several meters to hundreds of meters.

QTb — Basalt (Pleistocene to Pliocene)—Lava flows, pyroclastic rocks, and some intercalated gravel. Thickness several meters to a few hundred meters in most places. Radiometrically dated at 0.25, 1.0, and 3.2 m.y. old

Tva — Extensive andesite and dacite (Miocene and Upper Oligocene)—Lava flows, pyroclastic rocks, some intercalated epiclastic rocks, and dikes. Mostly gray, fine-grained, porphyritic rocks; includes some very coarse feldspar porphyry andesite (Turkey track porphyry, an informal term of Cooper, 1961). Thickness mostly several meters to several tens of meters. Dated at 24, 25, 27, 33, and 39 m.y.

Tv — Extrusive rhyolite and rhyodacite (Miocene and Upper Oligocene—Lava flows, welded tuff, pyroclastic rocks, and some intercalated epiclastic rocks. Light-gray to grayish-pink, vitric to fine-grained, porphyritic. Commonly a few tens to a few thousand of meters thick. Dated at 23, 24, 25, 26, 26, 26, and 27 m.y. An additional date of 47 m.y., if substantiated, may indicate the presence of Eocene rocks in the lower member of the S O Volcanics of Cochise Co.

Tlc — Lower conglomerate, gravel, and sand (Oligocene and Eocene?)—Alluvium; commonly grayish-red deposits of small, well rounded, nonvolcanic clasts. Mostly several meters to a few tens of meters thick.

Tlv — UPPER CORDILLERAN (LARAMIDE) IGNEOUS ROCKS (LOWER PALEOCENE):—Lower volcanic rocks—Rhyolite to andesite lava flows, pyroclastic rocks, and some intercalated epiclastic rocks. Dated at 57 m.y. Possibly younger age to east.

TKd — MAIN CORDILLERAN (LARAMIDE) IGNEOUS ROCKS:—Porphyritic and aplitic intrusive rocks (Paleocene and Upper Cretaceous)—Mostly latitic porphyry to dacitic porphyry in small stocks and plugs and aplitic bodies not associated with other granitoid stocks. Dated at 61, 63, 63, 64, and 65 m.y.

Kib — Fluidized intrusive breccia - exact age unknown, but penetrates, and thus younger than Uncle Sam porphyry.

Kr — Rhyodacite tuff and welded tuff. —Includes parts of Salero Formation, Sugarloaf Quartz Latite, and Bronco Volcanics, and all of Red Bay Rhyolite, Cat Mountain Rhyolite of Brown (1939) and Uncle Sam Prophyry. Includes local intrusive bodies and locally contains fragments of exotic rocks. Thickness commonly several tens of meters to several hundreds of meters. Dated at 66(?), 70, 72, 73, and 73 m.y. The Uncle Sam, in the Tombstone area, is dated 72 m.y.

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Klg — Lower quartz monzonite and graodiorite—Includes some quartz diorite; appears in small stocks. Locally associated with mineralization. Dated at 70, 71, 72, 73, 74, 74, 74, and 76 m.y. The Schiefflin granodorite at Tombstone is 72 m.y.

Kb — BISBEE FORMATION OR GROUP, UNDIFFERENTIATED (LOWER CRETACEOUS):—Upper part of Bisbee Formation or Group, undifferentiated, and related rocks.—Includes upper part of Bisbee Formation, Mural Limestone, Morita, Cintura, Willow Canyon, Apache Canyon, Shellenberger Canyon and Turney Ranch Formations (not listed in stratigraphic sequence) of the Bisbee Group, Amole Arkose of Bryant and Kinnison (1954), and Angelic Arkose. Consists of brownish- to reddish-arkose, gray siltstone, sandstone, conglomerate, and some fossiliferous gray limestone. Commonly several hundred meters thick

Jg — GRANITE AND QUARTZ MONZONITE (JURASSIC)—Stocks of pinkish-gray coarse-grained rock. Locally associated with mineralization. Dated at 140, 148, 149, 149, 150, 153, 160, 161, 167, 178, 185 m.y.

PIPs — Sedimentary rocks (Lower Permian and Upper Pennsylvanian)—consists of Epitaph Dolomite (Lower Permian), Colina Limestone (Lower Permian), and Earp Formation (Lower Permian and Upper Pennsylvanian), undifferentiated. Epitaph Dolomite is a dark- to light-gray slightly cherty dolomite, limestone, marl, siltstone, and gypsum, 120-280 meters thick. Colina Limestone is a medium gray, thick-bedded, sparsely cherty, and sparsely fossiliferous limestone 120-280 meters thick. Earp Formation is a pale-red siltstone, mudstone, shale, and limestone, 120-240 meters thick.

IPh — Horquilla Limestone (Upper and Middle Pennsylvanian)—Light-pinkish-gray, thick- to thin-bedded, cherty, fossiliferous limestone and intercalated pale-brown to pale-reddish-gray siltstone that increases in abundance upward. Typically 300-490 meters thick.

MDs — SEDIMENTARY ROCKS (MISSISSIPPIAN AND DEVONIAN)—Consists mainly of Escabrosa Limestone (Mississippian)—locally (Armstrong and Silberman, 1974) called Escabrosa Group—and Martin Formation (Upper Devonian), undifferentiated. In part of the Chiricahua Mountains also includes Paradise Formation (Upper Mississippian) and Portal Formation of Sabins, 1957a (Upper Devonian). In the Little Dragoon Mountains and some adjacent hills also includes Black Prince Limestone, whose fauna and correlation show strongest affinities with Mississippian rocks but which may include some Pennsylvanian rocks. Escabrosa Limestone is a medium-gray, massive to thick-bedded, commonly crinoidal, cherty, fossiliferous limestone 90-310 meters thick. Martin Formation is thick- to thin-bedded, gray to brown dolomite, gray sparsely fossiliferous, and some siltstone and sandstone, 90-120 meters thick. Paradise Formation is a brown, fossiliferous, shaly limestone. Portal Formation is a black shale and limestone 6-105 meters thick. Black Prince Limestone is pinkish-gray limestone with a basal shale and chert conglomerate, as much as 52 meters thick.

OCs — SEDIMENTARY ROCKS (LOWER ORDOVICIAN TO MIDDLE CAMBRIAN):—El Paso Limestone (Lower Ordovician and Upper Cambrian), Abrigo Formation (Upper and Middle Cambrian), and Bolsa Quartz (Middle Cambrian), undifferentiated.—El Paso Limestone is a gray, thin-bedded cherty limestone and dolomite 90 meters to about 220 meters thick. Abrigo Formation is a brown, thin-bedded fossiliferous limestone, sandstone, quartzite, and shale, 210-240 meters thick. Bolsa Quartzite is a brown to white or purplish-gray, thick-bedded, coarse-grained quartzite and sandstone with a basal conglomerate, 90-180 meters thick. To the east, equivalents of part of the Abrigo Formation and Bolsa Quartzite are known as the Coronado Sandstone.

Cs — Sedimentary rocks (Upper and Middle Cambrian)—Abrigo Formation (Upper and Middle Cambrian), and Bolsa Quartzite (Middle Cambrian), undifferentiated

Yg — GRANITOID ROCKS (PRECAMBRIAN Y):—Mainly granodiorite and quartz monzonite, unfoliated to foliated, in part metamorphosed. Generally in stocks, which ahve been little studied.

Xp — PINAL SCHIST (PRECAMBRIAN X)—Chlorite schist, phyllite, and some metavolcanic rocks, metavolcanic rocks, metaquartzite, metaquartzite conglomerate, and gneiss. One metavolcanic rock dated at 1715 m.y.

CONTACT—Dotted where concealed.

MARKER HORIZON—Dotted where concealed.

DIKES—Showing dip.

FAULTS—Showing dip. Dotted where concealed or intruded; ball and bar on downthrown side.

Normal

Reverse

Strike-slip—Arrow couple shows relative displacement. Single arrow shows movement of active block.

Major thrust fault—Sawteeth on upper plate.

Thrust fault—Sawteeth on upper plate.

Anticline.

Syncline.

Inclined strike and dip of beds.

EXOTIC BLOCK BRECCIA—Rock contains chip or block inclusions of rock different from those of host or other blocks nearby. Typically of volcanic tectonic or sedimentary-tectonic origin; excludes Tertiary megabreccia deposits.

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Roads and Highways

Dry wash

Southern Pacific Railroad

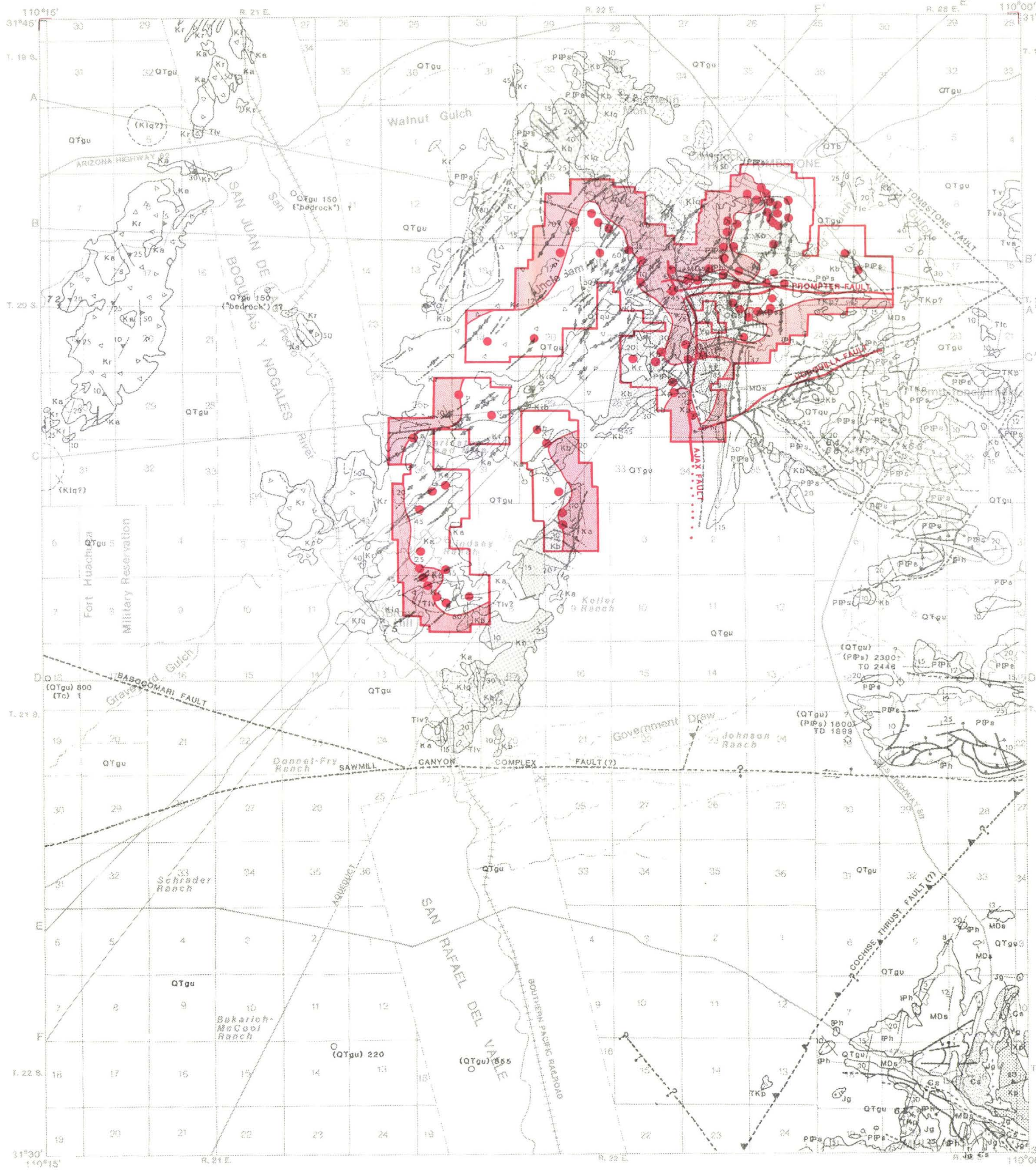
Government Reservation Boundary

Aqueduct

A——A' Cross section line

Dump sample location

Silver



Tombstone Development Company, Inc.
Tombstone, Arizona

Geology adopted from Drewes, Harold, 1980, and Newell, R.A., 1973.

By James A. Briscoe
James A. Briscoe and Associates
Tucson, Arizona

1 0 1 2 3 Miles

N

Figure 6. Dump sample location map showing area of influence boundaries and the Ajax, Prompter, and Horquilla faults, from Newell, R.A., 1973.

Distribution pattern for high silver ratios in dump samples (in red).

Explanation

Geology

QTgu — OLDER OR UNDIFFERENTIATED SURFICAL DEPOSITS (HOLOCENE TO OLIGOCENE):—Gravel, sand, and silt (Pleistocene and Pliocene—Mainly alluvium of basins; includes some colluvium and landslide deposits. Generally light-pinkish gray, weakly indurated, and with poorly rounded clasts; locally well indurated. Thickness several meters to hundreds of meters.

QTb — Basalt (Pleistocene to Pliocene)—Lava flows, pyroclastic rocks, and some intercalated gravel. Thickness several meters to a few hundred meters in most places. Radiometrically dated at 0.25, 1.0, and 3.2 m.y. old

Tva — Extensive andesite and dacite (Miocene and Upper Oligocene)—Lava flows, pyroclastic rocks, some intercalated epiclastic rocks, and dikes. Mostly gray, fine-grained, porphyritic rocks; includes some very coarse feldspar porphyry andesite (Turkey track porphyry, an informal term of Cooper, 1961). Thickness mostly several meters to several tens of meters. Dated at 24, 25, 27, 33, and 39 m.y.

Tv — Extrusive rhyolite and rhyodacite (Miocene and Upper Oligocene—Lava flows, welded tuff, pyroclastic rocks, and some intercalated epiclastic rocks. Light-gray to grayish-pink, vitric to fine-grained, porphyritic. Commonly a few tens to a few thousand of meters thick. Dated at 23, 24, 25, 26, 26, 26, and 27 m.y. An additional date of 47 m.y., if substantiated, may indicate the presence of Eocene rocks in the lower member of the S O Volcanics of Cochise Co.

Tlc — Lower conglomerate, gravel, and sand (Oligocene and Eocene?)—Alluvium; commonly grayish-red deposits of small, well rounded, nonvolcanic clasts. Mostly several meters to a few tens of meters thick.

Tlv — UPPER CORDILLERAN (LARAMIDE) IGNEOUS ROCKS (LOWER PALEOCENE):—Lower volcanic rocks—Rhyolite to andesite lava flows, pyroclastic rocks, and some intercalated epiclastic rocks. Dated at 57 m.y. Possibly younger age to east.

TKp — MAIN CORDILLERAN (LARAMIDE) IGNEOUS ROCKS:—Porphyritic and aplitic intrusive rocks (Paleocene and Upper Cretaceous)—Mostly latitic porphyry to dacitic porphyry in small stocks and plugs and aplitic bodies not associated with other granitoid stocks. Dated at 61, 63, 63, 64, and 65 m.y.

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MARKER HORIZON—Dotted where concealed.

DIKES—Showing dip.

70 — FAULTS—Showing dip. Dotted where concealed or intruded; ball and bar on downthrown side.

45 — Normal

45 — Reverse

Strike-slip—Arrow couple shows relative displacement. Single arrow shows movement of active block.

Major thrust fault—Sawteeth on upper plate.

Thrust fault—Sawteeth on upper plate.

Anticline.

Syncline.

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Roads and Highways

Dry wash

Southern Pacific Railroad

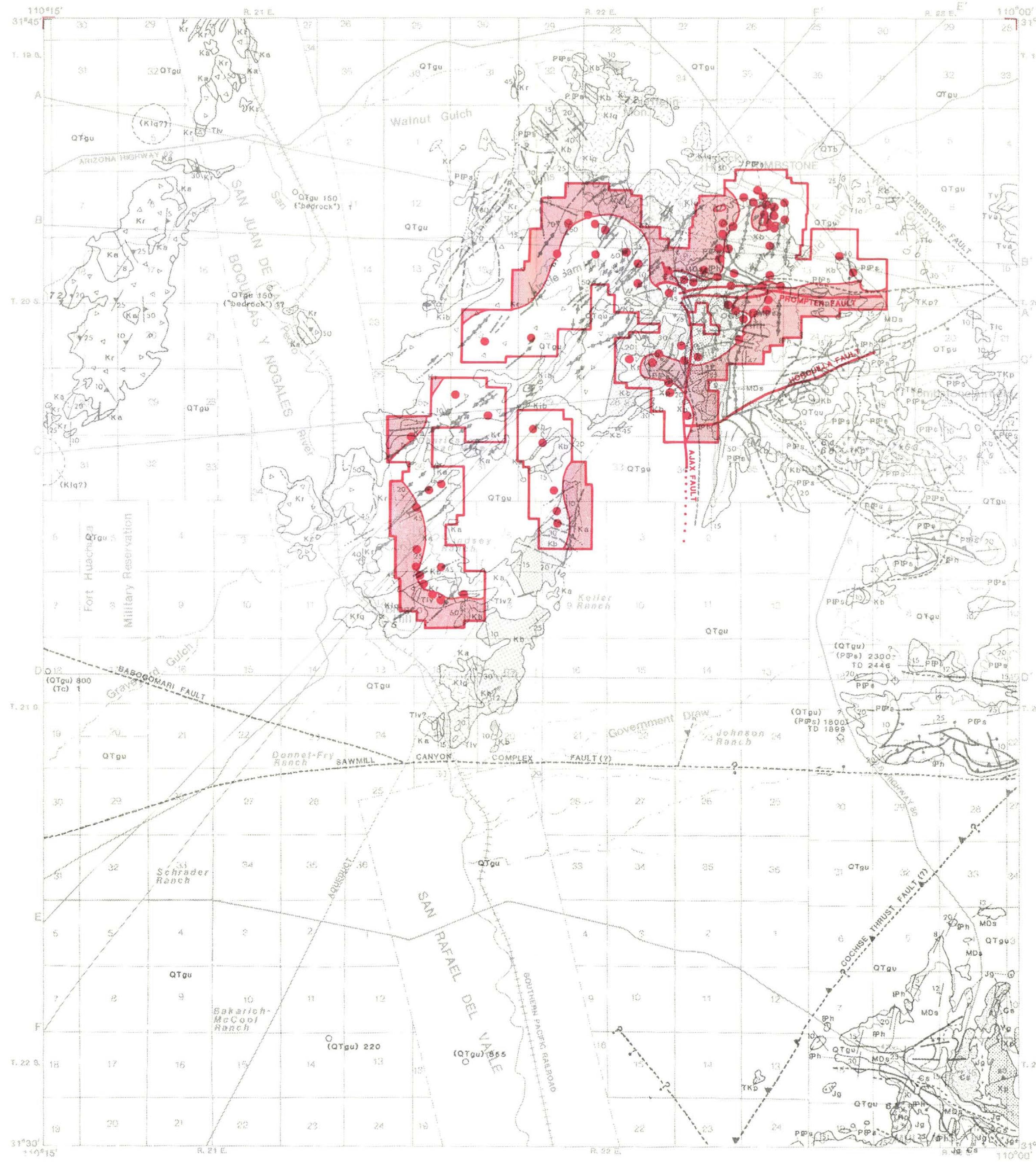
Government Reservation Boundary

Aqueduct

A—A' Cross section line

Dump sample location

Zinc



0 1 2 3 Miles

N

Tombstone Development Company, Inc.
Tombstone, Arizona

Geology adopted from Drewes, Harold, 1980, and Newell, R.A., 1973.

Figure 7. Dump sample location map showing area of influence boundaries and the Ajax, Prompter, and Horquilla faults, from Newell, R.A., 1973.

Distribution pattern for high zinc ratio in dump samples (in red).

By James A. Briscoe
James A. Briscoe and Associates
Tucson, Arizona

Explanation

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Roads and Highways

Dry wash

Southern Pacific Railroad

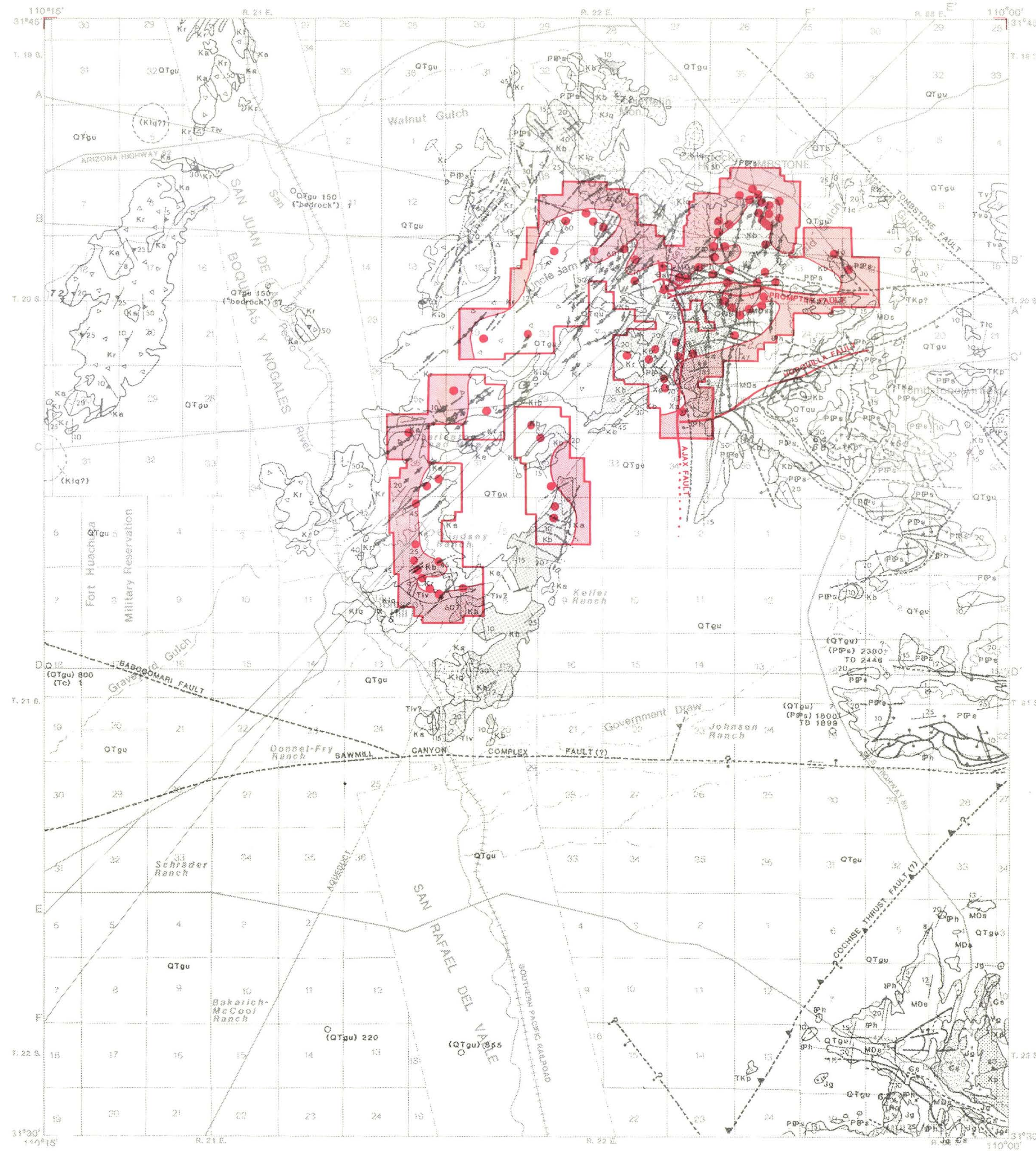
Government Reservation Boundary

Aqueduct

A—A' Cross section line

Dump sample location

Lead



Tombstone Development Company, Inc.
Tombstone, Arizona

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Kr — Rhyodacite tuff and welded tuff. —Includes parts of Salero Formation, Sugarloaf Quartz Latite, and Bronco Volcanics, and all of Red Bay Rhyolite, Cat Mountain Rhyolite of Brown (1939) and Uncle Sam Prophyry. Includes local intrusive bodies and locally contains fragments of exotic rocks. Thickness commonly several tens of meters to several hundreds of meters. Dated at 66(?), 70, 72, 73, and 73 m.y. The Uncle Sam, in the Tombstone area, is dated 72 m.y.

Ka — Andesitic to dacitic volcanic breccia.—Includes parts of Solero Formation, Sugarloaf Quartz Latite, and Bronco Volcanics, and all of Demetrie Volcanics and Silverbell Formation of Courtright (1958). Commonly contains large blocks of exotic rocks and locally includes some sedimentary rocks and intrusive rocks. Several tens of meters to several hundreds of meters thick in most places.

Klq — Lower quartz monzonite and graodiorite—Includes some quartz diorite; appears in small stocks. Locally associated with mineralization. Dated at 70, 71, 72, 73, 74, 74, 74, and 76 m.y. The Schiefflin granodorite at Tombstone is 72 m.y.

Kb — BISBEE FORMATION OR GROUP, UNDIFFERENTIATED (LOWER CRETACEOUS):—Upper part of Bisbee Formation or Group, undifferentiated, and related rocks.—Includes upper part of Bisbee Formation, Mural Limestone, Morita, Cintura, Willow Canyon, Apache Canyon, Shellenberger Canyon and Turney Ranch Formations (not listed in stratigraphic sequence) of the Bisbee Group, Amole Arkose of Bryant and Kinnison (1954), and Angelic Arkose. Consists of brownish- to reddish-arkose, gray siltstone, sandstone, conglomerate, and some fossiliferous gray limestone. Commonly several hundred meters thick

Jg — GRANITE AND QUARTZ MONZONITE (JURASSIC)—Stocks of pinkish-gray coarse-grained rock. Locally associated with mineralization. Dated at 140, 148, 149, 149, 150, 153, 160, 161, 167, 178, 185 m.y.

PIPs — Sedimentary rocks (Lower Permian and Upper Pennsylvanian)—consists of Epitaph Dolomite (Lower Permian), Colina Limestone (Lower Permian), and Earp Formation (Lower Permian and Upper Pennsylvanian), undifferentiated. Epitaph Dolomite is a dark- to light-gray slightly cherty dolomite, limestone, marl, siltstone, and gypsum, 120-280 meters thick. Colina Limestone is a medium gray, thick-bedded, sparsely cherty, and sparsely fossiliferous limestone 120-280 meters thick. Earp Formation is a pale-red siltstone, mudstone, shale, and limestone, 120-240 meters thick.

IPh — Horquilla Limestone (Upper and Middle Pennsylvanian)—Light-pinkish-gray, thick- to thin-bedded, cherty, fossiliferous limestone and intercalated pale-brown to pale-reddish-gray siltstone that increases in abundance upward. Typically 300-490 meters thick.

MDs — SEDIMENTARY ROCKS (MISSISSIPPIAN AND DEVONIAN)—Consists mainly of Escabrosa Limestone (Mississippian)—locally (Armstrong and Silberman, 1974) called Escabrosa Group—and Martin Formation (Upper Devonian), undifferentiated. In part of the Chiricahua Mountains also includes Paradise Formation (Upper Mississippian) and Portal Formation of Sabins, 1957a (Upper Devonian). In the Little Dragoon Mountains and some adjacent hills also includes Black Prince Limestone, whose fauna and correlation show strongest affinities with Mississippian rocks but which may include some Pennsylvanian rocks. Escabrosa Limestone is a medium-gray, massive to thick-bedded, commonly crinoidal, cherty, fossiliferous limestone 90-310 meters thick. Martin Formation is thick- to thin-bedded, gray to brown dolomite, gray sparsely fossiliferous, and some siltstone and sandstone, 90-120 meters thick. Paradise Formation is a brown, fossiliferous, shaly limestone. Portal Formation is a black shale and limestone 6-105 meters thick. Black Prince Limestone is pinkish-gray limestone with a basal shale and chert conglomerate, as much as 52 meters thick.

O€s — SEDIMENTARY ROCKS (LOWER ORDOVICIAN TO MIDDLE CAMBRIAN):—El Paso Limestone (Lower Ordovician and Upper Cambrian), Abrigo Formation (Upper and Middle Cambrian), and Bolsa Quartz (Middle Cambrian), undifferentiated.—El Paso Limestone is a gray, thin-bedded cherty limestone and dolomite 90 meters to about 220 meters thick. Abrigo Formation is a brown, thin-bedded fossiliferous limestone, sandstone, quartzite, and shale, 210-240 meters thick. Bolsa Quartzite is a brown to white or purplish-gray, thick-bedded, coarse-grained quartzite and sandstone with a basal conglomerate, 90-180 meters thick. To the east, equivalents of part of the Abrigo Formation and Bolsa Quartzite are known as the Coronado Sandstone.

€s — Sedimentary rocks (Upper and Middle Cambrian)—Abrigo Formation (Upper and Middle Cambrian), and Bolsa Quartzite (Middle Cambrian), undifferentiated.

Yg — GRANITOID ROCKS (PRECAMBRIAN Y):—Mainly granodiorite and quartz monsonite, unfoliated to foliated, in part metamorphosed. Generally in stocks, which ahve been little studied.

Xp — PINAL SCHIST (PRECAMBRIAN X)—Chlorite schist, phyllite, and some metavolcanic rocks, metavolcanic rocks, metaquartzite, metaquartzite conglomerate, and gneiss. One metavolcanic rock dated at 1715 m.y.

CONTACT—Dotted where concealed.

MARKER HORIZON—Dotted where concealed.

DIKES—Showing dip.

FAULTS—Showing dip. Dotted where concealed or intruded; ball and bar on downthrown side. (70)

Normal (45)

Reverse (45)

Strike-slip—Arrow couple shows relative displacement. Single arrow shows movement of active block.

Major thrust fault—Sawteeth on upper plate.

Thrust fault—Sawteeth on upper plate.

Anticline.

Syncline.

30 — Inclined strike and dip of beds.

EXOTIC-BLOCK BRECCIA—Rock contains chip or block inclusions of rock different from those of host or other blocks nearby. Typically of volcanic-tectonic or sedimentary-tectonic origin; excludes Tertiary megabreccia deposits.

(QTgu) 157 — Site of well or generalized site of several wells, showing unit penetrated, if known, and depth of well, in feet. 100 feet equals 30.5 meters.

72x — COLLECTION SITE—Radiogenically dated rock showing age in millions of years. Query before symbol where precise location uncertain.

Roads and Highways

Dry wash

Southern Pacific Railroad

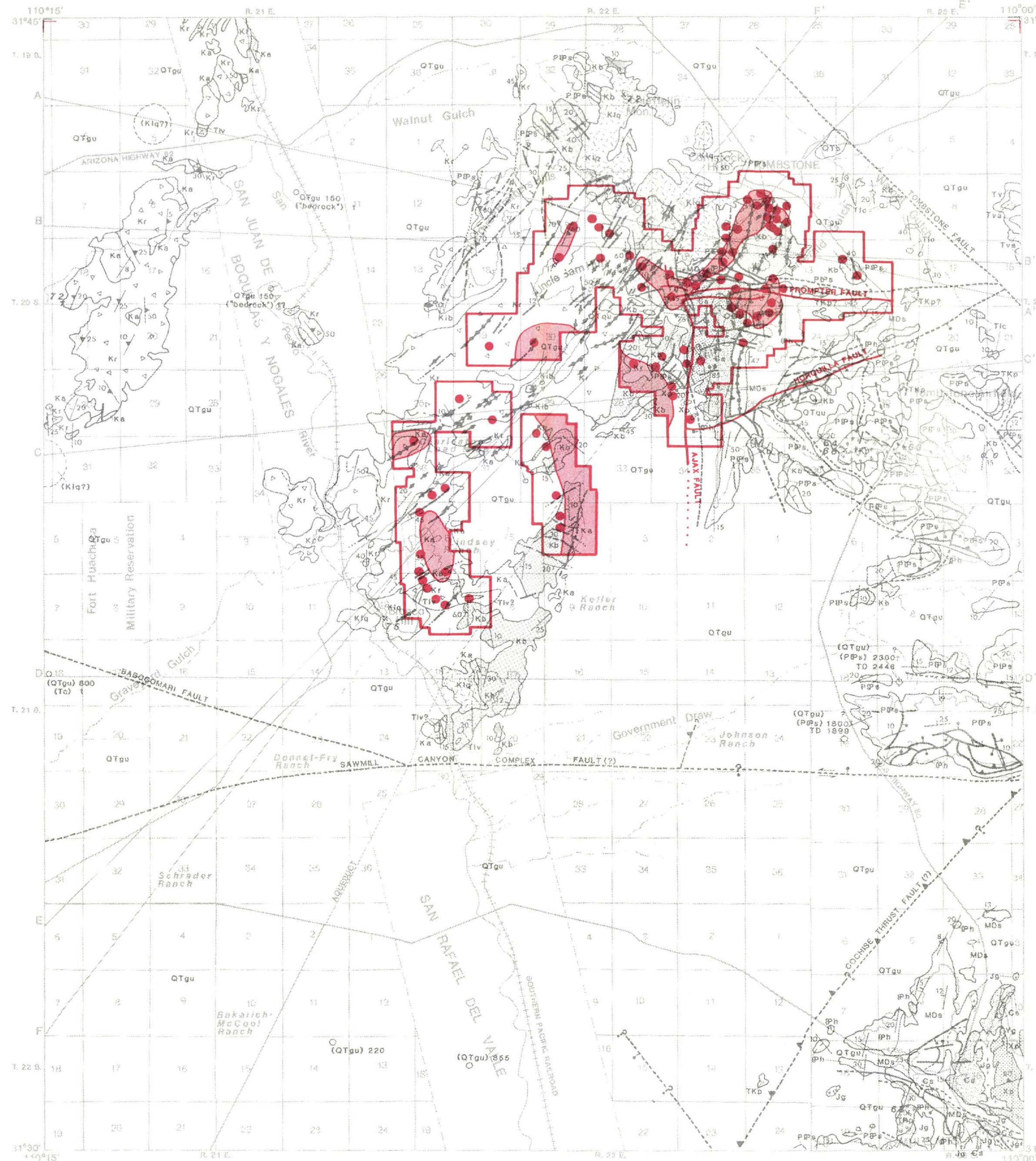
Government Reservation Boundary

Aqueduct

A—A' Cross section line

Dump sample location

Copper



Tombstone Development Company, Inc.
Tombstone, Arizona

1 0 1 2 3 Miles

N

Geology adopted from Drewes, Harold, 1980, and Newell, R.A., 1973.

By James A. Briscoe
James A. Briscoe and Associates
Tucson, Arizona

Figure 9. Dump sample location map showing area of influence boundaries and the Ajax, Prompter, and Horquilla faults, from Newell, R.A., 1973.

Distribution pattern for high copper ratios in dump samples (in red).

Explanation

Geology

QTgu — OLDER OR UNDIFFERENTIATED SURFICAL DEPOSITS (HOLOCENE TO OLIGOCENE):—Gravel, sand, and silt (Pleistocene and Pliocene—Mainly alluvium of basins; includes some colluvium and landslide deposits. Generally light-pinkish gray, weakly indurated, and with poorly rounded clasts; locally well indurated. Thickness several meters to hundreds of meters.

QTb — Basalt (Pleistocene to Pliocene)—Lava flows, pyroclastic rocks, and some intercalated gravel. Thickness several meters to a few hundred meters in most places. Radiometrically dated at 0.25, 1.0, and 3.2 m.y. old

Tva — Extensive andesite and dacite (Miocene and Upper Oligocene)—Lava flows, pyroclastic rocks, some intercalated epiclastic rocks, and dikes. Mostly gray, fine-grained, porphyritic rocks; includes some very coarse feldspar porphyry andesite (Turkey track porphyry, an informal term of Cooper, 1961). Thickness mostly several meters to several tens of meters. Dated at 24, 25, 27, 33, and 39 m.y.

Tv — Extrusive rhyolite and rhyodacite (Miocene and Upper Oligocene—Lava flows, welded tuff, pyroclastic rocks, and some intercalated epiclastic rocks. Light-gray to grayish-pink, vitric to fine-grained, porphyritic. Commonly a few tens to a few thousand of meters thick. Dated at 23, 24, 25, 26, 26, 26, and 27 m.y. An additional date of 47 m.y., if substantiated, may indicate the presence of Eocene rocks in the lower member of the S O Volcanics of Cochise Co.

Tlc — Lower conglomerate, gravel, and sand (Oligocene and Eocene?)—Alluvium; commonly grayish-red deposits of small, well rounded, nonvolcanic clasts. Mostly several meters to a few tens of meters thick.

Tlv — UPPER CORDILLERAN (LARAMIDE) IGNEOUS ROCKS (LOWER PALEOCENE):—Lower volcanic rocks—Rhyolite to andesite lava flows, pyroclastic rocks, and some intercalated epiclastic rocks. Dated at 57 m.y. Possibly younger age to east.

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- Reverse (45)
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Anticline.

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Roads and Highways

Dry wash

Southern Pacific Railroad

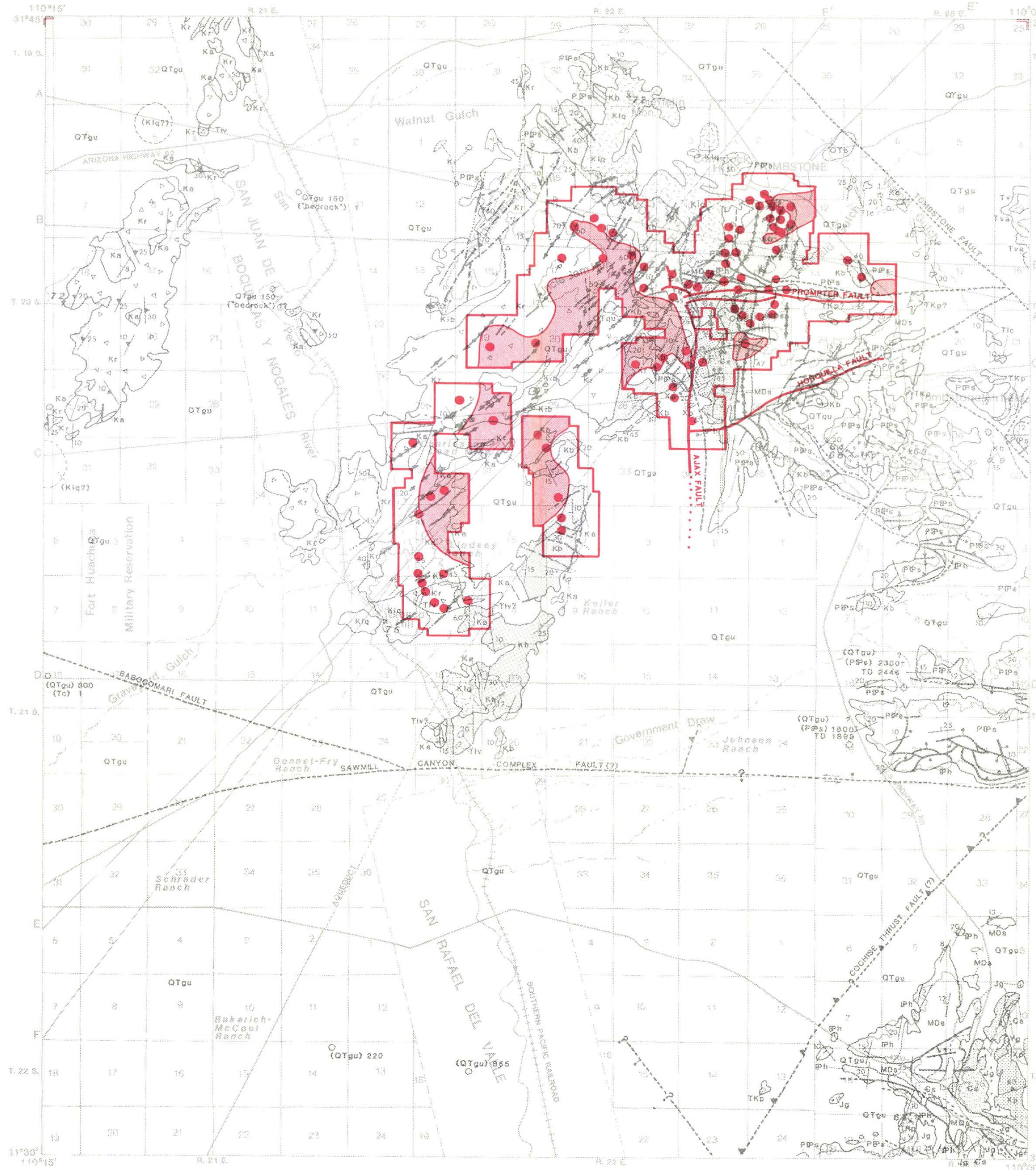
Government Reservation Boundary

Aqueduct

A——A' Cross section line

● Dump sample location

Molybdenum



Tombstone Development Company, Inc.
Tombstone, Arizona

Geology adopted from Drewes, Harold, 1980, and Newell, R.A., 1973.

By James A. Briscoe
James A. Briscoe and Associates
Tucson, Arizona

Figure 10. Dump sample location map showing area of influence boundaries and the Ajax, Prompter, and Horquilla faults, from Newell, R.A., 1973.

Distribution pattern for high molybdenum ratios in dump samples (in red).

Explanation

Geology

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Roads and Highways

Dry wash

Southern Pacific Railroad

Government Reservation Boundary

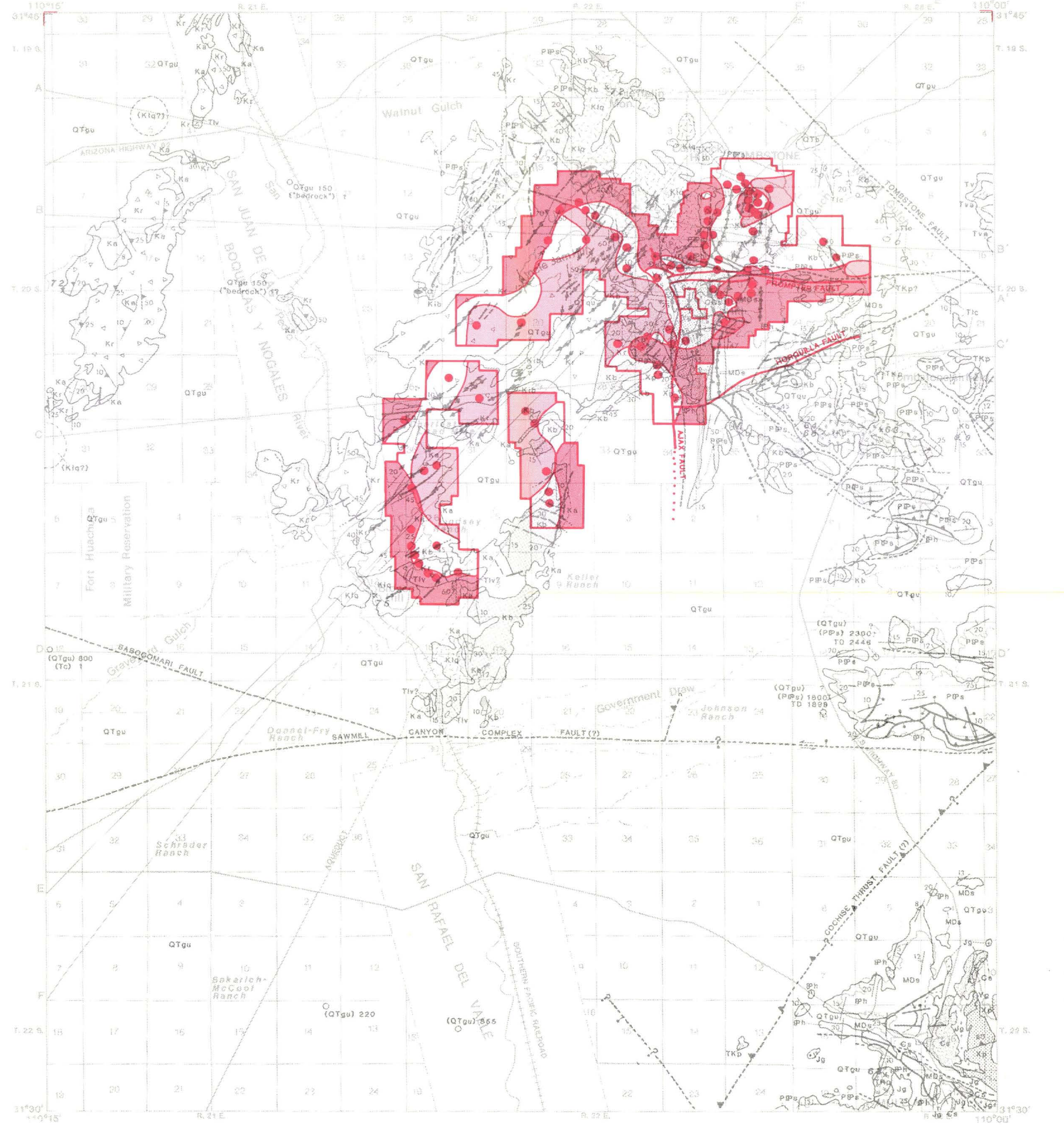
Aqueduct

A—A' Cross section line

● Dump sample location

Molybdenum

Zinc



Tombstone Development Company, Inc.

Tombstone, Arizona

Geology adopted from Drewes, Harold, 1980, and Newell, R.A., 1973.

By James A. Briscoe
James A. Briscoe and Associates
Tucson, Arizona

1 0 1 2 3 Miles

N

Figure 11. Dump sample location map showing area of influence boundaries and the Ajax, Prompter, and Horquilla faults, from Newell, R.A., 1973.

Distribution pattern for high molybdenum and zinc ratios in dump samples (in red).

Explanation

Geology

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Fluidized intrusive breccia - exact age unknown, but penetrates, and thus younger than Uncle Sam porphyry

Rhyodacite tuff and welded tuff. Includes parts of Salero Formation, Sugarloaf Quartz Latite, and Bronco Volcanics, and all of Red Bay Rhyolite, Cat Mountain Rhyolite of Brown (1939) and Uncle Sam Prophyry. Includes local intrusive bodies and locally contains fragments of exotic rocks. Thickness commonly several tens of meters to several hundreds of meters. Dated at 66(?), 70, 72, 73, and 73 m.y. The Uncle Sam, in the Tombstone area, is dated 72 m.y.

Andesitic to dacitic volcanic breccia.—Includes parts of Solero Formation, Sugarloaf Quartz Latite, and Bronco Volcanics, and all of Demetrie Volcanics and Silverbell Formation of Courtright (1958). Commonly contains large blocks of exotic rocks and locally includes some sedimentary rocks and intrusive rocks. Several tens of meters to several hundreds of meters thick in most places.

Lower quartz monzonite and graodiorite—Includes some quartz diorite; appears in small stocks. Locally associated with mineralization. Dated at 70, 71, 72, 73, 74, 74, 74, and 76 m.y. The Schieffin granodorite at Tombstone is 72 m.y.

BISBEE FORMATION OR GROUP, UNDIFFERENTIATED (LOWER CRETACEOUS):—Upper part of Bisbee Formation or Group, undifferentiated, and related rocks.—Includes upper part of Bisbee Formation, Mural Limestone, Morita, Cintura, Willow Canyon, Apache Canyon, Shellenberger Canyon and Turney Ranch Formations (not listed in stratigraphic sequence) of the Bisbee Group, Amole Arkose of Bryant and Kinnison (1954), and Angelic Arkose. Consists of brownish- to reddish-arkose, gray siltstone, sandstone, conglomerate, and some fossiliferous gray limestone. Commonly several hundred meters thick

GRANITE AND QUARTZ MONZONITE (JURASSIC)—Stocks of pinkish-gray coarse-grained rock. Locally associated with mineralization. Dated at 140, 148, 149, 149, 150, 153, 160, 161, 167, 178, 185 m.y.

Sedimentary rocks (Lower Permian and Upper Pennsylvanian)—consists of Epitaph Dolomite (Lower Permian), Colina Limestone (Lower Permian), and Earp Formation (Lower Permian and Upper Pennsylvanian), undifferentiated. Epitaph Dolomite is a dark- to light-gray slightly cherty dolomite, limestone, marl, siltstone, and gypsum, 120-280 meters thick. Colina Limestone is a medium gray, thick-bedded, sparsely cherty, and sparsely fossiliferous limestone 120-280 meters thick. Earp Formation is a pale-red siltstone, mudstone, shale, and limestone, 120-240 meters thick.

Horquilla Limestone (Upper and Middle Pennsylvanian)—Light-pinkish-gray, thick- to thin-bedded, cherty, fossiliferous limestone and intercalated pale-brown to pale-reddish-gray siltstone that increases in abundance upward. Typically 300-490 meters thick.

SEDIMENTARY ROCKS (MISSISSIPPIAN AND DEVONIAN)—Consists mainly of Escabrosa Limestone (Mississippian)—locally (Armstrong and Silberman, 1974) called Escabrosa Group—and Martin Formation (Upper Devonian), undifferentiated. In part of the Chiricahua Mountains also includes Paradise Formation (Upper Mississippian) and Portal Formation of Sabins, 1957a (Upper Devonian). In the Little Dragoon Mountains and some adjacent hills also includes Black Prince Limestone, whose fauna and correlation show strongest affinities with Mississippian rocks but which may include some Pennsylvanian rocks. Escabrosa Limestone is a medium-gray, massive to thick-bedded, commonly crinoidal, cherty, fossiliferous limestone 90-310 meters thick. Martin Formation is thick- to thin-bedded, gray to brown dolomite, gray sparsely fossiliferous, and some siltstone and sandstone, 90-120 meters thick. Paradise Formation is a brown, fossiliferous, shaly limestone. Portal Formation is a black shale and limestone 6-105 meters thick. Black Prince Limestone is pinkish-gray limestone with a basal shale and chert conglomerate, as much as 52 meters thick.

SEDIMENTARY ROCKS (LOWER ORDOVICIAN TO MIDDLE CAMBRIAN):—El Paso Limestone (Lower Ordovician and Upper Cambrian), Abrigo Formation (Upper and Middle Cambrian), and Bolsa Quartz (Middle Cambrian), undifferentiated.—El Paso Limestone is a gray, thin-bedded cherty limestone and dolomite 90 meters to about 220 meters thick. Abrigo Formation is a brown, thin-bedded fossiliferous limestone, sandstone, quartzite, and shale, 210-240 meters thick. Bolsa Quartzite is a brown to white or purplish-gray, thick-bedded, coarse-grained quartzite and sandstone with a basal conglomerate, 90-180 meters thick. To the east, equivalents of part of the Abrigo Formation and Bolsa Quartzite are known as the Coronado Sandstone.

Sedimentary rocks (Upper and Middle Cambrian)—Abrigo Formation (Upper and Middle Cambrian), and Bolsa Quartzite (Middle Cambrian), undifferentiated.

GRANITOID ROCKS (PRECAMBRIAN Y)—Mainly granodiorite and quartz monzonite, unfoliated to foliated, in part metamorphosed. Generally in stocks, which ahve been little studied.

PINAL SCHIST (PRECAMBRIAN X)—Chlorite schist, phyllite, and some metavolcanic rocks, metavolcanic rocks, metaquartzite, metaquartzite conglomerate, and gneiss. One metavolcanic rock dated at 1715 m.y.

CONTACT—Dotted where concealed.

MARKER HORIZON—Dotted where concealed.

DIKES—Showing dip.

FAULTS—Showing dip. Dotted where concealed or intruded; ball and bar on downthrown side.

Normal

Reverse

Strike slip—Arrow couple shows relative displacement. Single arrow shows movement of active block.

Major thrust fault—Sawteeth on upper plate.

Thrust fault—Sawteeth on upper plate.

Anticline.

Syncline.

Inclined strike and dip of beds.

EXOTIC BLOCK BRECCIA—Rock contains chip or block inclusions of rock different from those of host or other blocks nearby. Typically of volcanic tectonic or sedimentary-tectonic origin; excludes Tertiary megabreccia deposits.

(QTgu) 157 — Site of well or generalized site of several wells, showing unit penetrated, if known, and depth of well, in feet. 100 feet equals 30.5 meters.

72 x — COLLECTION SITE—Radiogenically dated rock showing age in millions of years. Query before symbol where precise location uncertain.

Roads and Highways

Dry wash

Southern Pacific Railroad

Government Reservation Boundary

Aqueduct

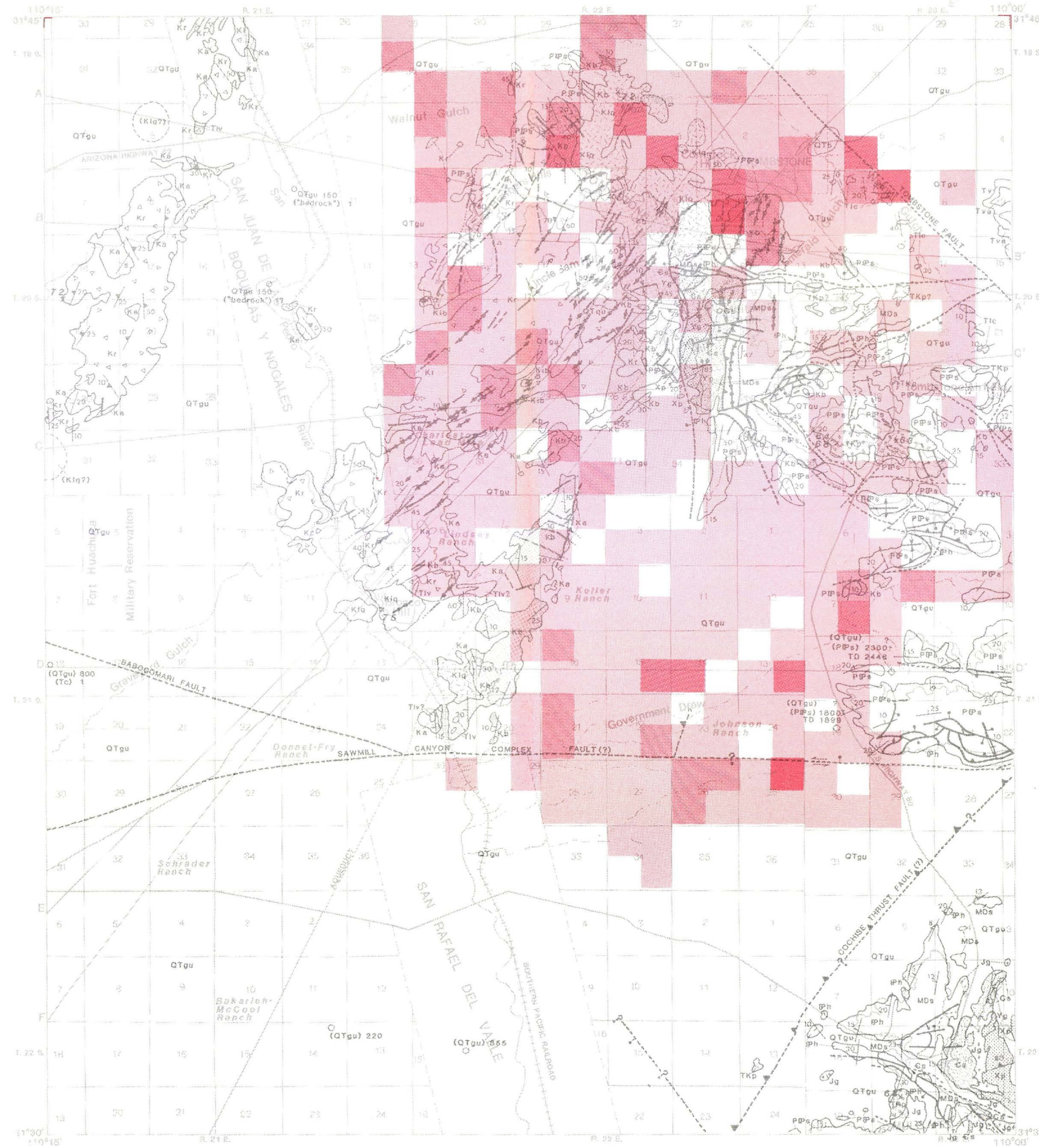
A—A' Cross section line

≤ 1 ppm

1.1 - 2 ppm

2.1 - 3 ppm

≥ 3 ppm



Tombstone Development Company, Inc.
Tombstone, Arizona

Geology adopted from Drewes, Harold, 1980, and Newell, R.A., 1973.

Figure 12. Distribution pattern of silver in mesquite trees (in red), from Newell, R.A., 1973.

1 0 1 2 3 Miles

N

By James A. Briscoe
James A. Briscoe and Associates
Tucson, Arizona

Explanation

Geology

QTgu — OLDER OR UNDIFFERENTIATED SURFICAL DEPOSITS (HOLOCENE TO OLIGOCENE):—Gravel, sand, and silt (Pleistocene and Pliocene—Mainly alluvium of basins; includes some colluvium and landslide deposits. Generally light-pinkish gray, weakly indurated, and with poorly rounded clasts; locally well indurated. Thickness several meters to hundreds of meters.

QTb — Basalt (Pleistocene to Pliocene)—Lava flows, pyroclastic rocks, and some intercalated gravel. Thickness several meters to a few hundred meters in most places. Radiometrically dated at 0.25, 1.0, and 3.2 m.y. old

Tva — Extensive andesite and dacite (Miocene and Upper Oligocene)—Lava flows, pyroclastic rocks, some intercalated epiclastic rocks, and dikes. Mostly gray, fine-grained, porphyritic rocks; includes some very coarse feldspar porphyry andesite (Turkey track porphyry, an informal term of Cooper, 1961). Thickness mostly several meters to several tens of meters. Dated at 24, 25, 27, 33, and 39 m.y.

Tv — Extrusive rhyolite and rhyodacite (Miocene and Upper Oligocene—Lava flows, welded tuff, pyroclastic rocks, and some intercalated epiclastic rocks. Light-gray to grayish-pink, vitric to fine-grained, porphyritic. Commonly a few tens to a few thousand of meters thick. Dated at 23, 24, 25, 26, 26, 26, and 27 m.y. An additional date of 47 m.y., if substantiated, may indicate the presence of Eocene rocks in the lower member of the S O Volcanics of Cochise Co.

Tlc — Lower conglomerate, gravel, and sand (Oligocene and Eocene?)—Alluvium; commonly grayish-red deposits of small, well rounded, nonvolcanic clasts. Mostly several meters to a few tens of meters thick.

Tlv — UPPER CORDILLERAN (LARAMIDE) IGNEOUS ROCKS (LOWER PALEOCENE):—Lower volcanic rocks—Rhyolite to andesite lava flows, pyroclastic rocks, and some intercalated epiclastic rocks. Dated at 57 m.y. Possibly younger age to east.

TKp — MAIN CORDILLERAN (LARAMIDE) IGNEOUS ROCKS:—Porphyritic and aplitic intrusive rocks (Paleocene and Upper Cretaceous)—Mostly latitic porphyry to dacitic porphyry in small stocks and plugs and aplitic bodies not associated with other granitoid stocks. Dated at 61, 63, 63, 64, and 65 m.y.

Kib — Fluidized intrusive breccia—exact age unknown, but penetrates, and thus younger than Uncle Sam porphyry.

Kr — Rhyodacite tuff and welded tuff.—Includes parts of Salero Formation, Sugarloaf Quartz Latite, and Bronco Volcanics, and all of Red Bay Rhyolite, Cat Mountain Rhyolite of Brown (1939) and Uncle Sam Prophyry. Includes local intrusive bodies and locally contains fragments of exotic rocks. Thickness commonly several tens of meters to several hundreds of meters. Dated at 66(?), 70, 72, 73, and 73 m.y. The Uncle Sam, in the Tombstone area, is dated 72 m.y.

Ka — Andesitic to dacitic volcanic breccia.—Includes parts of Solero Formation, Sugarloaf Quartz Latite, and Bronco Volcanics, and all of Demetrie Volcanics and Silverbell Formation of Courtright (1958). Commonly contains large blocks of exotic rocks and locally includes some sedimentary rocks and intrusive rocks. Several tens of meters to several hundreds of meters thick in most places.

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Jg — GRANITE AND QUARTZ MONZONITE (JURASSIC)—Stocks of pinkish-gray coarse-grained rock. Locally associated with mineralization. Dated at 140, 148, 149, 149, 150, 153, 160, 161, 167, 178, 185 m.y.

PIPe — Sedimentary rocks (Lower Permian and Upper Pennsylvanian)—consists of Epitaph Dolomite (Lower Permian), Colina Limestone (Lower Permian), and Earp Formation (Lower Permian and Upper Pennsylvanian), undifferentiated. Epitaph Dolomite is a dark- to light-gray slightly cherty dolomite, limestone, marl, siltstone, and gypsum, 120-280 meters thick. Colina Limestone is a medium gray, thick-bedded, sparsely cherty, and sparsely fossiliferous limestone 120-280 meters thick. Earp Formation is a pale-red siltstone, mudstone, shale, and limestone, 120-240 meters thick.

Ph — Horquilla Limestone (Upper and Middle Pennsylvanian)—Light-pinkish-gray, thick- to thin-bedded, cherty, fossiliferous limestone and intercalated pale-brown to pale-reddish-gray siltstone that increases in abundance upward. Typically 300-490 meters thick.

MDs — SEDIMENTARY ROCKS (MISSISSIPPIAN AND DEVONIAN)—Consists mainly of Escabrosa Limestone (Mississippian)—locally (Armstrong and Silberman, 1974) called Escabrosa Group—and Martin Formation (Upper Devonian), undifferentiated. In part of the Chiricahua Mountains also includes Paradise Formation (Upper Mississippian) and Portal Formation of Sabins, 1957a (Upper Devonian). In the Little Dragoon Mountains and some adjacent hills also includes Black Prince Limestone, whose fauna and correlation show strongest affinities with Mississippian rocks but which may include some Pennsylvanian rocks. Escabrosa Limestone is a medium-gray, massive to thick-bedded, commonly crinoidal, cherty, fossiliferous limestone 90-310 meters thick. Martin Formation is thick- to thin-bedded, gray to brown dolomite, gray sparsely fossiliferous, and some siltstone and sandstone, 90-120 meters thick. Paradise Formation is a brown, fossiliferous, shaly limestone. Portal Formation is a black shale and limestone 6-105 meters thick. Black Prince Limestone is pinkish-gray limestone with a basal shale and chert conglomerate, as much as 52 meters thick.

OCs — SEDIMENTARY ROCKS (LOWER ORDOVICIAN TO MIDDLE CAMBRIAN):—El Paso Limestone (Lower Ordovician and Upper Cambrian), Abrigo Formation (Upper and Middle Cambrian), and Bolsa Quartz (Middle Cambrian), undifferentiated.—El Paso Limestone is a gray, thin-bedded cherty limestone and dolomite 90 meters to about 220 meters thick. Abrigo Formation is a brown, thin-bedded fossiliferous limestone, sandstone, quartzite, and shale, 210-240 meters thick. Bolsa Quartzite is a brown to white or purplish-gray, thick-bedded, coarse-grained quartzite and sandstone with a basal conglomerate, 90-180 meters thick. To the east, equivalents of part of the Abrigo Formation and Bolsa Quartzite are known as the Coronado Sandstone.

Cs — Sedimentary rocks (Upper and Middle Cambrian)—Abrigo Formation (Upper and Middle Cambrian), and Bolsa Quartzite (Middle Cambrian), undifferentiated.

Yg — GRANITOID ROCKS (PRECAMBRIAN Y):—Mainly granodiorite and quartz monzonite, unfoliated to foliated, in part metamorphosed. Generally in stocks, which ahve been little studied.

Xp — PINAL SCHIST (PRECAMBRIAN X)—Chlorite schist, phyllite, and some metavolcanic rocks, metavolcanic rocks, metaquartzite, metaquartzite conglomerate, and gneiss. One metavolcanic rock dated at 1715 m.y.

CONTACT—Dotted where concealed.

MARKER HORIZON—Dotted where concealed.

DIKES—Showing dip.

FAULTS—Showing dip. Dotted where concealed or intruded; ball and bar on downthrown side.

Normal

Reverse

Strike-slip—Arrow couple shows relative displacement. Single arrow shows movement of active block.

Major thrust fault—Sawteeth on upper plate.

Thrust fault—Sawteeth on upper plate.

Anticline.

Syncline.

Inclined strike and dip of beds.

EXOTIC BLOCK BRECCIA—Rock contains chip or block inclusions of rock different from those of host or other blocks nearby. Typically of volcanic tectonic or sedimentary-tectonic origin; excludes Tertiary megabreccia deposits.

(QTgu) 187 — Site of well or generalized site of several wells, showing unit penetrated, if known, and depth of well, in feet. 100 feet equals 30.5 meters.

72x — COLLECTION SITE—Radiogenically dated rock showing age in millions of years. Query before symbol where precise location uncertain.

Roads and Highways

Dry wash

Southern Pacific Railroad

Government Reservation Boundary

Aqueduct

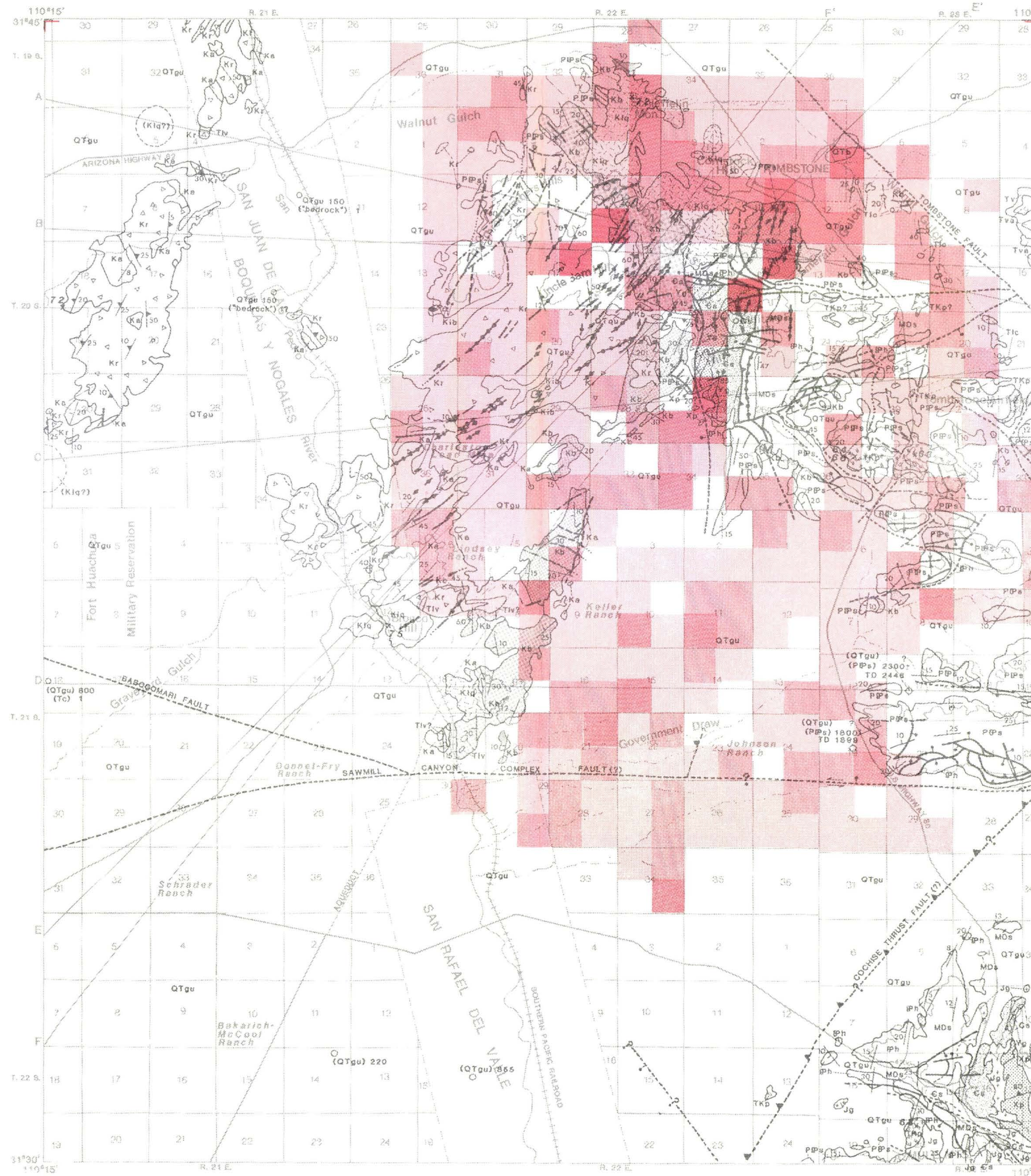
A—A' Cross section line

≤ 400 ppm

401 - 600 ppm

601 - 800 ppm

≥ 800 ppm



Tombstone Development Company, Inc.
Tombstone, Arizona

1 0 1 2 3 Miles

N

Geology adopted from Drewes, Harold, 1980, and Newell, R.A., 1973.

Figure 13. Distribution pattern of zinc in mesquite trees (in red), from Newell, R.A., 1973.

By James A. Briscoe
James A. Briscoe and Associates
Tucson, Arizona

Explanation

Geology

QTgu — OLDER OR UNDIFFERENTIATED SURFICAL DEPOSITS (HOLOCENE TO OLIGOCENE):—Gravel, sand, and silt (Pleistocene and Pliocene—Mainly alluvium of basins; includes some colluvium and landslide deposits. Generally light-pinkish gray, weakly indurated, and with poorly rounded clasts; locally well indurated. Thickness several meters to hundreds of meters.

QTb — Basalt (Pleistocene to Pliocene)—Lava flows, pyroclastic rocks, and some intercalated gravel. Thickness several meters to a few hundred meters in most places. Radiometrically dated at 0.25, 1.0, and 3.2 m.y. old

Tva — Extensive andesite and dacite (Miocene and Upper Oligocene)—Lava flows, pyroclastic rocks, some intercalated epiclastic rocks, and dikes. Mostly gray, fine-grained, porphyritic rocks; includes some very coarse feldspar porphyry andesite (Turkey track porphyry, an informal term of Cooper, 1961). Thickness mostly several meters to several tens of meters. Dated at 24, 25, 27, 33, and 39 m.y.

Tv — Extrusive rhyolite and rhyodacite (Miocene and Upper Oligocene—Lava flows, welded tuff, pyroclastic rocks, and some intercalated epiclastic rocks. Light-gray to grayish-pink, vitric to fine-grained, porphyritic. Commonly a few tens to a few thousand of meters thick. Dated at 23, 24, 25, 26, 26, 26, and 27 m.y. An additional date of 47 m.y., if substantiated, may indicate the presence of Eocene rocks in the lower member of the S O Volcanics of Cochise Co.

Tlc — Lower conglomerate, gravel, and sand (Oligocene and Eocene?)—Alluvium; commonly grayish-red deposits of small, well rounded, nonvolcanic clasts. Mostly several meters to a few tens of meters thick.

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MARKER HORIZON—Dotted where concealed.

DIKES—Showing dip.

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45 — Normal

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Roads and Highways

Dry wash

Southern Pacific Railroad

Government Reservation Boundary

Aqueduct

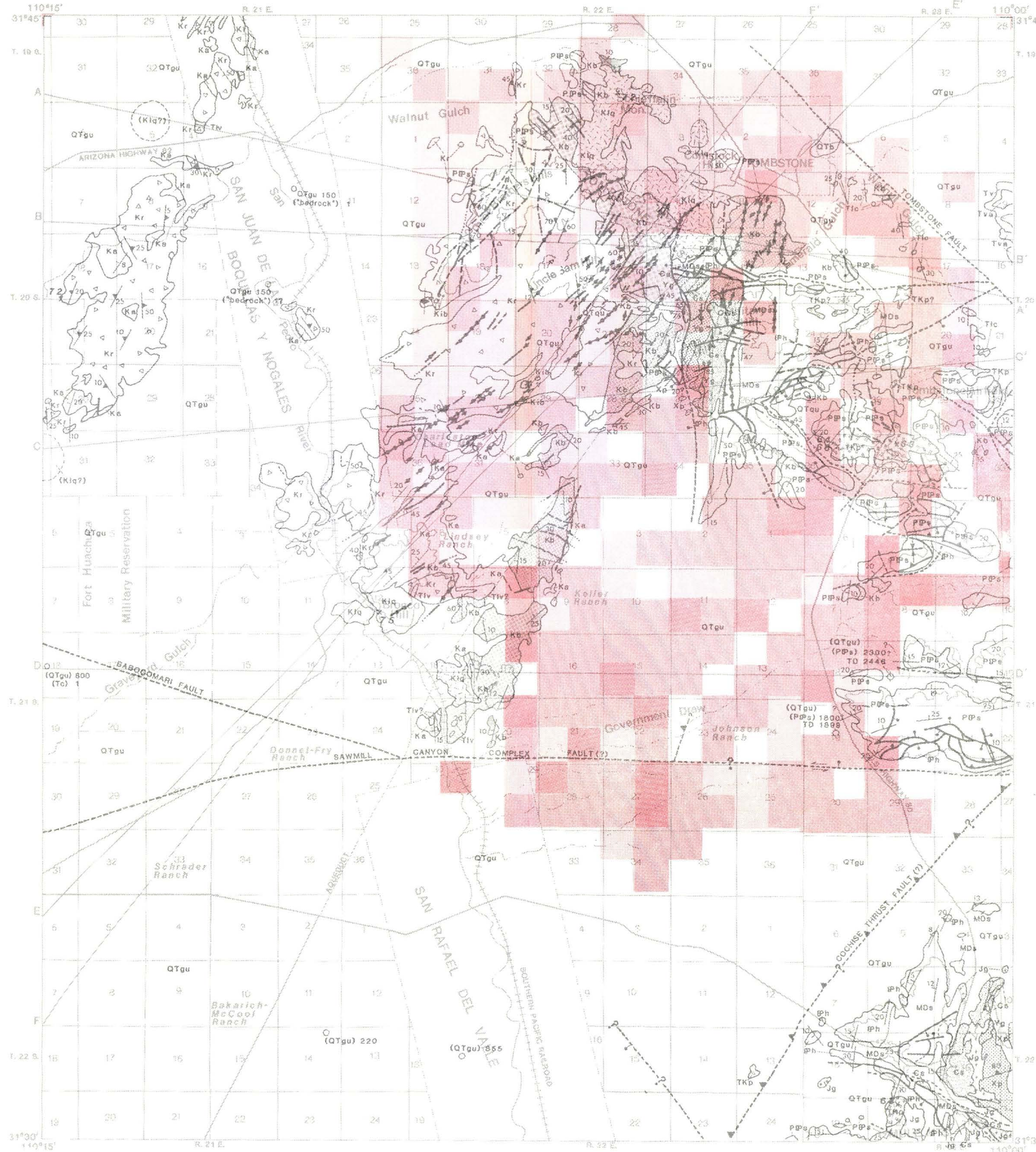
A——A' Cross section line

≤ 100 ppm

101 - 150 ppm

151 - 200 ppm

≥ 200 ppm



Tombstone Development Company, Inc.
Tombstone, Arizona

Geology adopted from Drewes, Harold, 1980, and Newell, R.A., 1973.

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By James A. Briscoe

James A. Briscoe and Associates

Tucson, Arizona

Explanation

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Kr — Rhyodacite tuff and welded tuff.—Includes parts of Salero Formation, Sugarloaf Quartz Latite, and Bronco Volcanics, and all of Red Bay Rhyolite, Cat Mountain Rhyolite of Brown (1939) and Uncle Sam Prophyry. Includes local intrusive bodies and locally contains fragments of exotic rocks. Thickness commonly several tens of meters to several hundreds of meters. Dated at 66(?), 70, 72, 73, and 73 m.y. The Uncle Sam, in the Tombstone area, is dated 72 m.y.

Ka — Andesitic to dacitic volcanic breccia.—Includes parts of Solero Formation, Sugarloaf Quartz Latite, and Bronco Volcanics, and all of Demetrie Volcanics and Silverbell Formation of Courtright (1958). Commonly contains large blocks of exotic rocks and locally includes some sedimentary rocks and intrusive rocks. Several tens of meters to several hundreds of meters thick in most places.

Klq — Lower quartz monzonite and graodiorite—Includes some quartz diorite; appears in small stocks. Locally associated with mineralization. Dated at 70, 71, 72, 73, 74, 74, 74, and 76 m.y. The Schieffin granodorite at Tombstone is 72 m.y.

Kb — BISBEE FORMATION OR GROUP, UNDIFFERENTIATED (LOWER CRETACEOUS):—Upper part of Bisbee Formation or Group, undifferentiated, and related rocks.—Includes upper part of Bisbee Formation, Mural Limestone, Morita, Cintura, Willow Canyon, Apache Canyon, Shellenberger Canyon and Turney Ranch Formations (not listed in stratigraphic sequence) of the Bisbee Group, Amole Arkose of Bryant and Kinnison (1954), and Angelic Arkose. Consists of brownish- to reddish-arkose, gray siltstone, sandstone, conglomerate, and some fossiliferous gray limestone. Commonly several hundred meters thick

Jg — GRANITE AND QUARTZ MONZONITE (JURASSIC)—Stocks of pinkish-gray coarse-grained rock. Locally associated with mineralization. Dated at 140, 148, 149, 149, 150, 153, 160, 161, 167, 178, 185 m.y.

PIPs — Sedimentary rocks (Lower Permian and Upper Pennsylvanian)—consists of Epitaph Dolomite (Lower Permian), Colina Limestone (Lower Permian), and Earp Formation (Lower Permian and Upper Pennsylvanian), undifferentiated. Epitaph Dolomite is a dark- to light-gray slightly cherty dolomite, limestone, marl, siltstone, and gypsum, 120-280 meters thick. Colina Limestone is a medium gray, thick-bedded, sparsely cherty, and sparsely fossiliferous limestone 120-280 meters thick. Earp Formation is a pale-red siltstone, mudstone, shale, and limestone, 120-240 meters thick.

IPh — Horquilla Limestone (Upper and Middle Pennsylvanian)—Light-pinkish-gray, thick- to thin-bedded, cherty, fossiliferous limestone and intercalated pale-brown to pale-reddish-gray siltstone that increases in abundance upward. Typically 300-490 meters thick.

MDs — SEDIMENTARY ROCKS (MISSISSIPPIAN AND DEVONIAN)—Consists mainly of Escabrosa Limestone (Mississippian)—locally (Armstrong and Silberman, 1974) called Escabrosa Group—and Martin Formation (Upper Devonian), undifferentiated. In part of the Chiricahua Mountains also includes Paradise Formation (Upper Mississippian) and Portal Formation of Sabins, 1957a (Upper Devonian). In the Little Dragoon Mountains and some adjacent hills also includes Black Prince Limestone, whose fauna and correlation show strongest affinities with Mississippian rocks but which may include some Pennsylvanian rocks. Escabrosa Limestone is a medium-gray, massive to thick-bedded, commonly crinoidal, cherty, fossiliferous limestone 90-310 meters thick. Martin Formation is thick- to thin-bedded, gray to brown dolomite, gray sparsely fossiliferous, and some siltstone and sandstone, 90-120 meters thick. Paradise Formation is a brown, fossiliferous, shaly limestone. Portal Formation is a black shale and limestone 6-105 meters thick. Black Prince Limestone is pinkish-gray limestone with a basal shale and chert conglomerate, as much as 52 meters thick.

O€s — SEDIMENTARY ROCKS (LOWER ORDOVICIAN TO MIDDLE CAMBRIAN):—El Paso Limestone (Lower Ordovician and Upper Cambrian), Abrigo Formation (Upper and Middle Cambrian), and Bolsa Quartz (Middle Cambrian), undifferentiated.—El Paso Limestone is a gray, thin-bedded cherty limestone and dolomite 90 meters to about 220 meters thick. Abrigo Formation is a brown, thin-bedded fossiliferous limestone, sandstone, quartzite, and shale, 210-240 meters thick. Bolsa Quartzite is a brown to white or purplish-gray, thick-bedded, coarse-grained quartzite and sandstone with a basal conglomerate, 90-180 meters thick. To the east, equivalents of part of the Abrigo Formation and Bolsa Quartzite are known as the Coronado Sandstone.

€a — Sedimentary rocks (Upper and Middle Cambrian)—Abrigo Formation (Upper and Middle Cambrian), and Bolsa Quartzite (Middle Cambrian), undifferentiated.

Yg — GRANITOID ROCKS (PRECAMBRIAN Y):—Mainly granodiorite and quartz monzonite, unfoliated to foliated, in part metamorphosed. Generally in stocks, which ahve been little studied.

Xp — PINAL SCHIST (PRECAMBRIAN X)—Chlorite schist, phyllite, and some metavolcanic rocks, metavolcanic rocks, metaquartzite, metaquartzite conglomerate, and gneiss. One metavolcanic rock dated at 1715 m.y.

CONTACT—Dotted where concealed.

MARKER HORIZON—Dotted where concealed.

DIKES—Showing dip.

FAULTS—Showing dip. Dotted where concealed or intruded; ball and bar on downthrown side.

Normal

Reverse

Strike-slip—Arrow couple shows relative displacement. Single arrow shows movement of active block.

Major thrust fault—Sawteeth on upper plate.

Thrust fault—Sawteeth on upper plate.

Anticline.

Syncline.

Inclined strike and dip of beds.

EXOTIC BLOCK BRECCIA—Rock contains chip or block inclusions of rock different from those of host or other blocks nearby. Typically of volcanic-tectonic or sedimentary-tectonic origin; excludes Tertiary megabreccia deposits.

(QTgu) 157 — Site of well or generalized site of several wells, showing unit penetrated, if known, and depth of well, in feet. 100 feet equals 30.5 meters.

72x — COLLECTION SITE—Radiogenically dated rock showing age in millions of years. Query before symbol where precise location uncertain.

Roads and Highways

Dry wash

Southern Pacific Railroad

Government Reservation Boundary

Aqueduct

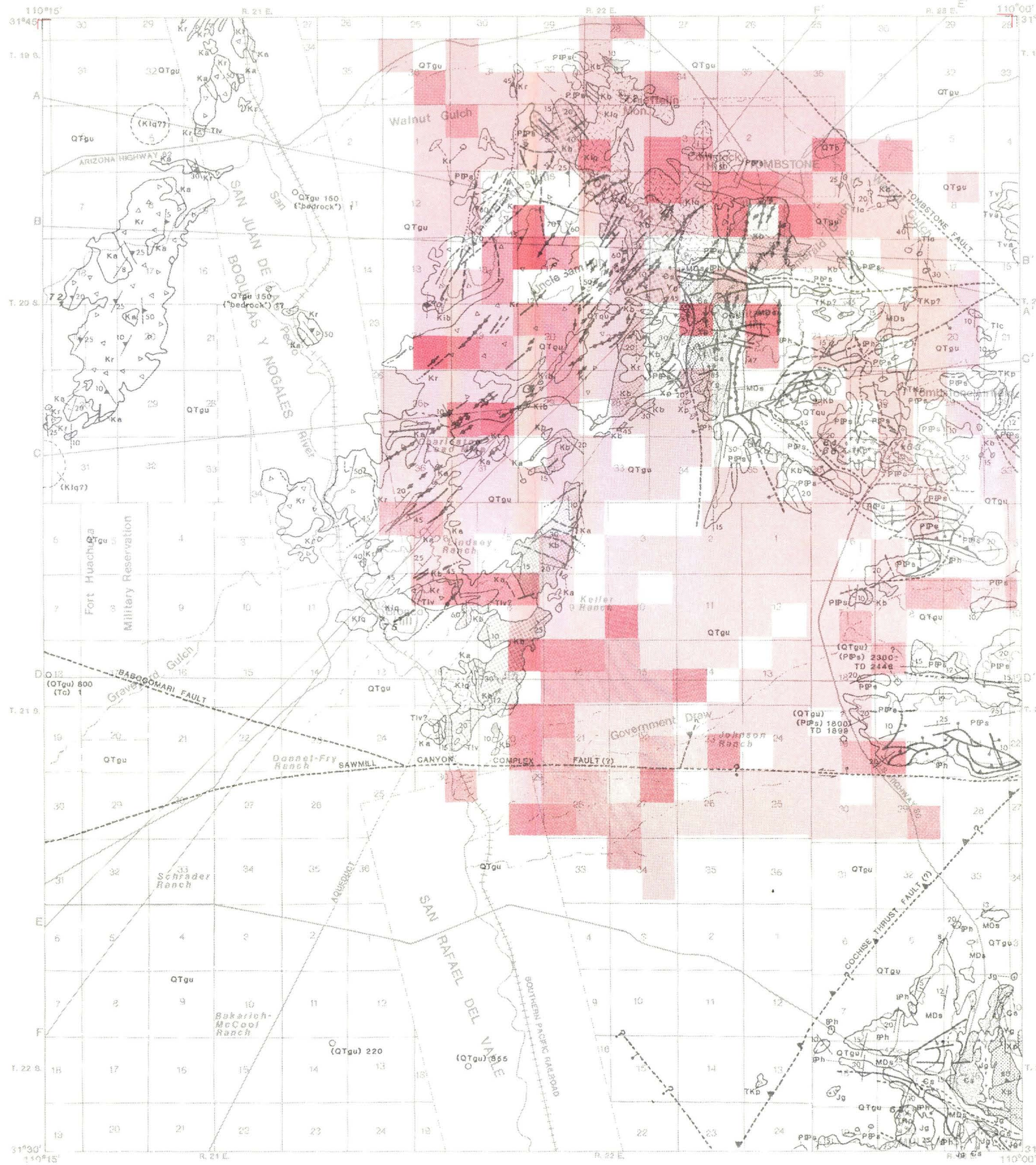
A———A′ Cross section line

≤ 5 ppm

5.1 - 9 ppm

9.1 - 14 ppm

≥ 14 ppm



Tombstone Development Company, Inc.
Tombstone, Arizona

Geology adopted from Drewes, Harold, 1980, and Newell, R.A., 1973.

Figure 15. Distribution pattern of molybdenum in mesquite trees (in red), from Newell, R.A., 1973.

By James A. Briscoe
James A. Briscoe and Associates
Tucson, Arizona

Explanation

Geology

QTgu — OLDER OR UNDIFFERENTIATED SURFICAL DEPOSITS (HOLOCENE TO OLIGOCENE):—Gravel, sand, and silt (Pleistocene and Pliocene—Mainly alluvium of basins; includes some colluvium and landslide deposits. Generally light pinkish gray, weakly indurated, and with poorly rounded clasts; locally well indurated. Thickness several meters to hundreds of meters.

QTb — Basalt (Pleistocene to Pliocene)—Lava flows, pyroclastic rocks, and some intercalated gravel. Thickness several meters to a few hundred meters in most places. Radiometrically dated at 0.25, 1.0, and 3.2 m.y. old

Tva — Extensive andesite and dacite (Miocene and Upper Oligocene)—Lava flows, pyroclastic rocks, some intercalated epiclastic rocks, and dikes. Mostly gray, fine-grained, porphyritic rocks; includes some very coarse feldspar porphyry andesite (Turkey track porphyry, an informal term of Cooper, 1961). Thickness mostly several meters to several tens of meters. Dated at 24, 25, 27, 33, and 39 m.y.

Tv — Extrusive rhyolite and rhyodacite (Miocene and Upper Oligocene—Lava flows, welded tuff, pyroclastic rocks, and some intercalated epiclastic rocks. Light-gray to grayish-pink, vitric to fine-grained, porphyritic. Commonly a few tens to a few thousand of meters thick. Dated at 23, 24, 25, 26, 26, 26, and 27 m.y. An additional date of 47 m.y., if substantiated, may indicate the presence of Eocene rocks in the lower member of the S O Volcanics of Cochise Co.

Tlc — Lower conglomerate, gravel, and sand (Oligocene and Eocene?)—Alluvium; commonly grayish-red deposits of small, well rounded, nonvolcanic clasts. Mostly several meters to a few tens of meters thick.

Tlv — UPPER CORDILLERAN (LARAMIDE) IGNEOUS ROCKS (LOWER PALEOCENE):—Lower volcanic rocks—Rhyolite to andesite lava flows, pyroclastic rocks, and some intercalated epiclastic rocks. Dated at 57 m.y. Possibly younger age to east.

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Ca — Sedimentary rocks (Upper and Middle Cambrian)—Abrigo Formation (Upper and Middle Cambrian), and Bolsa Quartzite (Middle Cambrian), undifferentiated.

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CONTACT—Dotted where concealed.

MARKER HORIZON—Dotted where concealed.

DIKES—Showing dip.

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Normal

Reverse

Strike-slip—Arrow couple shows relative displacement. Single arrow shows movement of active block.

Major thrust fault—Sawteeth on upper plate.

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Roads and Highways

Dry wash

Southern Pacific Railroad

Government Reservation Boundary

Aqueduct

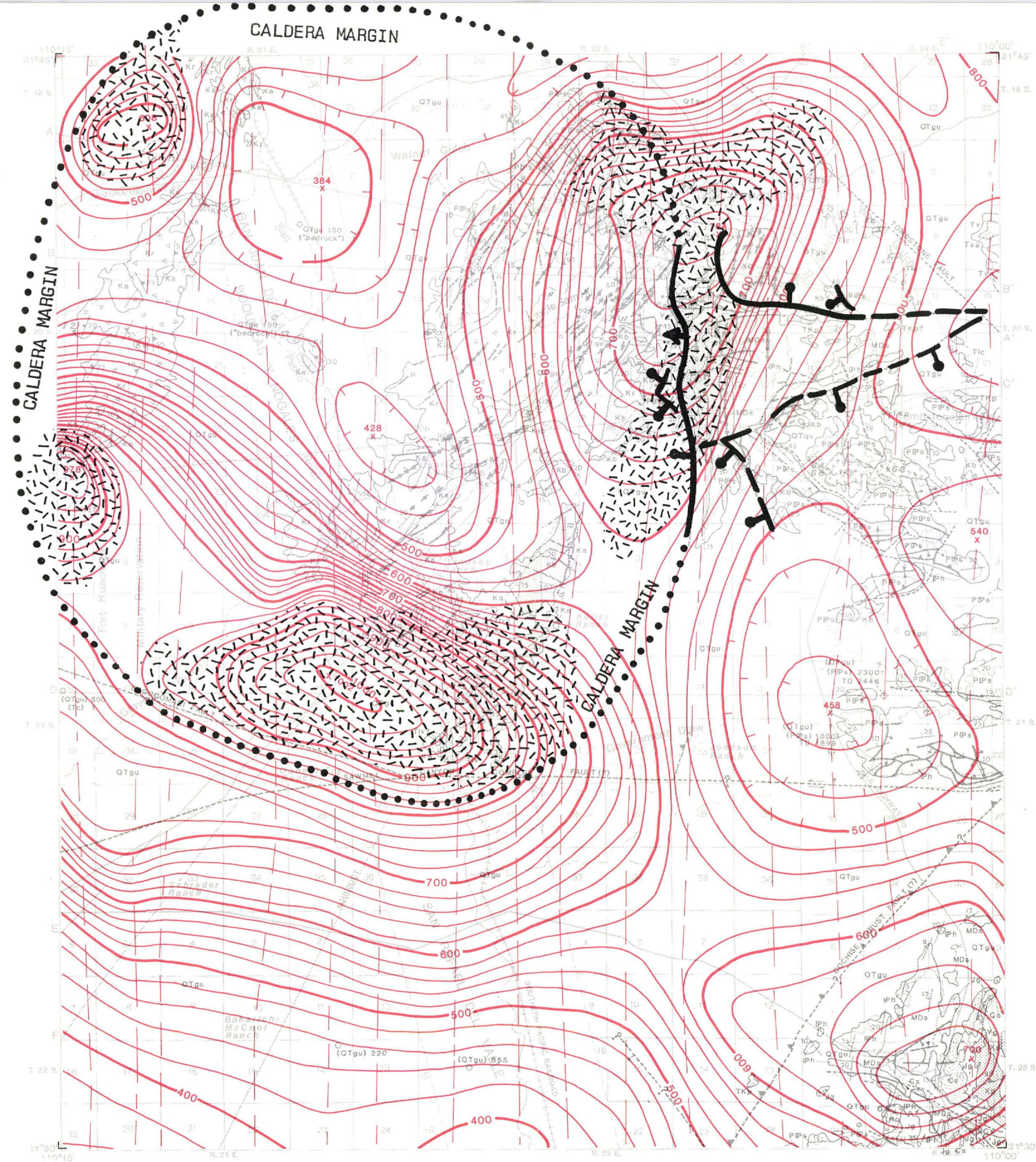
A—A' Cross section line

Flight line

Index contour line

Contour line

Contour interval: 25 gammas



Tombstone Development Company, Inc.
Tombstone, Arizona

1 0 1 2 3 Miles

N

Geology adopted from Drewes, Harold, 1980, and Newell, R.A., 1973.

By James A. Briscoe
James A. Briscoe and Associates
Tucson, Arizona

Figure 16. Aeromagnetic map of the Tombstone area.

From *Residual Aeromagnetic map of Southeastern Arizona*, Sauck, W.A., and Sumner, J.S., 1970. From Andreason, G.E., Mitchell, C.M., and Tyson, N.S., 1965

Explanation

Geology

QTgu — OLDER OR UNDIFFERENTIATED SURFICAL DEPOSITS (HOLOCENE TO OLIGOCENE):—Gravel, sand, and silt (Pleistocene and Pliocene—Mainly alluvium of basins; includes some colluvium and landslide deposits. Generally light-pinkish gray, weakly indurated, and with poorly rounded clasts; locally well indurated. Thickness several meters to hundreds of meters.

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CONTACT—Dotted where concealed.

MARKER HORIZON—Dotted where concealed.

DIKES—Showing dip.

FAULTS—Showing dip. Dotted where concealed or intruded; ball and bar on downthrown side. (70)

Normal (45)

Reverse (45)

Strike-slip—Arrow couple shows relative displacement. Single arrow shows movement of active block.

Major thrust fault—Sawteeth on upper plate.

Thrust fault—Sawteeth on upper plate.

Anticline

Syncline.

30 — Inclined strike and dip of beds.

EXOTIC BLOCK BRECCIA—Rock contains chip or block inclusions of rock different from those of host or other blocks nearby. Typically of volcanic tectonic or sedimentary-tectonic origin; excludes Tertiary megabreccia deposits.

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Roads and Highways

Dry wash

Southern Pacific Railroad

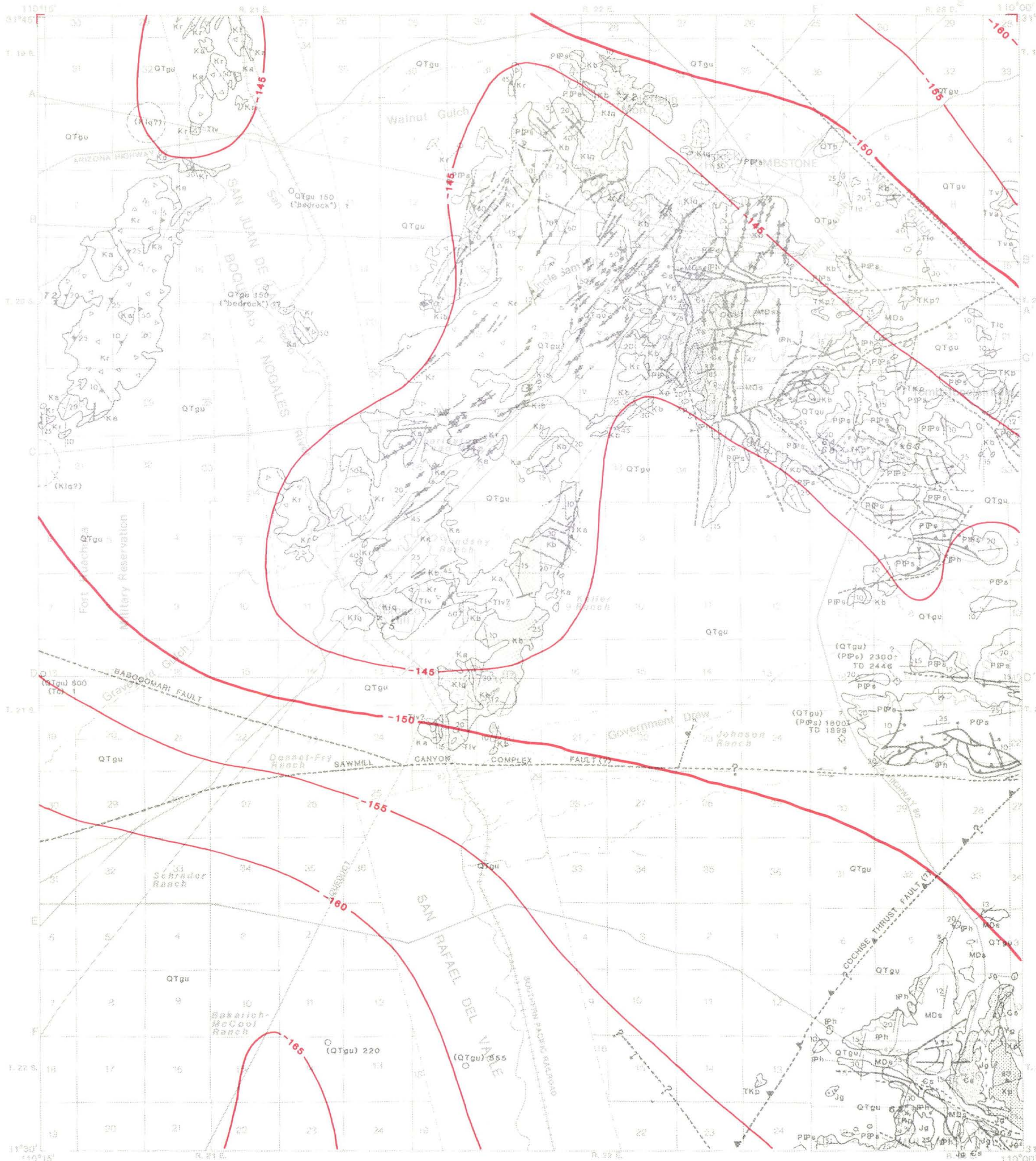
Government Reservation Boundary

Aqueduct

A——A' Cross section line

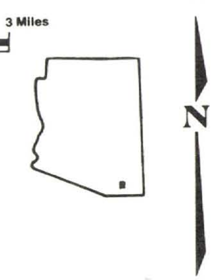
-150 Gravity contour line

Contour interval: 5 milligals



Tombstone Development Company, Inc.
Tombstone, Arizona

1 0 1 2 3 Miles



Geology adopted from Drewes, Harold, 1980, and Newell, R.A., 1973.

By James A. Briscoe
James A. Briscoe and Associates
Tucson, Arizona

Figure 17. Gravity map of the Tombstone area.

From *Bouguer Gravity Anomaly map of Southeastern Arizona*, West, E.E., Sumner, J.S., Aiken, C.L.V., and Conley, J.N., 1973.

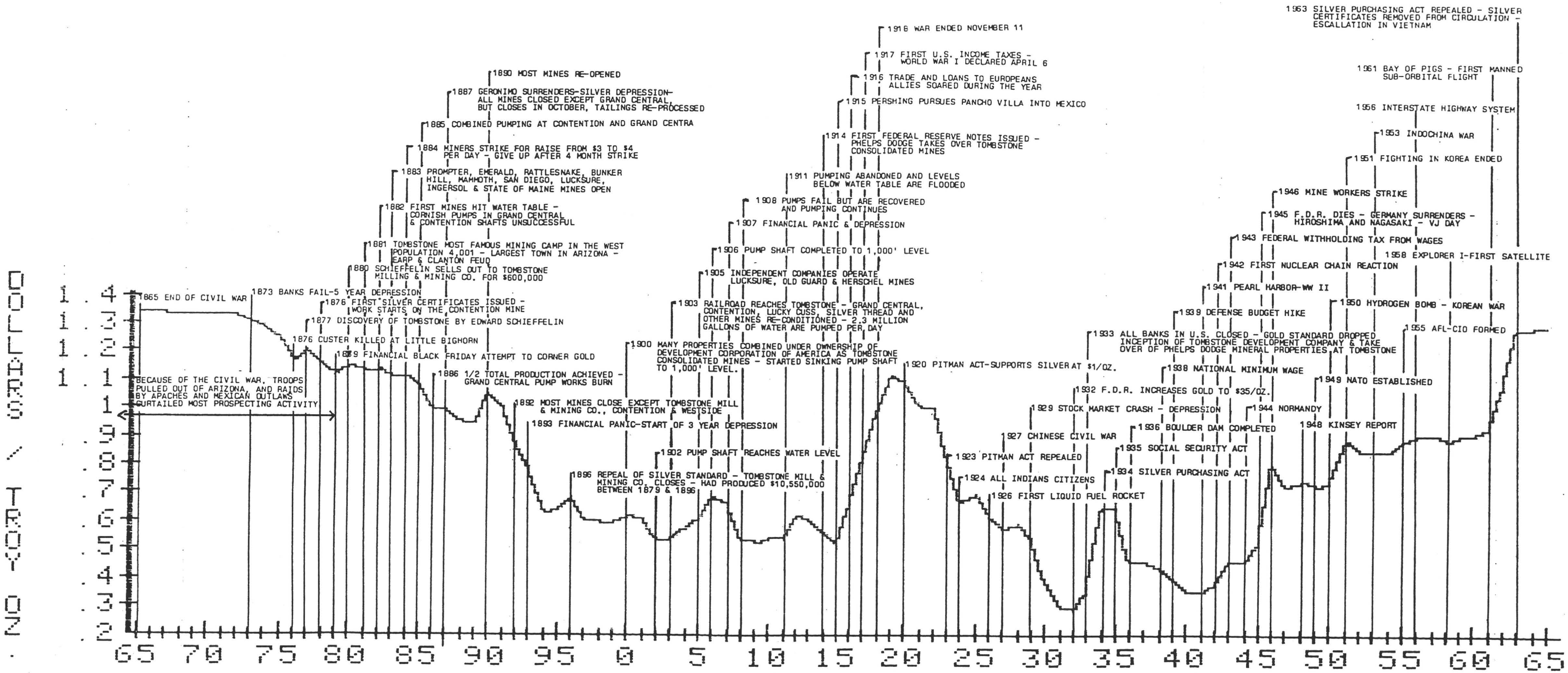


Figure 18: 100 Year Silver Price Chart

100 YEAR SILVER PRICE CHART

AVERAGE ANNUAL SILVER PRICE

YEARS: 1865 THROUGH 1965

an hour away by U.S. 80 and Interstate 10 to the northeast. Tucson is served by an international airport, with scheduled flights by several carriers. The Tombstone Municipal Airport has a 5,000-foot oiled strip, adequate for light planes, but no fuel or other facilities. Tombstone, until 1950, was serviced by a standard gauge branch S.P. railroad line at Fairbank, seven miles west of Tombstone. This connection to Fairbank has been dismantled, though the rail line which connects with Douglas, Arizona, is currently in service. There are plans to re-establish the branch line to Tombstone, so it could bring tourists in for visits to the historic townsite. If this comes to pass, freight could also be hauled.

Physical Features

Physical features in italics are quoted directly from Butler, B.S., Wilson, E.D, and Rasor, C.A., 1938, with some deletions:

> *The Tombstone district is in the Tombstone hills, a group of low, scattered mountains that extend northwestward from the Mule Mountains in which the Bisbee district is located. Tombstone is near the northwest margin of the area, at an altitude of 4,530 feet or 670 feet above the San Pedro River at Fairbank. The Tombstone Hills rise to a maximum altitude of 5,339 feet or some 800 feet above the surrounding plain, which slopes westward to the San Pedro River. In the vicinity of the hills, this plain is a pediment, cut on hard rock.*
>
> *Even slopes and rounded contours characterize the northern half of the area in contrast to the steep-sided, linear ridges that prevail in the southern half.*
>
> *There are no perennial streams in the area. Drainage is westward to the San Pedro River through steep-sided gulches or arroyos that dissect the plain. Torrential rains flood these arroyos for short periods, but during most of the year no water flows at the surface.*
>
> *Water is encountered in the mines of the eastern part of the district at an elevation of 4,120 feet above sea level. This mine water has been used for concentration of ores, but, according to analyses by H. V. Smith, of the University of Arizona, its fluorine content makes it unsuitable for drinking. Some water is obtained from shallow wells in the gulches, but the main supply for Tombstone is piped from springs in the Huachuca Mountain, about 25 miles southwest of the town.*

In general, the gentle, rolling topography is ideally suited to mining activities of all sorts.

Climate and Vegetation

The following italics are also quoted directly from Butler, Wilson, and Rasor, 1938:

> *The climate of Tombstone is that of the intermediate altitudes of southern Arizona. The winters are characterized by moderate temperatures and only a few light falls of snow. In summer the days are hot, but the nights are comfortably cool. The average range in temperature for a twenty-seven-year period, prior to 1928, is from an extreme maximum in June of 101.9º to an extreme minimum of 20.8 degrees in January. The average annual precipitation for a thirty-one-day period prior to 1928 was 14.48 inches. The main rainy season is from July to September, and the driest months are April, May, and June.*

The vegetation of the district is likewise characteristic of the intermediate elevations of southern Arizona. It is above the altitudes favorable to abundant cacti and below those favorable to forest trees. Desert shrubs predominate. Cat's-claw and creosote or greasewood bush, together with some mesquite and ocotillo, form thickets on the foothill slopes and pediments. Several species of cacti are present, but prickly pear is most abundant. Mescal and yucca are sparingly present. Along gulches and arroyos mesquite, palo verde, and walnut are common. No trees in the district are suitable for lumber or for ordinary mine timber. On flats and slopes where soil and moisture are favorable, various grasses thrive.

Climatic conditions do not appear to have changed significantly since those paragraphs were written.

PREVIOUS WORK

The following section in italics is quoted from Newell, 1974, with portions deleted. Geology and structure, adapted from Newell (1973) & Drewes (1980), are given on Figure 3:

<u>Previous Investigations.</u> The geological and mining literature abounds with references to the Tombstone district, and attention will be limited to those which provide significant insight into the geology and the development of the area.

Between the years 1879 and 1886, E/MJ published numerous notes concerning the nature, extent, and progress of underground development work in the district. E/MJ (1881, v. 31, p. 316-317) stated the Tombstone silver ores were mostly of a carbonate or chloride nature, and that production was about 300 tons/day. Recoveries were about 80%, and the average yield was about $75/ton. E/MJ (1883, v. 35, p. 267-269) reported that on the third level of the Westside mine the ore was assaying about 40 oz/ton silver and about 0.5 oz/ton gold. Manganese ore from the Lucky Cuss mine at a depth of 100 ft, carried about 25 oz/ton of silver. E/MJ (1883, v. 36, p. 229-230) announced the discovery, between the third and fourth levels, in the Westside mine, of several tons of telluride ore that averaged $1200/ton (assumed to be gold telluride - at $20/oz, about 60 oz per ton).

Blake (1882a, b, c, d) provided the earliest geologic descriptions of the district, and he recognized that the mineralization was closely associated with north-south trending dikes and cross-cutting northeast-southwest fissures. He also stated that, where either dikes or fissures crossed anticlinal structures, mineralization often developed along crests of the folds as bedded replacement deposits. Comstock (1900, p. 1045, 1089) confirmed that folds were important to ore deposition at Tombstone.

(Church, 1903) believed that dikes in the district exercised a relatively minor control on the mineralization, and that the major controls were anticlinal folds and cross-cutting fissures. Lakes (1904) compared anticlinal structures at Tombstone with those at Bendigo, Australia.

Between 1904 and 1920 little was published that dealt with the geology in Tombstone.

Ransome (1920) described the manganese mineralization at Tombstone. High concentrations of manganese were associated with the Prompter fault, and the principal manganese production was derived from the Oregon, Prompter, Lucky Cuss, Luck Sure, Bunker Hill, and Comet mines. Psilomelane, the major manganese mineral, typically occurred in pipes and chimneys in limestone horizons. Supergene processes were considered to have been *responsible for forming the present manganese deposits. High grade mineralization contained between 70% and 80% MnO_2 after sorting, while low grade mineralization contained about 40% MnO_2. Ransome mentioned that in 1917 the manganese ore contained between 7 and 8 oz/ton silver.*

The geology at Tombstone was investigated in more detail during the later 1930's. Butler and Wilson (1937) noted that the mineralization was associated with north-south dike fissures, faults, anticlines, and northeast-southwest fissures. Rasor (1937) investigated the mineralogy and petrography of the district, and he found hypogene silver-bearing minerals to include hessite, tetrahedrite, and galena. Alabandite was found to be the only definitely hypogene manganese mineral. Bromyrite, embolite, cerargyrite, argentite (acanthite), stromeyerite, native silver, (native gold - addition by Briscoe, 1985, see Butler et al. p. 51), *and argentojarosite were identified as supergene ore minerals. The zone of oxidation was thought to be at least 600 ft deep (Rasor, 1937, p. 83), and bromyrite was believed to be the most abundant supergene silver mineral. Butler, Wilson and Rasor (1938) and Butler and Wilson (1938) published insight into a complex sequence of structural events in the district, and the authors also suggested a broad pattern of mineral zoning. Butler and Wilson (1942) summarized their work at Tombstone in Newhouse (1942).*

Ingerson (1939) measured joint and platy inclusion orientations within the Uncle Sam "porphyry" west of Tombstone. The emplacement of the Uncle Sam "porphyry" was discussed at length by Gilluly (1945), and he considered the body to be either laccolithic or sill-like in form.

Gilluly, Cooper and Williams (1954) described the Late Paleozoic stratigraphy of central Cochise County. Gilluly (1956) incorporated his earlier work on the Uncle Sam "porphyry", with the stratigraphy to provide an exhaustive description of the geology of central Cochise County.

Creasey and Kistler (1962) determined radiometric ages for an intrusive rhyolite and the Schieffelin Granodiorite by potassium-argon methods as 63 and 72 m.y. respectively.

Andreason, Mitchell and Tyson (1965) published an aeromagnetic map for the area around and including Tombstone. Background values at Tombstone were about 300 to 400 gammas, but the granodiorite was found to have values between 700 and 1000 gammas. Brant (1966) found the Schieffelin Granodiorite to have a magnetic susceptibility of 1800×10^{-6} (c.g.s. units). Brant assumed the Schieffelin to be of Tertiary age, and he stated that this relatively high susceptibility was typical for Tertiary intrusives in southern Arizona. In fact the Schieffelin is a Laramide intrusive (Drewes, 1971), and Brant (1966) stated that most Laramide intrusives in southern Arizona have an average susceptibility of only 100×10^{-6}. Thus, for a Laramide intrusive, the Schieffelin is anomalously magnetic.

<u>Previous Mineralogical Investigations.</u> E/MJ (1881, v. 31, p. 316-317) reported that the Tombstone silver ores were mainly of chloride varieties, and that the ore contained a little lead. In 1883, E/MJ (v. 36, p. 229-230) reported the discovery of several tons of telluride ore between the third and fourth levels of the Westside mine.

Penrose (1890) noted the presence of manganiferous silver ore at Tombstone, and Moses and Laquer (1892) reported the existence of alabandite at the Lucky Cuss mine. Silver-bearing manganese minerals in Arizona and New Mexico were studied by Hewett and Pardee (1933), and they found that silver was present as argentiferous manganite. These authors observed that black calcite was commonly associated with the manganese deposits, and that the calcite had *black manganese oxide intergrowths that could be manganite, but not hausmannite.*

Rasor (1937) conducted the first detailed study of the mineralogy at Tombstone. He identified four main stages of hypogene mineralization. Rasor (1938) apparently reported the first United States occurrence of bromyrite at Tombstone. Hewett (1972) observed that the minerals hollandite, psilomelane, and cryptomelane formed most of the manganese oxide deposits, and he assigned a hypogene origin to all of them.

<u>Previous Milling and Smelting Investigations.</u> The earliest mention of milling procedures at Tombstone (E/MJ, 1879, v. 27, p. 468) indicated the successful operation of a 10 stamp mill, which yielded a recovery of about 77%. In 1881 about 120 stamps were in operation at Tombstone, treating about 300 tons/day (E/MJ, 1881, v. 31, p. 316-317).

Chapman, later to become Dean and Dean Emeritus of the College of Mines at the University of Arizona, wrote a masters thesis for the University of Arizona entitled <u>The Metallurgy of Silver Chloride Ore From the State of Maine Mine in the Tombstone District</u>. Chapman stated that the State of Maine mine produced 200,000 to 300,000 ounces of silver from 1900 to 1921.

Romslo and Ravitz (1947) reported the successful treatment of manganese-silver ore from Tombstone. Very poor results were obtained by direct cyanide and flotation methods, but a calcium dithionate process recovered 80% to 90% of the silver and 90% of the manganese.

<u>Previous Hydrological Investigations.</u> After water was first encountered in the Sulphurette mine in 1881, pumps with a capacity of 700 gpm were installed at the Contention and Grand Central mines in December 1883 (E/MJ, 1883, v. 36, p. 328, 400). The pumps worked successfully until 1886, when the Grand Central pump house burned (Dunning, 1959). Blake (1904a, b) mentioned that new pumps had lowered the water level to near the 700 ft level of the Contention mine. The water temperature was reported to be about 80º F.

Walker (1909) stated that water volumes of up to 4500 gpm were not uncommon. High pumping costs coupled with a low silver price (about $.50/oz) forced abandoning operations on January 19, 1911. Water pumps still remain on the 1000-, 800-, 700-, and 600-ft levels (Butler, Wilson, and Rasor, 1938, p. 47).

GENERAL GEOLOGY OF THE DISTRICT

District Geology

The Tombstone Mining District lies in the southwestern North American porphyry copper province (Fig. 19), and on the edge of the Cretaceous Sonoran Basin.

The Tombstone area has had a complex geologic history, which includes sedimentation, folding, thrust faulting, explosive acid volcanism and caldera formation and resurgence, several stages of igneous intrusion, and mineralization from hydrothermal solutions at least between 72 m.y. and 63 m.y.

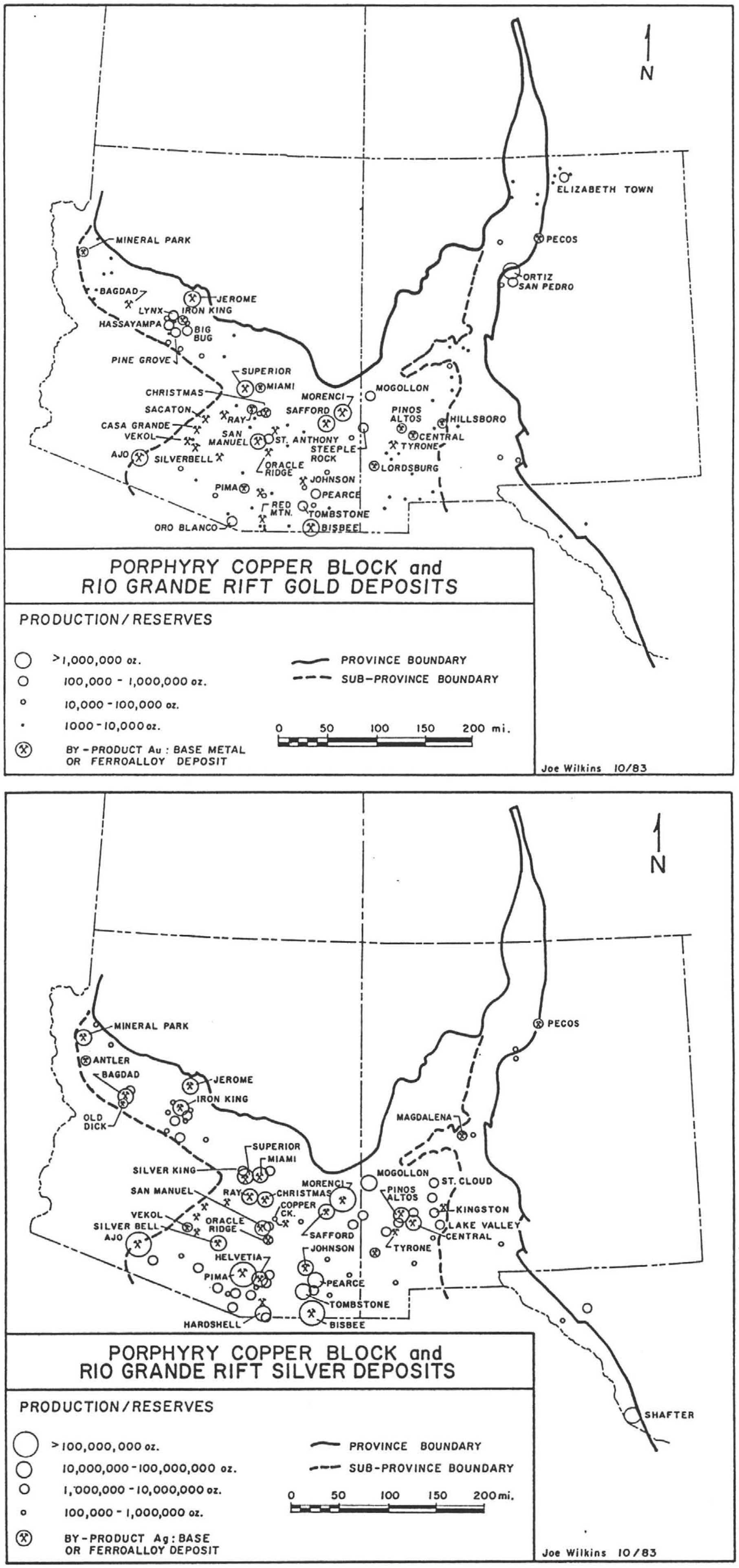


Figure 19: **Porphyry Copper Block and Rio Grande Rift Gold and Silver Deposits**

Basement rocks are Precambrian granodiorite and Pinal schist beneath approximately 2000m of Paleozoic sediments consisting, for the most part, of limestone. Mesozoic sedimentation deposited unconformably over rugged to moderate topography developed on the upper Paleozoic sediments includes the early Cretaceous Bisbee Formation consisting of more than 1000m of sandstones, shales, mudstones, and minor limestones over a basal conglomerate of varying thickness.

Pre-Laramide Structural Deformation

The post-Paleozoic tectonic history of the Tombstone area has been complex. It was certainly affected by tectonics, plutonism, volcanism, and hydrothermal activity while the Jurassic magmatic arc comprised the edge of the North American craton and emplaced porphyry-copper-type mineralization at Bisbee and Courtland Gleeson to its south (50 Km) and to the northeast (25 Km) respectively. At least two episodes of folding and thrust faulting have taken place (Gilluly 1956, p. 122-130). It is apparent that an earlier (Jurassic?) period of deformation created eastward-trending features, and later deformation formed north-trending and oblique features. During the first stage, north-south compression formed east-trending folds and minor thrusts, with a north strike and northerly low-angle dips. Later, the area underwent southwest-northeast compression, which produced thrust faults of northwesterly trend, and was probably responsible for large features visible in the district today, including the Empire anticline and the north 50^0 east fractures.

Laramide Volcanism and Caldera Formation

There must have existed profound structural weakness, perhaps a lineament intersection, at the current location of the Tombstone Hills, because Laramide volcanism appears to form a focus at Tombstone, with relatively lesser effects in the surrounding terrain for a distance of 30 or more Km. Laramide surface volcanism began with the extrusion of the Bronco volcanics, comprised of lower andesite flows and breccias, overlain by rhyolitic tuffs and flows. The lower Bronco andesites, which were extruded as flows, flow breccias, and probable lahars, are of the Silver Bell type. Briscoe (1985) suggests that the upper rhyolites, at least in part, may be a series of coalescing rhyolite domes, as they exhibit contorted flow and, in places, flow breccia structures. Extruded over the Bronco volcanics is the 71.9 $\pm$ 2.4 m.y. (Drewes, 1971) Uncle Sam quartz latite tuff. The extrusion of the tuff, which probably started from the area of the Bronco Hills, resulted in partial evacuation of the underlying magma chamber and caldera collapse, with later resurgent extrusion of more quartz latite tuffs (Briscoe, 1985). The current Ajax fault, with some 1600m of stratigraphic throw, formed the eastern margin of the caldera, and appears to localize some of the 'Uncle Sam' vents, as well as later intrusives. Apophyses of the parent magma intruded along the northeasterly portion of the caldera, forming the present outcrops of Schieffelin Granodiorite southwest of Tombstone. Additional apophyses of Schieffelin Granodiorite intruded along the caldera margin at Bronco Hill, near Fairbank, and on the west side of the San Pedro River on the Ft. Huachuca Military Reservation. These probable intrusions are thought to be the source of aeromagnetic anomalies (Figure 16). The Prompter and Horquilla faults may, in part, be radiating tension fractures due to doming before the extrusion of the Uncle Sam tuff. Several episodes of explosive eruption are indicated by multiple cooling units of Uncle Sam tuff, best exposed in the Charleston area. Convection cells that propelled fluids along fractures in the cooling volcanic and related plutonic rocks at depth gave rise to copper, molybdenum, lead, zinc, silver, and gold mineralization centers within and adjacent to the caldera.

Phreatic explosions and venting probably gave rise to the breccia pipes in the Robbers' Roost-Charleston Lead mine area. Deep exploration drill holes in this area confirm unexposed apophyses of porphyritic quartz monzonite below these altered areas, the probable driving mechanism of both hydrothermal fluidization in the breccia pipes and mineralization. David Sawyer, in his Stanford PhD dissertation, determined the Silver Bell mineral-volcanic complex to be a caldera complex. The Silver Bell andesite, dacite, and Mt. Lord ignimbrite sequence is the same type and sequence of extrusives as are present at Tombstone, i.e., the Bronco andesite, Bronco rhyolite, and Uncle Sam tuff. At Silver Bell, quartz monzonites intrude the caldera fault, to be later mineralized by copper-, molybdenum-, silver-, lead- and zinc-bearing hydrothermal solutions. At Silver Bell, the volcanic complex is Laramide, approximately 65 m.y old.

Age Dates of Volcanic and Intrusive Events

Age dating of samples of altered rock collected by Newell (1974) at the Charleston Lead mine, show a potassium-argon age of sericite of 74.5 $\pm$ 3 m.y., while a sample of the altered Contention dike material collected by Gustafson (Newell, 1974) yielded an age of 72 m.y. The age date of 63 m.y. by Creasey, et al. (1962) for potassium-argon on rhyolite intimately associated with manganese south of the Emerald mine suggests that the age of manganese mineralization (at least in the Military Hill-Emerald mine area south of the Prompter Fault) is approximately 10 m.y. younger than mineralization in the Contention dike and at Charleston. In 1982, Briscoe mapped a previously unnoticed apophysis of quartz monzonite porphyry in the Tombstone Extension area, and dikes of the same material in the Comstock Hill area, northwest of the Tombstone townsite. In 1985, Drewes reported that this rock, the Comstock porphyry, has an age of 62.6 $\pm$ 2.8 m.y. This intrusive may be the source of the rhyolite dated by Creasey that intruded the Prompter fault and occurs as dikes south of the Prompter fault, as well as in sill-like bodies southwest of Tombstone near the municipal airport. Further, they may be the source of rhyolite dikes associated with mineralization in the State of Maine mine area. Unfortunately, no date on the mineralization on the State of Maine mine has been made.

As pointed out by Livingston et al. (1968), "*15 of the 16 known porphyry copper deposits in Arizona are intimately related to late-Cretaceous or early-Tertiary plutons of the Laramide (75 to 55 m.y.)...*", and of these 15 deposits, 10 had dates between 55 and 65 m.y., and only two had dates greater than 70 m.y. The importance of determining the age of Tombstone mineralization is paramount if it is to be linked to porphyry copper systems. If mineralization at Tombstone can be shown to be contemporaneous with other productive 'porphyry copper' deposits in the area, then the long-term potential for deeper mineralization would be enhanced. Briscoe (1985) believes that the extrusion of the Uncle Sam tuff through a series of vents resulted in evacuation of the underlying magma chamber and caldera collapse. The deepest collapse documented by geologic mapping so far is along the Ajax Hill fault, where some 1600m of stratigraphic throw, between the Precambrian on the upside and Cretaceous Bisbee on the downside, is also the locus of conduits for various extrusions and intrusions including the Uncle Sam tuff, the Schieffelin Granodiorite, the quartz latite porphyry, the granophyre, and the rhyodacite.

The reopening of the northeast-trending fracture zones, the prevalent fracture direction in Arizona inherited from the Precambrian, allowed the circulation of geothermally convecting fluids that altered the surrounding rock and emplaced base and precious metal mineralization. At specific spots of high permeability, this hydrothermal activity appeared to be concentrated and the zones of concentration as known at this time would include the main part of the Tombstone district, the State of Maine area, the Robbers' Roost breccia pipe area, the Charleston lead mine area, possibly mesquite-twig Mo geochemical anomalies at Government Draw and Louis Springs (Newell, 1974), and possibly magnetic anomalies at the Charleston crossing, on the Huachuca Military Reservation, west of the San Pedro River, and at Fairbank.

Generally following Newell's (1974) chronology, Briscoe has convincingly rearranged the geochronology to include the new dates and evidence for caldera formation, and intrusion of the Schieffelin Granodiorite after the extrusion of the Uncle Sam tuff and caldera collapse. The rearranged chronology is built upon the chronological evidence cited by Newell. The only major changes are the timing of movement on the Ajax fault, the extrusion of the Uncle Sam tuff, and the intrusion of the Schieffelin Granodiorite along the caldera fracture zone:

Chronological Summary--Igneous and Structural Activity

1. *Pre-Cretaceous movement along the Prompter-Horquilla faults. Evidence: Total offset on the Prompter Fault is about 1300m but the Cretaceous Bisbee Formation is offset only about 900m.*

2. *Folding of the Bisbee Formation in the central portion of the Tombstone district. Evidence:*
   a. *The Tombstone basin is bounded on the west by the Ajax Hill fault.*
   b. *Fold trends are cut by the Schieffelin Granodiorite, which also cuts the Ajax Hill fault.*

3. *Movement along the Ajax Hill fault. Evidence:*
   a. *The Ajax Hill fault cuts the Prompter fault.*
   b. *The Ajax Hill fault is cut by the Schieffelin Granodiorite.*
   c. *The Ajax Hill fault bounds the western margin of the Tombstone basin.*

4. *Extrusion of the Bronco Andesite, followed by extrusion of the Bronco Rhyolite. Evidence:*
   a. *The Bronco Rhyolite cuts the andesite immediately north of the Charleston lead mine.*
   b. *The Uncle Sam tuff cuts the Bronco Andesite (center sec. 28, T.20S., R.22E.).*
   c. *The Uncle Sam tuff intrudes the Ajax Hill fault. Note: The Ajax Hill fault is not in contact with the Bronco volcanics, and the possibility exists that these volcanics pre-date the Ajax Hill fault.*

5. *Intrusion of the north-trending andesite porphyry dikes. Evidence:*
   a. *The dikes cut folds within the Bisbee Formation.*
   b. *The dikes occur in sedimentary rocks which contain the Schieffelin Granodiorite at depth.*
   c. *The dikes do not cut the Schieffelin Granodiorite.*

6. *Intrusion of the Schieffelin Granodiorite. 72 my. Evidence:*
   a. *The granodiorite cuts the Ajax Hill fault.*
   b. *The Schieffelin is less siliceous than the Uncle Sam tuff.*
   c. *Creasey et al. (1962) dated the granodiorite at 72 m.y.*

7. *Renewed movement along the Prompter fault. Evidence:*
   a. *The Prompter fault cuts andesite porphyry dikes.*
   b. *The Prompter fault offsets the Ajax Hill fault.*

8. *Emplacement and extrusion of the Uncle Sam tuff. 71.9 my. Evidence:*
   a. *The Uncle Sam tuff cuts the Bronco volcanics (sec. 28, T.20S., R.22E., and Sec. 25, T.20S., R.21E.).*
   b. *The Uncle Sam tuff follows the Ajax Hill fault.*
   c. *A hornblende andesite dike cuts the Schieffelin Granodiorite and the Uncle Sam tuff north of Bronco Hill.*
   d. *The Uncle Sam tuff is more siliceous than the Schieffelin Granodiorite.*
   e. *A potassium-argon date (71.9 $\pm$ 2.4 m.y., Drewes, 1971) from the Uncle Sam tuff indicates the same age as the Schieffelin Granodiorite.*

9. *Emplacement of the quartz latite porphyry. Evidence:*
   a. *The quartz latite porphyry cuts the Bronco Andesite.*
   b. *The quartz latite porphyry is compositionally very similar to the Uncle Sam tuff. Note: The quartz latite porphyry is probably an equivalent of the Uncle Sam tuff, but textural evidence suggests the porphyry did not vent to the surface.*

10. *Emplacement of the granophyre. Evidence:*
    a. *The granophyre intrudes the Ajax Hill fault.*
    b. *The granophyre is intensely altered, and this may follow upon emplacement of the rhyodacite.*

11. *Emplacement of the rhyodacite. Evidence:*
    a. *The rhyodacite intrudes the Ajax Hill fault.*
    b. *The rhyodacite intrudes the Uncle Sam tuff.*
    c. *Hydrothermal activity with its rhyodacite probably altered the granophyre.*

12. *Earliest fracturing along the northeast-trending fissures. Evidence:*
    a. *The fissures cut the Uncle Sam tuff.*
    b. *The fissures are intruded by hornblende andesite dikes.*

13. *Emplacement of the hornblende andesite dikes. Evidence: The dikes follow the northeast-trending fissures in the Uncle Sam tuff and in the Schieffelin Granodiorite.*

14. *Introduction of hydrothermal solutions and formation of the base-metal and silver deposits at Charleston and at Tombstone. Evidence:*
    a. *Hornblende andesite dikes are hydrothermally altered (Charleston lead mine; sericite date 74.5 $\pm$ 3 m.y., Appendix I).*
    b. *The mineralization followed northeast-trending fractures at Tombstone (Butler and Wilson, 1942, p. 201).*
    c. *Alteration along the Contention dike yielded a potassium-argon date of about 72 m.y. (Gustafson, pers. comm.).*

15. *Emplacement of the rhyolite porphyry, and associated dikes and sills. Evidence:*
   a. *A rhyolite dike cuts an andesite porphyry dike immediately west of Military Hill.*
   b. *The rhyolite intruded the Prompter fault zone.*
   c. *Creasey et al. (1962) obtained a potassium-argon date of 63 m.y. for the rhyolite.*

16. *Renewed minor fracturing along the northeast-trending fissures. Evidence: A northeast-trending fissure cuts the rhyolite dike west of Military Hill.*

17. *Renewed movement along the Prompter fault. Evidence:*
   a. *A rhyolite porphyry dike is cut and offset left laterally about 200 ft by the Prompter fault system.*
   b. *The northeast-trending fissures do not cross faults belonging to the Prompter system.*

18. *Introduction of the manganese mineralization, in the southern part of the district. Evidence:*
   a. *Manganese mineralization is intimately associated with the rhyolite porphyry in the Side Wheel mine west of Military Hill.*
   b. *Alteration related to silver mineralization along the Contention dike yielded an age of about 72 m.y. (Gustafson, pers. comm.)*
   c. *The age of the rhyolite porphyry is about 63 m.y. (Creasey et al., 1962)*
   d. *Manganese deposits are closely associated with the Prompter fault (Butler, Wilson and Rasor, 1938, p. 80), and the rhyolite porphyry has intruded along the Prompter fault.*
   e. *Quartz veinlets were observed paralleling the ore fissure which cuts the rhyolite dike west of Military Hill.*

19. *Partial district tilting to the northeast possibly associated with the northwest faulting. Evidence:*
   a. *Quaternary (?) conglomerate beds along Walnut gulch dip 40º NE.*
   b. *Northwest-trending faults (Grand Central, East Boundary, and Walnut Gulch) have progressively lowered the district to the northeast.*
   c. *Northwest-trending faults post-date the mineralization (Butler, Wilson and Rasor, 1938, p. 37)*

20. *Emplacement of the basalt and phonolite in Walnut Gulch. Evidence: The basalt cuts Tertiary and Quaternary (?) gravels.*

Here follows a chronological summary of igneous and structural activity that accommodates the hypothesis by Briscoe that the Tombstone volcanics and mineral deposits are part of a Laramide caldera complex.

The summary is presented in a tabulated form to allow better separation and understanding of the complex structural history. Underlined words and phrases are those added to Newell's summary by Briscoe.

1. *Pre-Cretaceous* (Nevadan, 180 m.y., contemporaneous with movement along the parallel Dividend fault at Bisbee) *movement along the Prompter-Horquilla faults. Evidence: Total maximum offset on the Prompter fault is about 4,000 ft, and the Cretaceous Bisbee Formation*

is offset only about 2,800 ft.

2. Folding of the Bisbee Formation in the central portion of the Tombstone district - the folding is probably district-wide at least, and may be regional. Evidence:
   a. The Tombstone basin is bounded on the west by the Ajax Hill fault.
   b. Fold trends are cut by the Schieffelin Granodiorite, which also cuts the Ajax Hill fault.
   c. Isoclinal folds in basal Bisbee group sediments, north of the Uncle Sam shaft, State of Maine area.

3. Extrusion of the Bronco Andesite, followed by extrusion of the Bronco Rhyolite. Evidence:
   a. The Bronco Rhyolite cuts the andesite, immediately north of the Charleston lead mine.
   b. The Uncle Sam tuff cuts the Bronco Andesite (center sec. 28, T.20S., R.22E.).
   c. The Uncle Sam tuff intrudes the Ajax Hill fault. Note: The Ajax Hill fault is not in contact with the Bronco volcanics, and the possibility exists that these volcanics pre-date the Ajax Hill fault.

4. Intrusion of the north-trending andesite porphyry dikes. Evidence:
   a. The dikes cut folds within the Bisbee Formation.
   b. The dikes occur in sedimentary rocks which contain the Schieffelin Granodiorite at depth.
   c. The dikes do not cut the Schieffelin Granodiorite.

5. Explosive acid volcanism - extrusion of the Uncle Sam tuff, followed by caldera collapse and resurgence. Evidence:
   a. The Uncle Sam tuff cuts the Bronco volcanics (sec. 28, T.20S., R.22E., and sec. 25, T.20S., R.21E.).
   b. The Uncle Sam tuff follows the Ajax Hill fault.
   c. A hornblende andesite dike cuts the Schieffelin Granodiorite and the Uncle Sam tuff north of Bronco Hill.
   d. (?)The Uncle Sam tuff is more siliceous than the Schieffelin Granodiorite(?).
   e. A potassium-argon date (71.9 $\pm$ 2.4 m.y., Drewes, 1971) from the Uncle Sam tuff indicates it to be the same age as the Schieffelin Granodiorite.

6. Movement along the Ajax Hill fault following caldera collapse - 5 above. Evidence:
   a. The Ajax Hill fault cuts the Prompter fault.
   b. The Ajax Hill fault is cut by the Schieffelin Granodiorite.
   c. The Ajax Hill fault bounds the western margin of the Tombstone basin.

7. Renewed movement along the Prompter fault. Evidence:
   a. The Prompter fault cuts andesite porphyry dikes.
   b. The Prompter fault offsets the Ajax Hill fault.

8. Emplacement of the quartz latite porphyry after caldera resurgence above. Evidence:
   a. The quartz latite porphyry cuts the Bronco Andesite.

b. The quartz latite porphyry is compositionally very similar to the Uncle Sam tuff. Note: The quartz latite porphyry is probably an equivalent of the Uncle Sam tuff, but textural evidence suggests the porphyry did not vent to the surface

9. Intrusion of the Schieffelin Granodiorite. Evidence:
   a. The granodiorite cuts (intrudes) the Ajax Hill fault.
   b. (?)The Schieffelin is less siliceous than the Uncle Sam tuff(?).
   c. Creasey et al. (1962) dated the granodiorite at 72 m.y.

10. Emplacement of the granophyre. Evidence:
    a. The granophyre intrudes the Ajax Hill fault.
    b. The granophyre is intensely altered, and this may be due to the emplacement of the rhyodacite.

11. Earliest fracturing along the northeast-trending fissures. Evidence:
    a. The fissures cut the Uncle Sam tuff.
    b. The fissures are intruded by hornblende andesite dikes.

12. Emplacement of the hornblende andesite dikes. Evidence: The dikes follow the northeast-trending fissures, in the Uncle Sam tuff, and in the Schieffelin Granodiorite.

13. Emplacement of the rhyodacite. Evidence:
    a. The rhyodacite intrudes the Ajax Hill fault.
    b. The rhyodacite intrudes the Uncle Sam tuff.
    c. The rhyodacite probably altered the granophyre (and related alteration of the hornblende andesite dikes above).

14. Introduction of hydrothermal solutions and formation of the base-metal and silver deposits at Charleston and at Tombstone. Phreatic explosive activity at the surface and fluidized breccia pipe formation in the sub-surface at Robbers' Roost and the Charleston lead mine area with attendant hydrothermal alteration and base and precious metal mineralization. Evidence:
    a. Hornblende andesite dikes are hydrothermally altered. (Charleston lead mine; sericite date 74.5 $\pm$ 3 m.y., Appendix I).
    b. The mineralization followed northeast-trending fractures at Tombstone (Butler & Wilson, 1942, p. 201).
    c. Alteration along the Contention dike yielded a potassium-argon date of about 72 m.y. (Gustafson, pers. comm.).
    d. Fluidized breccia pipes at Robbers Roost and Charleston lead mine.
    e. Cupola of quartz monzonite porphyry intersected in Asarco drill holes in Robbers Roost area.
    f. Secondary K-spar, biotite, purple anhydrite, disseminated pyrite, chalcopyrite and molybdenite intersected in Asarco drill holes in the Robbers Roost area.
    g. Sericite, sphalerite, galena, disseminated pyrite, and silver values intersected by Horne drilling in Charleston lead mine area.

15. Emplacement of Extension/Comstock quartz monzonite porphyry. Evidence: Potassium-argon (hornblende) of 62.8 $\pm$ 2.6 m.y. by Briscoe/Drewes.

16. Emplacement of the rhyolite porphyry and associated dikes and sills. Evidence:
    a. A rhyolite dike cuts an andesite porphyry dike immediately west of Military Hill.
    b. The rhyolite intruded the Prompter fault zone.
    c. Creasey et al. (1962) obtained a potassium-argon date of 63 m.y. for the rhyolite.

17. Renewed minor fracturing along the northeast-trending fissures. Evidence: A northeast-trending fissure cuts the rhyolite dike west of Military Hill.

18. Introduction of the manganese mineralization in the southern part of the district. Evidence:
    a. Manganese mineralization is intimately associated with the rhyolite porphyry in the Side Wheel mine west of Military Hill.
    b. Alteration related to silver mineralization along the Contention dike yielded an age of about 72 m.y. (Gustafson, pers. comm.).
    c. The age of the rhyolite porphyry is about 63 m.y. (Creasey et al., 1962).
    d. Manganese deposits are closely associated with the Prompter fault (Butler, Wilson & Rasor, 1938, p. 80), and the rhyolite porphyry has intruded along the Prompter fault.
    e. Quartz veinlets were observed paralleling the ore fissure which cuts the rhyolite dike west of Military Hill.

19. Renewed movement along the Prompter fault. Evidence:
    a. A rhyolite porphyry dike is cut and offset left laterally about 200 ft by the Prompter fault system. <u>The Free Coinage vein in the State of Maine area is offset 200 ft left laterally by the northern bifurcation of the Prompter fault.</u>
    b. The northeast-trending fissures do not cross faults belonging to the Prompter system.

20. Partial district tilting to the northeast possibly associated with the northwest faulting. Evidence:
    a. Quaternary (?) conglomerate beds along Walnut Gulch dip 40^0 NE.
    b. Northwest-trending faults (Grand Central, East Boundary, and Walnut Gulch) have progressively lowered the district to the northeast.
    c. Northwest-trending faults post-date the mineralization (Butler, Wilson & Rasor, 1938, p. 37).

21. Emplacement of the basalt and phonolite in Walnut Gulch. Evidence: The basalt cuts Tertiary and Quaternary(?) gravels.

Perhaps the greatest impact of this expanded interpretation of the geologic history of the Tombstone area is upon the scale of the potential mineralized totality. Until about 1970, most geologists viewed Tombstone as a small-scale localized precious-metal epithermal to mesothermal replacement system in carbonate host rocks, generally restricted to a square kilometer or so of area around the Lucky Cuss-Toughnut sites beneath the streets of the townsite. We now perceive of it as not just a single porphyry-related system and thus of 10 square Km potential, but rather as a ring of porphyry-related systems along a sub-circular fracture zone with exploration targets of several tens of Km^2. Recent (post 1988) understanding of gold peripheral enrichments, normally accompanied by silver, further enhance these exploration targets and elevate Tombstone into the ranks of attractive gold exploration situations.

The following paragraphs develop that concept.

A Model for Caldera Formation and Multiple Zoned Porphyry-Copper-Related Precious Metal Hydrothermal Systems

Improved understanding of the extrusive volcanic environment and of associated intrusive systems, and the relationship of both to convective hydrothermal cells, allows better understanding of the mineral systems within the Tombstone Mining District (Figures 21 & 22). We have known for two decades that porphyry systems are zoned laterally as well as vertically (Figures 23, 24 & 25). Further, the surface expressions of porphyries appear to be volcanic edifices (Figures 23). It appears, at least in the southwestern USA, that porphyries can be associated with caldera complexes, and that the Tombstone volcanic terrain is such a Laramide caldera complex (Briscoe, 1982 & Lipman & Sawyer, 1985). The remaining volcanic tuff - the Uncle Sam tuff - is an intracaldera tuff, but the tuff outside the caldera rim, however thick, appears to be completely eroded away.

From a variety of evidence including characteristic alteration zoning, mineralization zoning, and geochemical halos, there are several porphyry centers within and around the Tombstone caldera complex. The geologic developments of this last decade suggest that additional porphyry centers may be recognized as the details of the geologic picture unfold.

The most compelling evidence for such porphyry centers is the regional geochemical pattern derived from the district-wide sampling conducted by Newell (1974). That data, re-compiled by Briscoe and Waldrip (1982), is presented here as Figures 6 through 15. It shows characteristic porphyry copper metal zoning of Cu-Mo 'high' areas surrounded by lead-zinc-silver halos, most strikingly apparent when Mo is presented with Zn (Figure 11).

When the geochemical data from Newell are combined with data from geologic mapping, aeromagnetic surveys, drill information, metal production, observations of surface characteristics, and color air photo interpretation, it can be deduced that 'porphyry' centers are present at:
(1) the main Tombstone district, the porphyry center under the southeast corner of the Tombstone townsite; (2) the State of Maine mine area; (3) the Robbers' Roost breccia pipe area; and (4) because the mesquite tree geochemical anomalies are similar, the Johnson Ranch area in the southeast part of the district, adjacent to the caldera.

PROPOSED EXPLORATION

The actual target claim blocks to be examined by JABA and Excellon are blocks either staked or acquired by JABA over a period of several years between 1980 and 1993. There are five prime areas, the Walnut Creek, the Prompter Ridge, the State of Maine Escapule, the Johnson Ranch, and the Robbers' Roost lease groups.

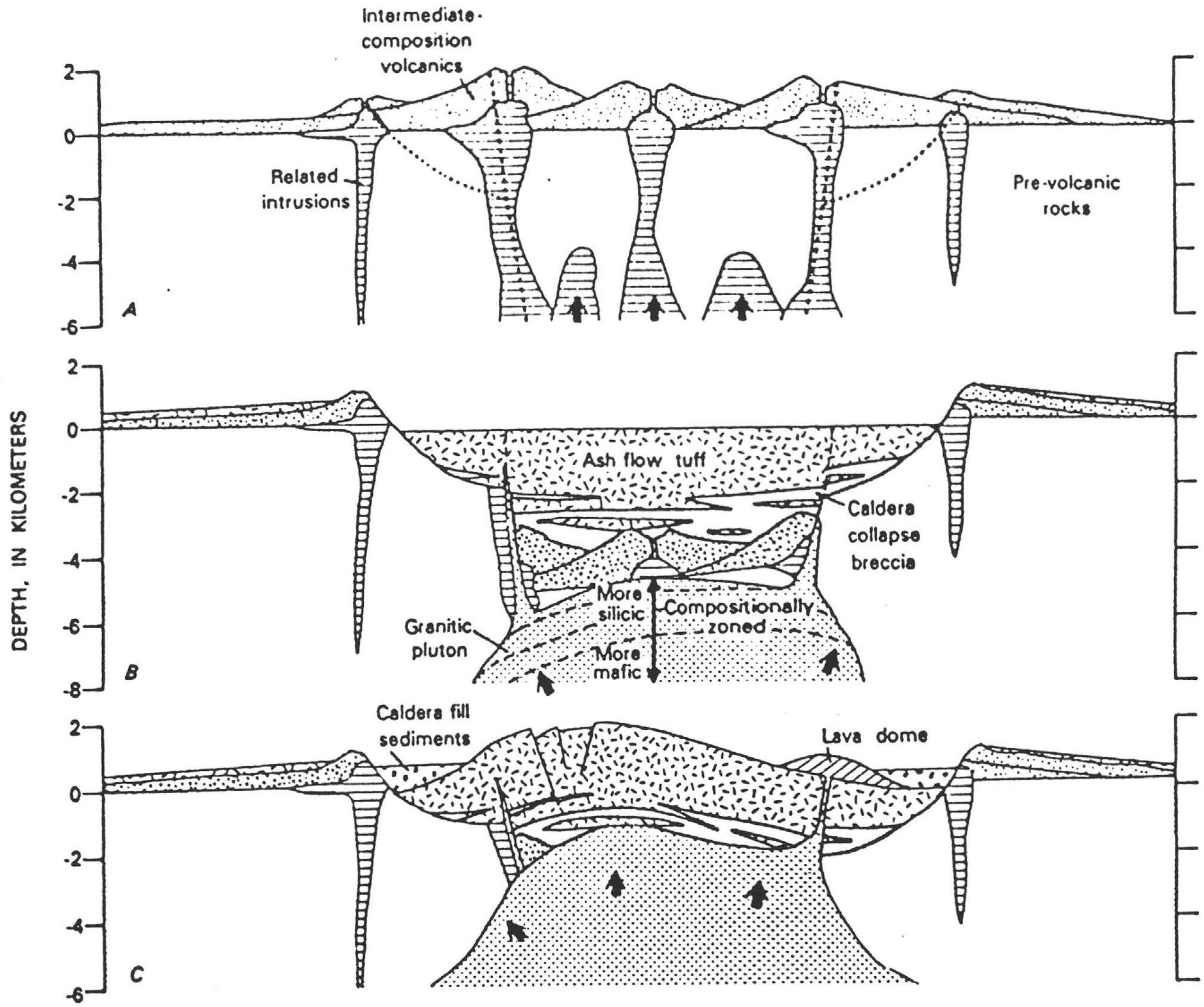
SUMMARY OF TOTAL RECORDED PRODUCTION AT TOMBSTONE
1879 TO 1937
CALCULATED TO CURRENT VALUES - $400 GOLD, $10 SILVER, $1.00 COPPER, $.50 LEAD, $.40 ZINC

SOURCE & YEAR	TOTAL VALUE OF PRODUCTION IN YEAR PRODUCED	CALCULATED OUNCES OF GOLD PRODUCED	VALUE AT $400/OZ.	CALCULATED OUNCES OF SILVER PRODUCED	VALUE AT $10/OZ.	CALCULATED POUNDS OF LEAD PRODUCED	VALUE AT $.50/LB.	CALCULATED POUNDS OF COPPER PRODUCED	VALUE AT $1.00/LB.	CALCULATED POUNDS OF ZINC PRODUCED	VALUE AT $.40/LB.	TOTAL CURRENT VALUE OF PRODUCTION
J. B. TENNEY												
1879 TO 1907	28400000	192356	76942400	24338159	243381590	31805070	15902535	NRP*	NRP	NRP	NRP	336226525
MINERAL RESOURCES OF THE UNITED STATES												
1908 TO 1934	8138571	57971	23188400	6659692	66596920	23767829	11883915	2358495	2358495	1058234	423294	104451023
TOMBSTONE DEVELOPMENT TOMBSTONE MINING CO'S.												
1935 TO 1936	564437	6375	2550000	390305	3903050	3197305	1598653	157536	157536	NRP	NRP	8209239
TOMBSTONE EXTENSION												
1930 TO 1937	374972	1083	433056	1080491	10804907	6335734	3167867	NRP	NRP	NRP	NRP	14405829
TOTAL	37477980	257785	103113856	32468647	324686467	65105938	32552969	2516031	2516031	1058234	423294	463292616
AVERAGE/TON**		0.21	82.22	25.89	258.90	51.91	25.96	2.01	2.01	0.84	0.34	369.42

*NO RECORDED PRODUCTION

**TOTAL TONNAGE ASSUMED TO BE - 1254097

Figure 20: **Metal Production and Average Grade Per Ton at Tombstone, 1879 to 1937**



A generalized ash flow caldera cycle. These diagrams incorporate many common elements of ash flow calderas; complex possible alternative scenarios are discussed in the text. (*a*) Precollapse volcanism. Clustered intermediate-composition stratovolcanoes grow over isloated small high-level plutons that mark beginning of accumulation of batholithic size silicic magma body that will feed ash flow eruptions. Uplift related to emplacement of plutons leads to development of arcuate ring fractures: site of subsequent caldera collapse indicated by dotted lines. Heavy arrows indicate upward movement of magma. (*b*) Caldera geometry just after ash flow eruptions and concurrent caldera collapse. Central area of clustered earlier volcanoes caves into collapsed area. Intracaldera tuff ponds during subsidence and is an order of magnitude thicker than cogenetic outflow ash flow sheet. Initial collapse along ring faults is followed by slumping of oversteepened caldera walls and accumulation of voluminous collapse breccias that interfinger with ash flow tuff in the caldera fill sequence. Caldera floor subsides asymmetrically and is tilted to the left side of diagram. Main magma body underlies entire caldera area and is compositionally zoned (or was prior to eruptions), becoming more mafic downward. (*c*) Resurgence and postcaldera deposition. Resurgence is asymmetrical, with greatest uplift in area of greatest prior collapse. Extensional graben faults form over crest of the dome. Some resurgent uplift is accommodated by movement along the ring faults in the sense oppposite that during caldera subsidence. Magma body has risen into volcanic pile and intrudes cogenetic intracaldera welded tuff. Original caldera floor has been almost entirely obliterated by rise of the magma chamber to near the level of prevolcanic land surface. Caldera moat is partly filled by lava domes and volcaniclastic sediments. Hydrothermal activity and mineralization become dominant late in cycle.

Figure 21: Generalized Ash Flow Caldera Cycle - Peter Lipman

tains, base- and precious-metal veins are widespread (Drewes, 1971a), and the potential for concealed mineralization seems high.

TOMBSTONE-CHARLESTON AREA

The Uncle Sam Porphyry, considered intrusive rhyolite by Gilluly (1956), was identified as a 74 Ma welded tuff by Drewes (1971b, p. 75). Our observations (Fig. 2D) confirm previous suggestions of a possible Cretaceous caldera in this area (Drewes, 1980, section D-D′; J. A. Briscoe, 1982, written commun.). The Tombstone-Charleston area contains a little-deformed caldera-fill assemblage 15 by 20 km across, including intracaldera Uncle Sam tuff and associated collapse breccia, intruded by the 76 Ma Schieffelin Granodiorite. Exposed granodiorite is postulated to

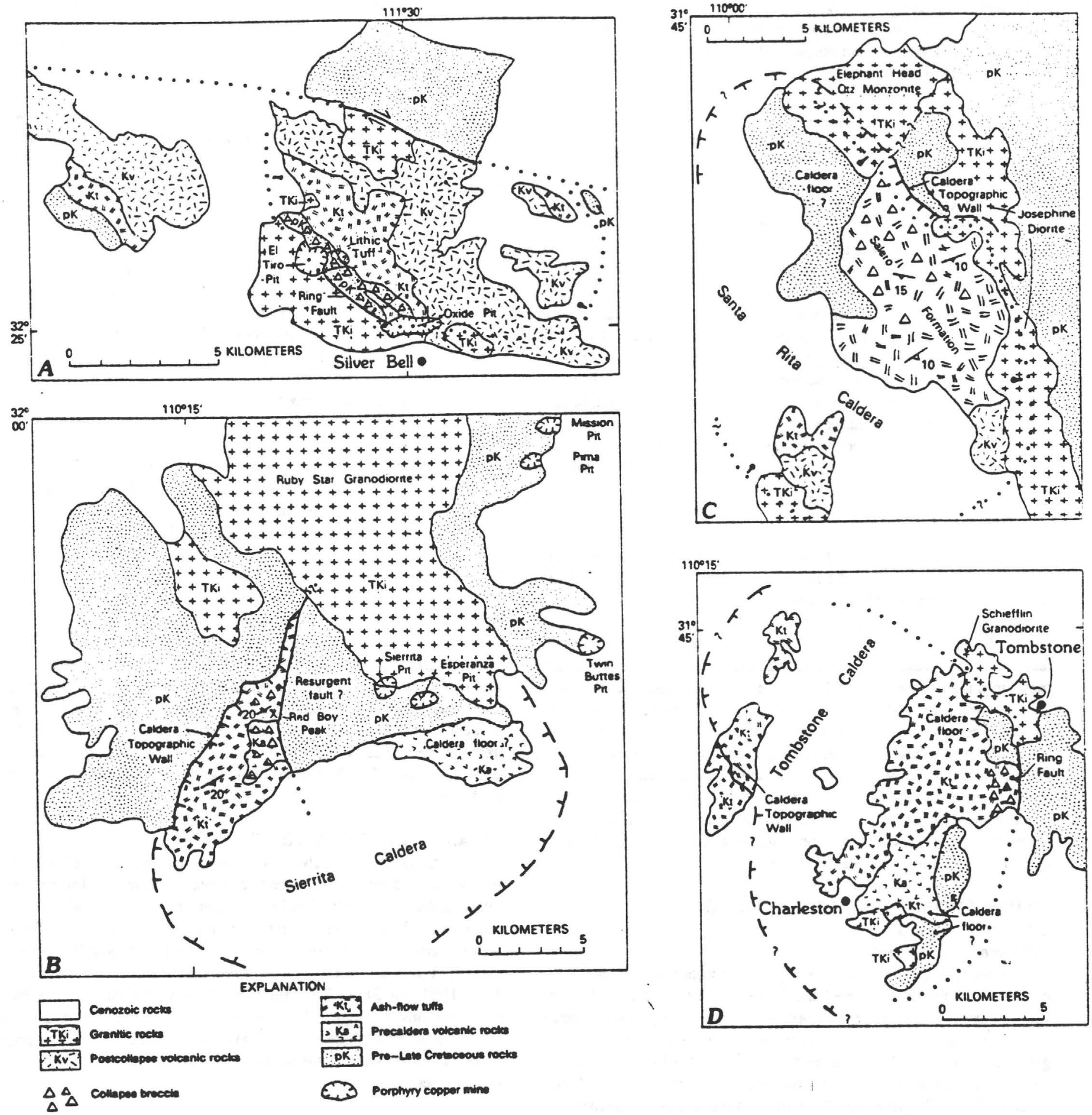


Figure 2. Generalized geologic maps of areas interpreted as containing fragments of Late Cretaceous calderas (most regional structures omitted). A: Silver Bell Mountains, Arizona (from D. A. Sawyer, in prep.). B: Southern Sierrita Mountains (modified from Cooper, 1973). C: Southwest Santa Rita Mountains (modified from Drewes, 1971a). D: Tombstone-Charleston area (modified from Gilluly, 1956; Drewes, 1980).

Figure 21b: **Tombstone Caldera with Three Other Porphyry Copper Associated Calderas, SE AZ - Lipman and Sawyer** constitute a ring-fault intrusion. Southwest of Tombstone, the Uncle Sam Porphyry" encloses variably rotated megabreccia blocks of Lower Cretaceous sedimentary rocks; the tuff is at least 1 km thick; no base is exposed and the top is eroded. Northwest of Charleston, gently dipping Uncle Sam tuff abruptly thickens to the east, truncates an older ash-flow sheet, and farther east becomes the matrix of compositionally diverse blocks of lava tens of metres across. These features are interpreted to mark the western topographic wall of the Tombstone caldera. The productive Ag-Pb-Zn-Cu veins of the Tombstone district are along the northeast caldera margin, and porphyry-type alteration (Newell, 1974) is locally strong within the caldera.

DOS CABEZAS MOUNTAINS

Cretaceous volcanic rocks in the northern Dos Cabezas Mountains were recognized as fragmental pyroclastic breccias by Erickson (1968), who considered them to be intrusive. Drewes et al. (1985) interpreted the pyroclastic breccias as partly intrusive, partly extrusive, and perhaps related to caldera subsidence. We interpret the entire pyroclastic assemblage as an eruptive caldera-fill sequence at least 3–4 km thick and dipping homoclinally southwest, as indicated by compaction foliation. The sequence is relatively lithic-poor welded tuff in its lower part; fragments increase in size and abundance upward, but the upper part is again lithic-poor tuff. At least part of a mapped rhyolite "ring dike" (Drewes et al., 1985) is concordant lithic-poor densely welded tuff low in the caldera-fill sequence. Several areas mapped by Drewes as intrusive breccia are semiconcordant lithic-rich horizons within the caldera fill. Mineralized rock is associated with several Cretaceous granitic intrusions into the intracaldera tuff and breccia, but assessment of the mineral potential would benefit from an improved genetic understanding of the volcanic ocks.

TUCSON MOUNTAINS

The "Tucson Mountain Chaos" contains sedimentary and volcanic blocks tens of metres across, set in a pyroclastic matrix, and ascribed to diverse tectonic and igneous processes (Mayo, 1963). The chaos underlies the Upper Cretaceous Cat Mountain Rhyolite (72 Ma), a welded tuff at least 300–400 m thick. Much of the matrix of the chaos is petrographically similar to weakly welded Cat Mountain, and the contact between these units is locally gradational. A caldera-collapse breccia origin has been inferred previously for the chaos (Lipman, 1976), and we interpret the entire central and southern Tucson Mountains to be remnants of the fill and floor of a large Late Cretaceous caldera that was the source of the Cat Mountain Rhyolite. Caldera boundaries to the east and west are under adjacent valley fill, but the 73 Ma Amole pluton in the northern Tucson Mountains is interpreted as a caldera-margin intrusion. Several porphyry copper prospects have been identified in the Tucson Mountains, although none have been developed.

OTHER PROBABLE LATE CRETACEOUS CALDERA FRAGMENTS

Hillsboro, New Mexico

A nearly circular exposure of Upper Cretaceous andesite 5–6 km across, within which is centered the 72 Ma Copper Flat Quartz Monzonite and associated porphyry copper deposits, was interpreted as a small caldera by Dunn (1982). No Cretaceous ash-flow tuff is preserved as regional outflow, but quartz-bearing tuff breccia occurs locally within the exposed andesite and also was encountered during exploratory drilling Dunn, 1982). The presence of this tuff and the lack of stratigraphy in the thick intracaldera andesite (base not penetrated in a 900-m drill hole) suggest that the Copper Flat caldera may have been a source of ash-flow eruptions whose outflow deposits have been completely eroded. The intracaldera andesite may be collapse breccia, as suggested by the intermixed tuff. This caldera, though smaller than many ash-flow calderas, is similar in size to Crater Lake, Oregon, if structural margins are compared.

Courtland-Gleason

The Sugarloaf Quartz Latite, discontinuously exposed in the southeast Dragoon Mountains, was recognized as pyroclastic by Gilluly (1956) and dated at 75 Ma at its type locality (Drewes, 1971b). There, it is relatively unaltered quartz latite welded tuff several hundred metres thick; no depositional top is exposed. In the adjacent Courtland mining district, which contains porphypry copper mineralization (D. Norton, 1984, oral commun.), altered rhyolitic tuff correlated with the Sugarloaf by Gilluly contains map-scale megabreccia blocks of Paleozoic sediments (Drewes, 1981, Pl. 4). If Gilluly's correlation is valid, the thickness of the Sugarloaf Quartz Latite and its enclosed blocks make it an attractive candidate for caldera fill, associated in space and time with porphyry copper mineralization.

Ajo

The 63 Ma Cornelia Quartz Monzonite, host to the porphyry copper system at Ajo, intrudes the Cretaceous Concentrator Volcanics, an assemblage of andesitic flows, breccia, and rhyolitic tuff. Stratigraphic relations are obscure among these rocks, which are likely more than 1000 m thick; neither base nor top is exposed. In places, the tuff forms matrix surrounding and veining irregular masses of andesite (Watson, 1968), suggesting a deeply eroded caldera-collapse breccia.

Red Mountain (Patagonia Mountains)

Intense hydrothermal alteration obscures the origin of Upper Cretaceous–lower Tertiary tuffaceous silicic rocks at least 1 km thick overlying a major porphyry copper system at Red Mountain. Preservation in a small (5-km diameter) caldera seems possible (Corn, 1975).

Central Galiuro Mountains

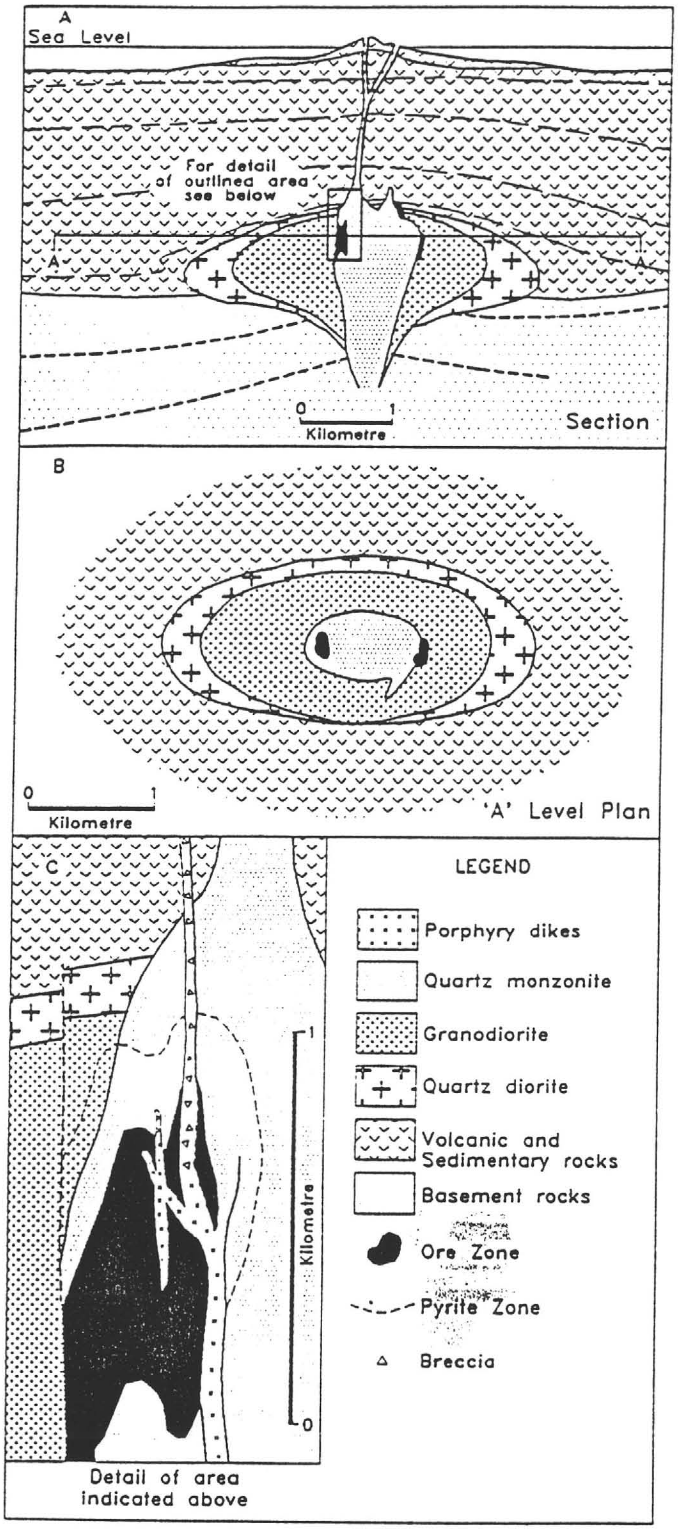
In the Copper Creek area, features of the Upper Cretaceous Glory Hole Volcanics (Simons, 1964) suggest a caldera-fill assemblage, intruded by the 68 Ma Copper Creek Granodiorite which generated a porphyry copper system. The Glory Hole Volcanics are described as a chaotic assemblage of ash-flow tuff and andesitic breccia more than 500 m thick; neither depositional base nor top is exposed; pyroclastic rocks are dominant and tuffaceous breccia abundant. Mappable Paleozoic rocks, interpreted as later landslide deposits (Krieger, 1968) but locally enclosed within the Glory Hole Volcanics, could be synvolcanic megabreccia related to caldera collapse.

JURASSIC CALDERA FRAGMENTS

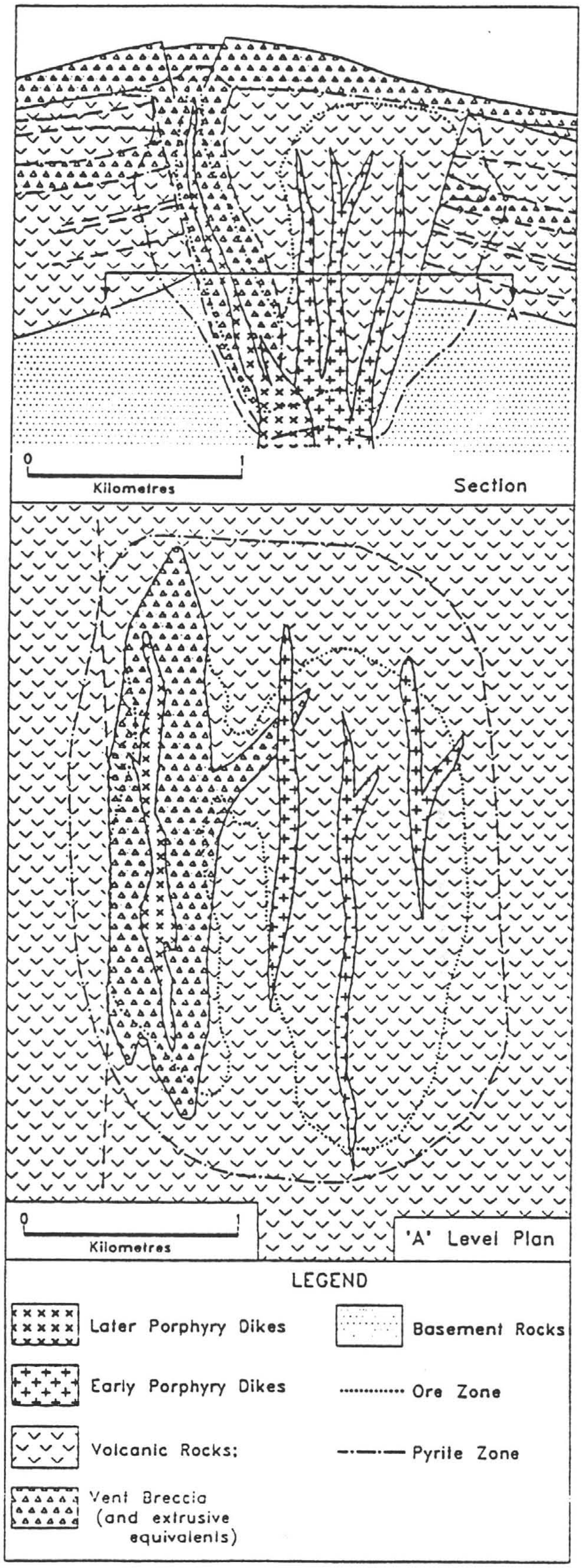
The Cretaceous pyroclastic rocks and associated caldera fragments just summarized overlie tectonically disrupted remnants of Jurassic arc volcanics that also display local evidence of ash-flow and caldera origin. Sequences of Jurassic welded tuff 1 km or more thick, locally enclosing "exotic-block" breccias, are present in the Canelo Hills and Patagonia Mountains (Simons et al., 1966), the Huachuca Mountains (Hayes and Raup, 1968), the Santa Rita Mountains (Drewes, 1971b), and the Pajarito Mountains (N. Riggs, 1985, oral commun.). Little mineralization has been reported from these rocks, but association of the porphyry copper deposit at Bisbee with a Jurassic intrusion suggests additional potential in Jurassic rocks.

DISCUSSION

At least 10 latest Cretaceous–early Tertiary calderas have been identified within a region of about 20 000 km^2 (Fig. 1), and at least 5 more of Jurassic age are probably present. These are minimum numbers, as



Model of Cordilleran plutonic-type porphyry copper deposits (after Sutherland Brown, 1976).



Model of Cordilleran volcanic-type porphyry copper deposits (after Sutherland Brown, 1976).

Figure 22: Models of Plutonic and Volcanic Porphyry Coppers

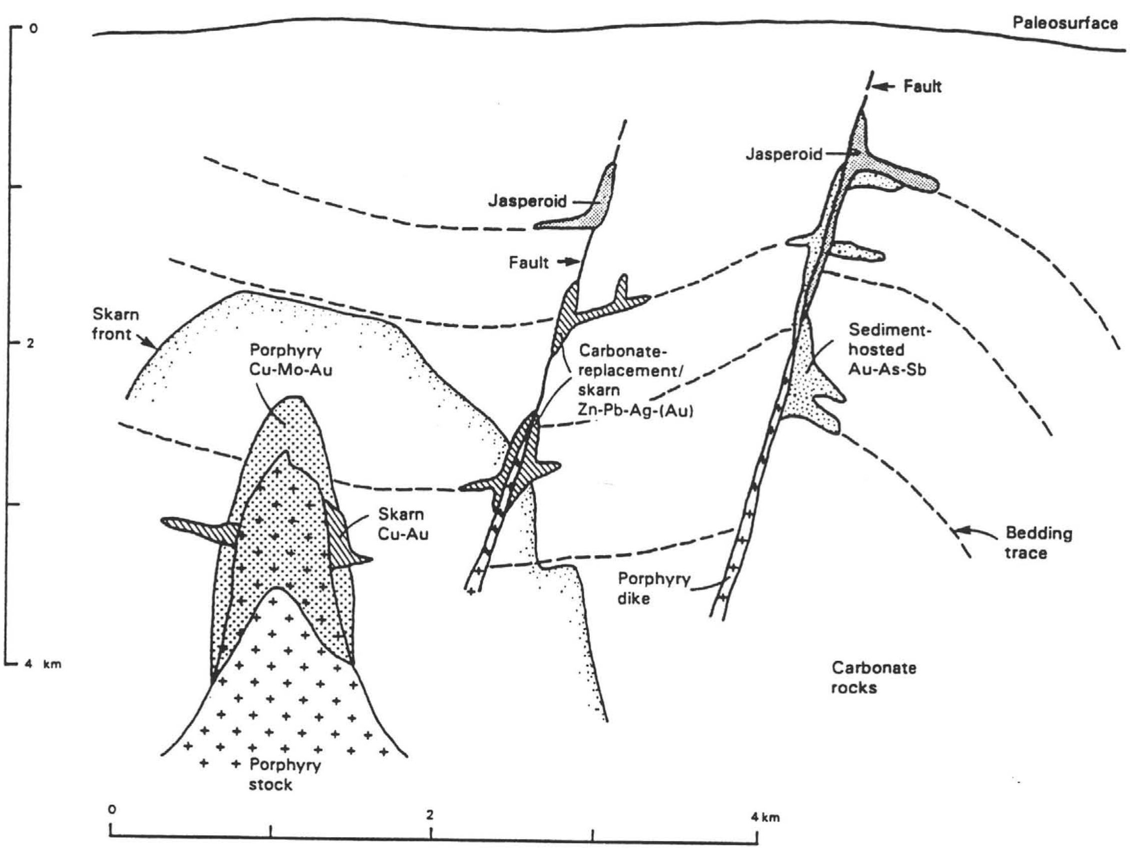


Figure 3. Schematic model to illustrate typical position of sediment-hosted gold deposits on peripheries of intrusion-centered base- and precious-metal districts.

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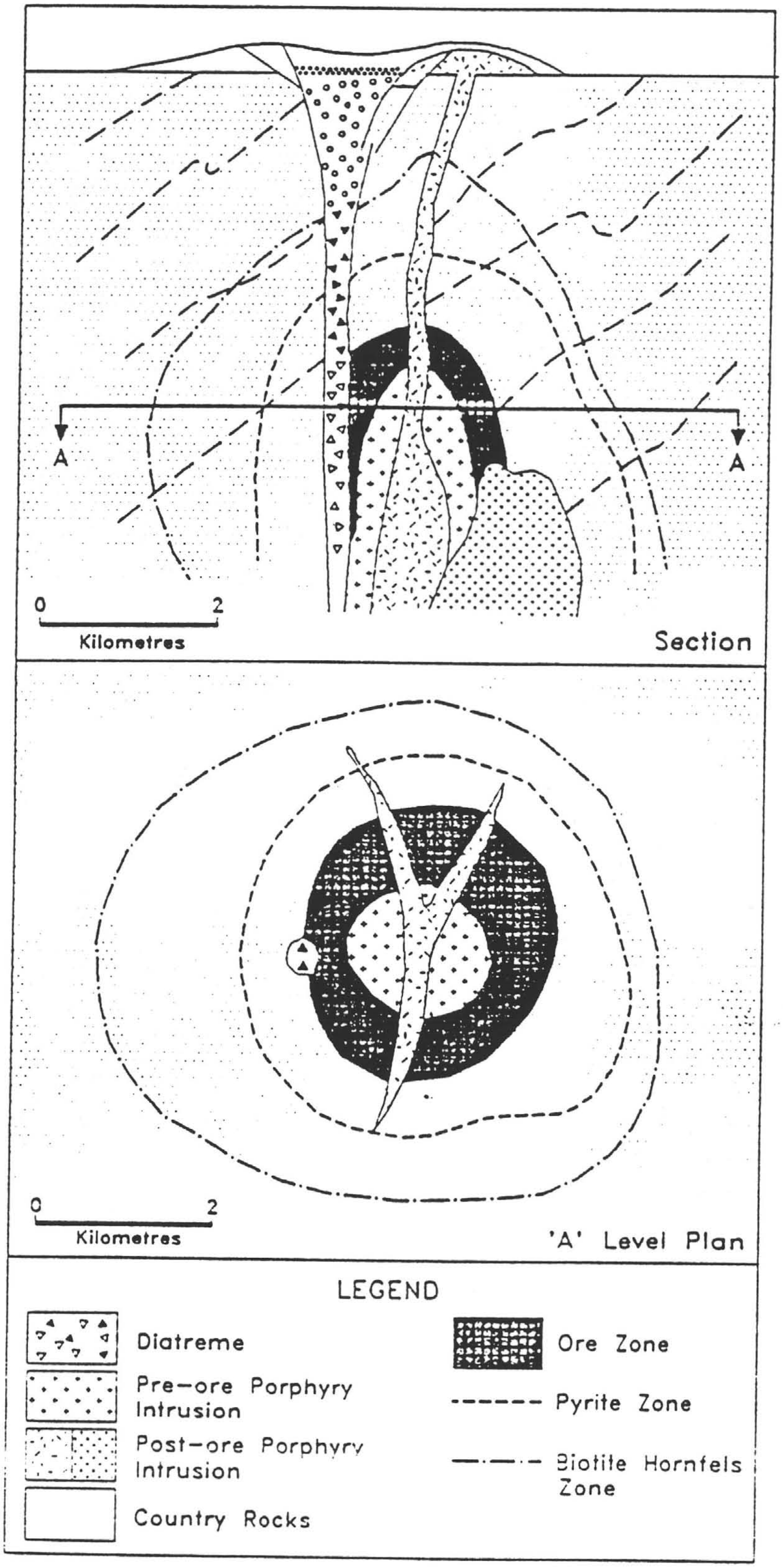
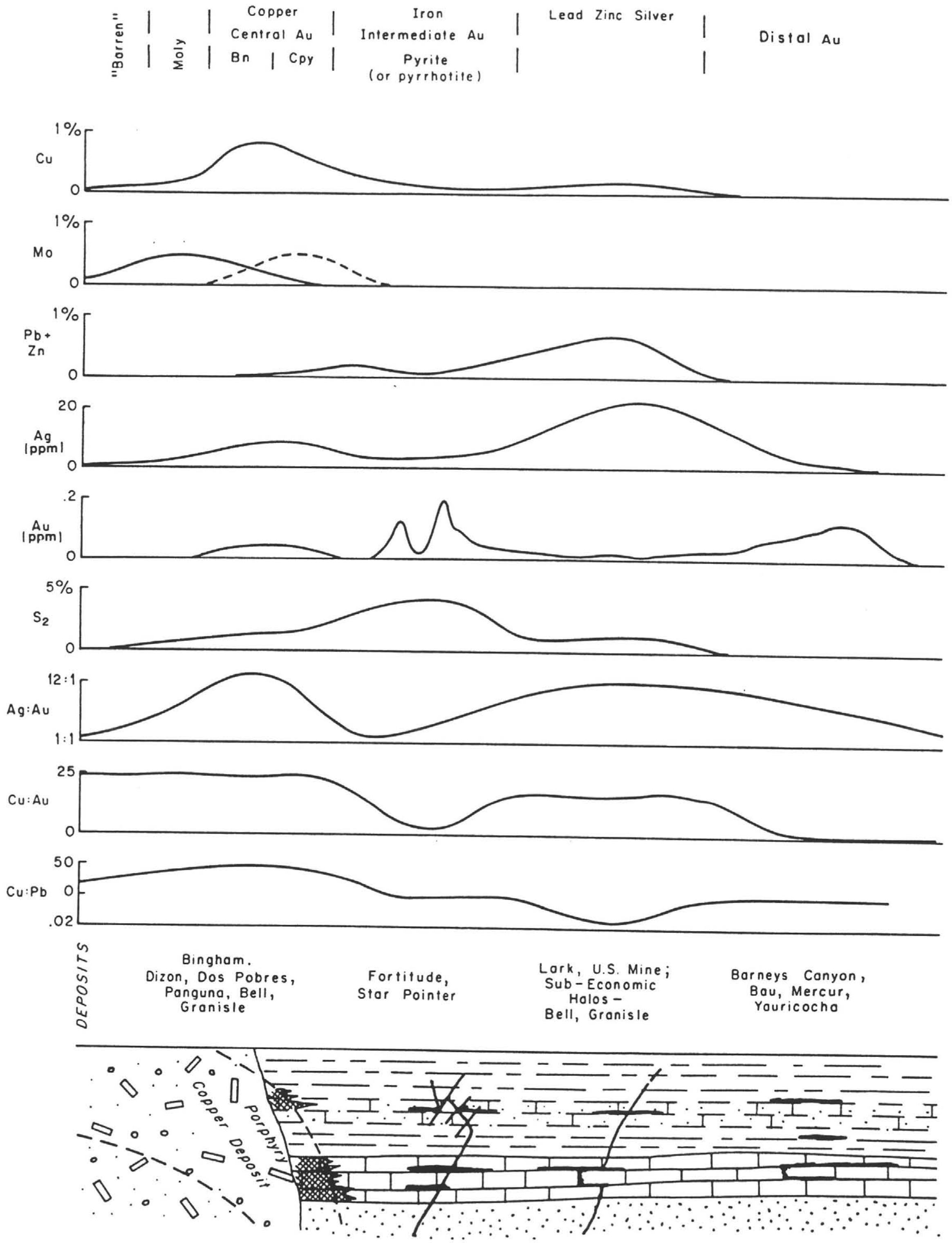
Figure 23: Schematic Model of Possible Links Between Porphyry Districts and Sediment-Hosted Gold Deposits



Model of Cordilleran classic-type porphyry copper deposits (after Sutherland Brown, 1976).

Figure 24: Model of Classic-Type Porphyry Copper Deposits



Generalized zoning model for gold-enriched porphyry copper systems showing changes in metal concentrations and metal ratios with distance from the source intrusion. All element concentrations are in ppm, unless "%" shown. Ag:Au is ppm Ag/ppm Au; Cu:Au is %Cu/ppmAu; and Cu:Pb is %Cu/%Pb.

Figure 25: Generalized Zoning Model for Gold Enriched Porphyry Copper Systems

The Walnut Creek group has no bedrock outcrop, but it is staked over and near a geochemically-geophysically-geologically projected porphyry-copper center. The Prompter Ridge has moderate outcrop and is of porphyry-distal gold-silver interest. The State of Maine-Escapule has moderate outcrop and excellent subsurface data and is a distal porphyry target, and the Johnson Ranch is similar to Walnut Creek. The recently discovered Zebra Project resource of gold mineralization in Paleozoic limestones distal to the claim areas - near the airport (Figure 3) - adds to the project feasibility. An ongoing USMX drilling project immediately west of the Contention pit is designed to intersect projections of fold-fault-shear structures known from old workings and the literature to be mineralized along strike; the project also reflects a new exploration strategy in which gold, rather than silver, is the prime economic target.

The following paragraphs describe the JABA-Excellon claim blocks and exploration strategies in greater detail.

The Main Tombstone District - Walnut Creek Porphyry Center (Block 1) and Prompter Ridge Distal Gold Target (Block 2)

The main Tombstone district has produced approximately 1/3 of a billion modern dollars worth of gold, silver, lead, copper, zinc, and manganese. A zoning pattern is apparent from production and alteration-mineralization studies. High manganese-silver mineralization characterized the outer arcuate rim of mines from northwest to southeast, including the Lucky Cuss, Prompter-Oregon, Emerald, and Bunker Hill. As one moves from the outer manganese zone toward the southeast corner of the townsite, Mn decreases while Zn, Cu, silica, Au, F, and Mo increase (Figures 6-11). Because of cover, the central zone porphyry, if it exists, is never seen. The bedrock into which the mineral system is presumed to have been emplaced is composed of a thick section in all directions of 2 Km of Paleozoic carbonates capped by an unknown remaining thickness of Cretaceous clastics of the Bisbee formation. Before its erosion, a blanket of unknown thickness of extracaldera Uncle Sam tuff capped the Laramide erosion surface on the Bisbee sediments. It would be expected that such a porphyry mineral system would consist of skarn alteration of the carbonates proximal to the mineral center along with carbonate replacement bodies of massive sulfides of zinc, lead, and perhaps at some depth copper and molybdenum. The record of such mineralization is an exploration objective, but what we do know is compelling. Exploration by Eagle Pitcher Mining Co. in the 1950's discovered massive sphalerite galena-silver bodies (Burton Devere, pers. comm. to Briscoe, 1982), and production of this type of material from the Jeanes Roll was documented by Butler & Wilson. Ransome's unpublished notes from his first investigations in the district in 1914 contain comments about pervasive calc-silicate alteration of the Naco limestone on the 600 ft level of the Contention mine.

Although the suspected Walnut Creek porphyry center is under cover, zonation of precious metals in exposed rocks around the projected porphyry center is similar to recently recognized haloes around better exposed porphyries (Figure 25). Excellon Resources, as part of its exploration campaign in the Tombstone area, contracted for new orthophotography at 1" = 2,000'. It is apparent on this new photography that the Prompter fault is not straight as it has been mapped previously, but rather is concave to the north. It lines up with the north- to northeast-concave Lucky Cuss fault system. The combination of the two faults describes an arcuate structure the centroid of which is the projected Walnut Creek porphyry center. These faults localize manganese-silver mineralization that may reasonably be interpreted as the outer part of a porphyry alteration zonation.

Recent gold discoveries at Chimney Creek, Bingham Canyon, and the adjacent Barney's Canyon and studies on these and other areas by Osterberg and Guilbert (1989), Sillitoe and Bonham (1990), and Schuh and Guilbert (1993) show that there can be a distal gold zone around porphyry systems hosted by carbonate and pelitic sedimentary rocks. According to Sillitoe and Bonham (1990) these gold halos occur up to a radius of 5 Km away from the porphyry center. Mineralization can consist of little besides gold and minor silica as jasperoid. Volatile metals such as mercury and arsenic may be present geochemically. The inner portion of this outer gold zone may be the outer manganese zone (pers. comm., Sillitoe, 1992), which is also present as a halo around Bisbee, Ruth-Ely, San Manuel, and elsewhere. Such an outer gold zone appears to have been discovered by Santa Fe Pacific Mining in the spring of 1992 in the area south of the Prompter mine. Another significant occurrence of the distal Tombstone gold zone is at the Zebra Property which lies just south of the Tombstone airport. There, disseminated invisible Carlin? style gold of up to an ounce per ton on the surface is disseminated in the Upper Paleozoic Naco formation. The Zebra Property is about 5 Km from the projected porphyry center in the southeast corner of Tombstone.

These targets were recognized by Briscoe circa 1980, and at that time Walnut Creek, Block 1, consisting of 55 unpatented lode mining claims, and Prompter Ridge, Block 2, consisting of 48 lode mining claims, were staked (Attachment 1). Block 1 covers the area of the projected porphyry copper center while Block 2 covers area prospective for distal gold mineralization south of the Prompter fault.

The Johnson Ranch Porphyry Center (Block 3)

This block is comprised of 66 unpatented lode mining claims totalling 1,366 acres (Attachment 1). The claims are staked over a silver-molybdenum anomaly defined by Newell (1974) in his mesquite twig geochemical sampling (Figures 12 & 15), a pattern similar to that over the main Tombstone porphyry center. The suggestion is that there may be another Tombstone-like porphyry system in the Johnson Ranch area. If so, it is hidden beneath Quaternary soil and alluvium. Molybdenum and copper in mesquite tree new growth, whose roots probe as deep as 80m, have been a recognized geochemical exploration tool since 1970 studies in the Pima Mining District south of Tucson and elsewhere, showed such anomalies to reflect the presence of porphyry ore bodies. Silver goes along with molybdenum geochemically and reinforces the anomaly at Johnson Ranch.

State of Maine-Escapule Porphyry Center (Block 4)

The State of Maine mine area and an area within a radius of about 2 Km around the State of Maine shaft appears to be another porphyry center. Again the most compelling evidence is Newell's geochemistry data, which shows a significant molybdenum anomaly over this area (Figures 10 & 11). Mapping shows wide hydrothermal veins in Uncle Sam tuff. Vein area (length x width of mapped veins) is greater than in the Tombstone center. An apophysis of rhyolite near the State of Maine mine may be the top of a porphyry body.

Outcrops in the immediate State of Maine mine area are intracaldera Uncle Sam tuff, the type locality being Uncle Sam Hill adjacent to the State of Maine mine. Alteration at the surface is

INTERPRETIVE CROSS SECTION OF THE STATE OF MAINE MINE AREA
SCALE APPROXIMATELY 1 INCH = 300 FEET

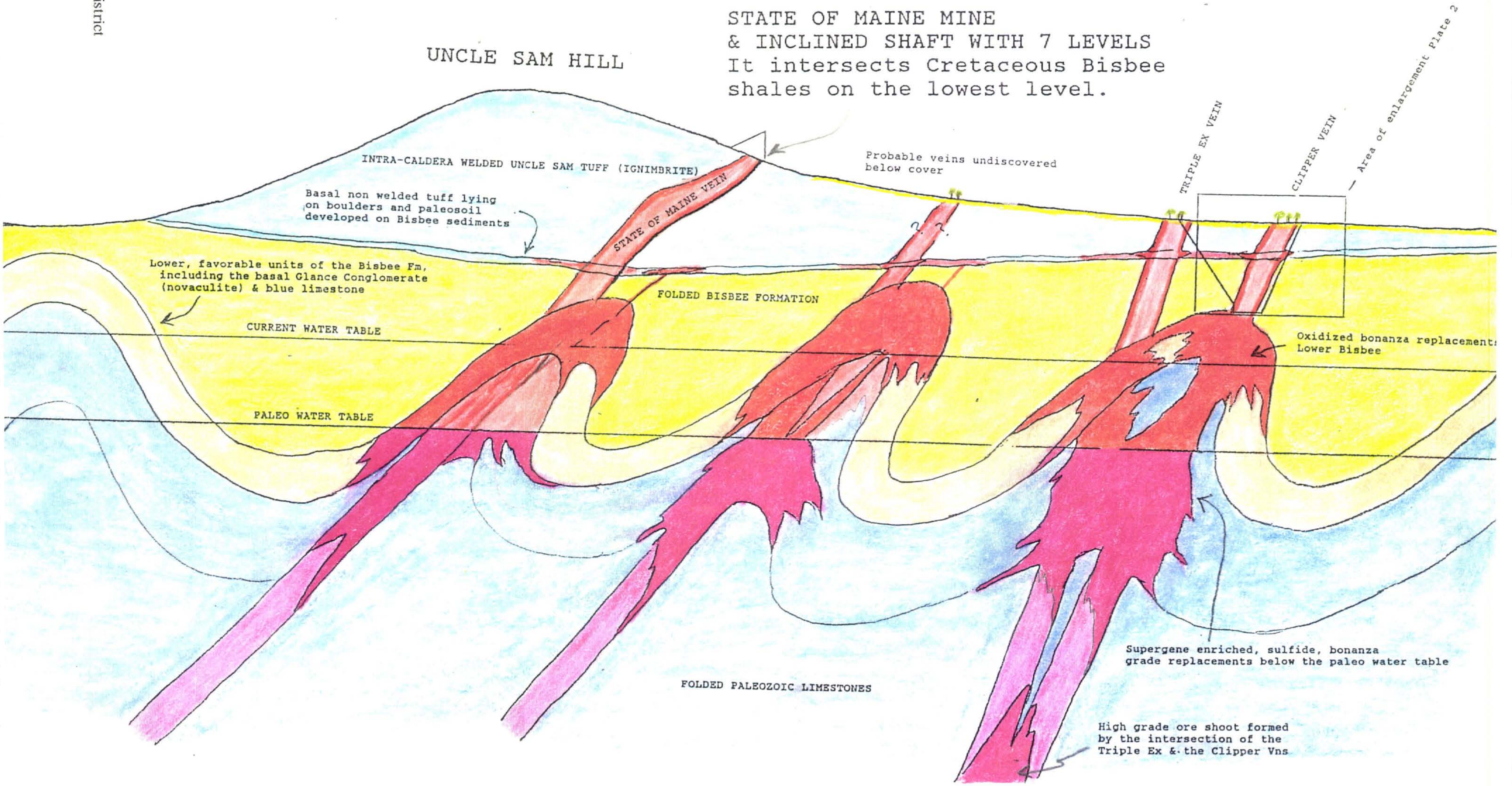


Figure 26: Interpretive Cross-Section of the State of Maine Mine Area

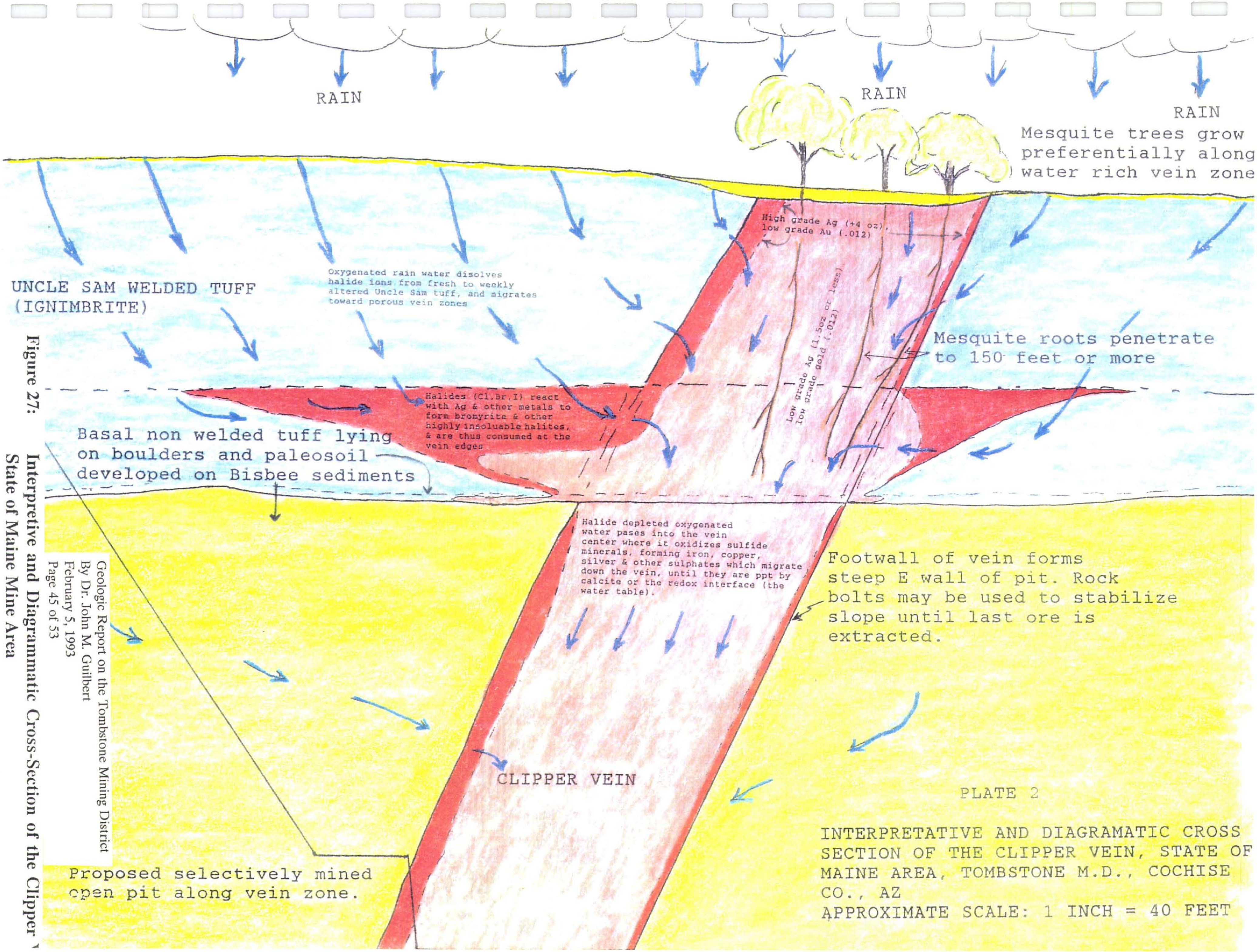


Figure 27: Interpretive and Diagrammatic Cross-Section of the Clipper State of Maine Mine Area

different than that exposed in the main part of the Tombstone district. Phyllic alteration predominates along wide vein zones such as along the State of Maine vein on the 2nd level, which is 60m wide. Leached capping from these vein zones appears similar to that of porphyry copper leached capping elsewhere. This material has never been drilled to the sulfide zone; the mineral content in the sulfide zone is thus unknown. However, copper sulfate (chalcanthite) in the walls of the State of Maine underground workings at and below the #2 level attest to the presence of copper in the rock. As in the Tombstone center, manganese, silver, and gold are ubiquitous, but their depositional mechanisms are not well known. A mechanism illustrated in cartoon fashion (Figures 26 & 27) is thought to account for the enriched bonanza ore mined in the Tombstone center, as well as the potential for the same in the State of Maine center.

JABA has acquired by lease three groups of claims, the West Fox, the Solstice, and the Misy, comprising 78 unpatented lode mining claims that make up Block 3 (Attachment 1). Block 3 surrounds the State of Maine patented lode claims. These patents are the only asset of a bankrupt corporation. Several mineralization modes involving replacement and open space filling may well pertain.

Robbers' Roost Breccia Pipe (Block 5)

Located in the SE1/4 of Section 30 and the N1/2 of the SW1/4 of Section 29,, and held under Arizona State Prospecting Permit (Attachment 1), the Robbers' Roost Breccia Pipe is a northeast-elongate elliptical area approximately 800m by 500m of outcropping breccia pipes and dikes of heterolithic, clast-supported, well-rounded fragments showing extensive phyllic alteration. Fragments are primarily crystal rich Uncle Sam tuff, intrusive into the same rock. Almost spherical, well-rounded golf-ball- to tennis-ball-sized fragments of quartzitic sedimentary rock are probably derived from the underlying Bisbee formation. The intruded Uncle Sam tuff is intensely fractured, with up to 60 fractures per meter over large areas. These fractures are lined with limonite-jarosite (goethite-hematite) and define a leached capping typical of igneous-hosted porphyry copper alteration zones in this climate zone. Interpretation of this leached capping suggests that pyrite is predominant, probably with supergene chalcocite coatings in the sub-outcrop. The pipes are generally siliceous and hold up the small knolls and hills in the area. The phyllically altered tuff on the other hand is relatively soft and comprises low areas, valleys, and arroyos in the alteration zone. The creeks and washes in which the alteration assemblages are exposed are ideal targets for quantitative alteration mapping and analysis.

The area is included in Newell's high copper and moly anomaly (Figures 9 & 10). Three deep holes, 1300m, 1650m, and 1000m, were drilled in the zone by ASARCO in 1973 and 1974. Briscoe's examination of core from these holes showed that they intercepted indications of a porphyry system. These indicators include multi-textured granodiorite to quartz monzonite porphyries that have not been mapped in outcrop, phyllic alteration, fluidized breccias grading into potassic alteration including secondary K-feldspar and biotite, and purple anhydrite. Mineralization included low grade but disseminated chalcopyrite and molybdenite. Some chalcocite was cut below the leached cap in one hole. Not all the core was split and analyzed and logging was substantially overgeneralized by ASARCO with key alteration features not noted in the logs. Luckily, though this core was poorly stored and vandalized and in part destroyed, a significant part of it was recovered and re-boxed in 1985 and safely stored so that it can be re-logged. It may be that the ASARCO holes were not positioned to penetrate the copper-moly portion of the mineral halo.

In the SE1/4 of Section 19 (Attachment 1), also held under an Arizona State Prospecting Permit, there is a wide vein zone showing extensive phyllic alteration and breccia dikes with the same golf-ball- to tennis-ball-sized rounded quartzitic fragments. This planar feature is 300m wide in the southeast corner of Section 19 and strikes 40° to 45° NE. It may be part of a major structure in the district as it appears to be either part of, or closely en echelon with, the State of Maine vein to the northeast and part of the Mustang vein-Charleston Lead mine vein to the southwest. Within the SE1/4 of Section 19 the vein appears to carry a few ppm silver. Cu and Mo assays have not been run. Shallow drill holes with the same silver content have been drilled to the water table at 33m without penetrating the leached capping and intersecting the sulfide zone.

The potential in the Robber's Roost (Block 5) is for several types of targets, essentially similar to the State of Maine zone. However, the top of the porphyry system is thought to be much nearer the surface at Robbers' Roost as evinced by fluidized breccias, more pervasive phyllic alteration, and much more extensive leached capping consistent with the potential of a chalcocite blanket beneath. Thus the exploration targets would include:

(1) A chalcocite blanket at about 50m, beneath limonite leached capping

(2) A sediment- or igneous-hosted porphyry copper deposit. Depth would probably preclude open pit mining. The center of such a copper porphyry could be offset from the exposed breccia pipe area.

(3) What is interpreted to be a manganese halo, similar to the one on the exposed perimeter of the Tombstone center, lies outside of the lease area in Section 32 and the SE corner of Section 29. A distal gold halo outside the manganese zone is a distinct possibility. An interior high gold zone (Figure 25) like that in the main Tombstone zone may be present within the Block 5 leases.

(4) Anticlinal saddle-reef-type silver-gold and carbonate replacement lead zinc ore like those of the main Tombstone center may also be present. Whether these are within economically mineable depths is a question that remains to be answered.

RECOMMENDED EXPLORATION PROGRAMS AND COST ESTIMATES

Basic Parameters

In the following recommended exploration programs for the various target zones, similar types of exploration tools have been used, based on the success of previous studies in the district and general familiarity with successful exploration techniques in the porphyry copper environment.

The most important and effective basic tool is accurate geology and zonal alteration characteristics plotted on accurate base maps. Geologic studies have been done by numerous geologists over the last century but the 1974 work by Newell gives good detail on the rock types in the district and shows the efficacy of biogeochemical phreatophyte (mesquite) twig sampling and rock chip sampling. Briscoe has designed several color air photo programs over the last 20 years that give complete coverage for the district, and in mid-October, 1992, Excellon Resources flew another color air photo campaign of Briscoe's design over the main Tombstone mining area, including the area of JABA's Block 1 and 2. This state-of-the-art photogrammetric survey makes available, in addition to color photography at scales of 1:36,000, and 1:12,500, an orthophoto mosaic at a scale of 1:24,000, traditional topographic map coverage over the same area at 1" = 200', with 5 ft contours in hard copy and computer disk as well as matching scale orthophotography, and a Digital Elevation Model (DEM) in computer format which provides for a 3-dimensional treatment of topography, geology and subsurface data. Using these detailed base maps, accurate outcrop geologic mapping and Quantitative Alteration Mapping can be done and then entered into the computer map data base.

Quantitative Alteration Mapping is a technique to show quantitatively the alteration mineral zoning that characterizes porphyry copper deposits and thus gives the investigator the ability to predict vectoriallly and in 3 dimensions the position of the porphyry copper system. I have developed this approach to alteration mapping over the past decade. We have recently used the technique with great effectiveness in evaluation of the Bajo De La Alumbera porphyry copper-gold deposit in Argentina (and elsewhere), both for surface mapping and down-hole logging. 'Alteration mapping', and 'alteration logging' of drill hole cuttings in the following exploration plan and cost estimate, will refer to the Quantitative Alteration Mapping technique.

Color air photo interpretation will be used to augment surface mapping. Remote sensing techniques using space imagery and the color air photos scanned into the computer may be used to augment traditional air photo interpretation. The digital information from the remote sensing can be combined with the digital orthophoto maps at any appropriate scale, or combined with the DEM model and geology, geochemistry, geophysics or any other thematic mapping or combination thereof.

Remote sensing geochemistry, i.e., geobotanical and soil sampling, may be of use in all 5 areas. Geobotanical sampling would be of deep rooted phreatophyte desert plants, including mesquite, cat's claw (acacia), and creosote bush (greasewood). Soil gas geochemistry including mercury and radon using track etch cups may be productive. Mercury and radon can rise through a significant thickness of cover, and uranium-radon anomalies are normal in porphyry systems. Radon might closely pinpoint the copper zone.

Biogeochemical plant twig samples will be taken at 1/4 mile intervals or 16 samples per square mile. Soil samples will be taken at the same intervals, but probably between each plant sample. Where outcrop is available, rock chip samples will be taken at 500 foot intervals, except over the Robbers' Roost Breccia Pipe outcrop area which will be sampled at 250 foot intervals. All samples, including drill cuttings, will be subjected to the same type of extremely low detection level analytical techniques, which include ICP and Graphite Furnace AA (GFAA). These methodologies will give the following detection limits: Plant ash (30 gm aliquots) gold 0.05 ppb, silver 1 ppb, copper 5 ppb, Mo 5 ppb; Soil (15 gm aliquots) gold 0.2 ppb, silver 3 ppb, copper 10 ppb, Mo 20 ppb; Rock chips (5 gm aliquots) gold 0.5 ppb, silver 15 ppb, copper 50 ppb and Mo 100 ppb. Twelve additional elements will be run on all samples and include As, Bi, Cd, Ga, Hg, Pb, Sb, Se, Sn, Te, Tl, and Zn. Recent studies suggest that metal ions migrate through bedrock into post mineral soil cover, along electrical current lines of self potential caused by oxidizing sulfides, and are detectable by these low level techniques. This would be a natural phenomenon capitalized on in the Russian electrogeochemical technique CHIM. Evidence suggests that mineral bodies can be detected through more than 100m cover. In the following cost estimates, where cost per sample is quoted, these are " all in " costs and include all sample collection costs including mobe and demobe, travel, food and lodging, field crew and supervision, base maps, sample bags, shipping, sample preparation and assay costs,. The "all in" cost per biogeochemical and soil samples at the designated spacing is $36.55 per sample. For rock chip samples the "all in" cost is $23.65.

Electrical-method geophysics across the zones should be able to identify specific drill targets. Controlled Source Audio Frequency Magneto Tellurics (CSAMT) may be able to give detail, while Induced Polarization (IP) would detect broad areas of disseminated sulfide mineralization. The approximate cost of the above electrical methods of assumed adequate detail in this area is about $5,000 per square mile. Detailed magnetic profile lines run across the zone may be helpful also. The approximate cost of ground magnetics is $2,000 per square mile. The Walnut Creek and Johnson Ranch blocks should be especially appropriate for geophysical techniques.

Drilling proposed for these projects is reverse circulation drilling using either a down-the-hole hammer or a tricone bit. The only exception to this is the Walnut Creek area "Scout Holes" which are designed to penetrate an expected average of 200' of post mineral cover and drill 50 feet into bedrock to sample for rock and alteration type and obtain geochemical samples. Here regular circulation will be used at a substantial cost savings - a direct drilling cost of $5 per foot. In all cases, dry drilling using air circulation will be used above the water table unless hole conditions dictate the use of water and lost circulation materials, or dust is a problem. Air circulation will also be used below the water table. Reverse circulation direct drilling costs are expected to range from $6.35 to $9.00 per foot depending on depth. All drill footage costs in the following cost estimates are "all in" estimates and include supervision, travel, food, and lodging, sample collection and bags, geologic and computer logging, cutting board (Core Board) construction, sample shipment, sample preparation and assay costs for 16 element analysis.

Data reduction where used in the following cost estimates shall mean computer entry into the AutoCad model of the district, or entry into RockWorks Logger, CrossSect or other appropriate programs. These data can be transferred where appropriate to MedsSystem or other appropriate ore reserve estimating software.

Walnut Creek (Block 1)

The Walnut Creek porphyry center is completely but thinly covered by Recent alluvium and Quaternary Gila Conglomerate, so exploration techniques will have to be able to penetrate post mineral cover. The adjacent precious metal-lead-zinc-manganese halo that has been mined can yield important vectors to the porphyry center. Exploration procedures include:

1. Plotting past production by metal and metal ratios to establish metal zoning patterns.

2. Geochemical sampling along suspected vectors (or radii) to determine the relative abundances and ratios of Cu, Mo, Pb, Zn, Ag, Au, Hg, Mn, F and Te.

3. Quantitative alteration mapping to determine the distribution of characteristic alteration minerals and assemblages, including skarn, phyllic, argillic, propylitic, and potassic associations with various types of sulfide minerals.

4. Color photo interpretation to identify structures and coloration features not readily seen on the ground. Remote sensing techniques applied to the color aerial photography may be useful.

5. Geologic interpretation of data available from old mine records giving subsurface understanding of the third dimension, where applicable. Excellon as part of their study of the Tombstone Development Company portion of the Walnut Creek porphyry center has a substantial portion of the old mine data digitized into a 3 dimensional AutoCAD model. This project should be completed, with emphasis placed on metal and alteration zoning.

6. Geochemical sampling including biogeochemical, soil and rock chip in areas of outcrop. Radon track etch samples to pinpoint the copper zone will be considered.

7. Electrical - method geophysics across the zone and ground magnetics with profile lines radial across the porphyry center or in a grid if the center cannot be spotted.

The following budget for Phase I, II and III programs is:

Phase I	Data Compilation, Photo and Remote Sensing Interpretation, Geologic and Alteration Mapping	$ 27,120
Phase II	Geochemical Sampling, Geophysics and "Scout" Overburden Drilling.	$100,000
Phase III	Target Drilling to a depth of 1,000 ft with Reverse Circulation, - 8 Holes	$100,000
	Total for Phase I through III	$227,120

Prompter Ridge Distal Gold Target (Block 2)

Prompter Ridge lies on the south flank of the high angle reverse Prompter fault. Much of the area is outcropping marbleized upper Paleozoic limestone, i.e., lower Pennsylvanian Horquilla, and Mississippian Escabrosa. Soil predominates in the southeast portion in the direction of the known gold bearing Zebra Prospect in the same rock types. The limestones are cut by 63 my rhyolite dikes and sills. Some prospects are present and mapped fissures (veins) can be projected into the area from the Tombstone Extension area to the north. The productive Bunker Hill silver-manganese mine lies on the northwest edge of the property block. Prompter Ridge lies on the outer periphery of the Tombstone Porphyry center and is thought to have potential for distal gold mineralization.

Exploration will be by soil and biogeochemical plant sampling and rock chip geochem sampling in areas of outcrop. Geologic and Quantitative Alteration Mapping will also be applied. Color air photo interpretation and remote sensing will be used to identify structure and alteration patterns not discernable from the ground.

After targets have been identified, ten 100 foot deep "Scout" holes will be drilled. Follow on will be ten 400 foot RC drill holes. As the terrain is relatively steep, road work and site preparation will be required.

The following budget for Phase I, II and III programs is:

Phase I	Biogeochemical and soil sampling over 9 square miles, rock chip sampling over 2.5 square miles, data reduction, interpretation and planning for Phase II.	$21,345
Phase II	Color air photo interpretation, & remote sensing, geologic and alteration mapping, data compilation, interpretation and design of phase III.	$24,100
Phase III	"Scout Drilling" - 10 drill holes to 100 feet, including road work and site prep.	$21,000
Phase IV	"Target Drilling" - 10 drill holes to 400 feet, including road work and site prep.	$54,000
	Total for Phase I through IV	$120,445

Johnson Ranch Biogeochemical Anomaly (Block 3)

Though less than 1.5 Km from outcrop at the northeast end, the Johnson Ranch is completely covered with post-mineral soil. Its location is based entirely on a molybdenum - silver biogeochemical (mesquite twig) anomaly from Newell's work. There is also a magnetic anomaly in the vicinity which is characteristic of porphyry copper alteration zones (verbal communication Dr. John S. Sumner, 1972), and was staked (but not drilled) by Sumner and the author.

Remote techniques will of necessity have to be used. These will include biogeochemical and soil sampling perhaps including soil gas sampling, electrical geophysics and ground magnetics. The geophysical surveys should give a good depth to bedrock indication, to determine the feasibility of drilling.

The following budget for Phase I, II, and III programs is:

Phase I	Electrical geophysics - CSAMT & IP, and ground magnetics.	$38,000
Phase II	Biogeochemistry and soil geochemistry	$14,036
Phase III	"Target" drilling - four 1,000 foot drill holes	$48,000
	Total for Phase I through III	$100,036

State of Maine - Escapule Porphyry Center (Block 4)

The State of Maine area, based on a variety of evidence previously cited, appears to be a porphyry center, with all zonal mineralization appurtenant thereto. Thus it is much like the Walnut Creek - Tombstone center, except that it is intracaldera and covered with pre-mineral Uncle Sam Tuff. Outcrop and soil cover are about equally divided. There is potential for near surface low grade ore, intermediate depth high grade ore and deep seated ore . The approach can be similar to the Walnut Creek - Tombstone center, except that there appears to be some shallow targets which could be drilled early on.

The following budget for Phase I, II, III, and IV programs is:

Phase I	Data compilation, interpretation, and drill program design.	$12,000
Phase II	Road work, site prep. and drilling for shallow precious metal targets. Five 400' drill holes.	$29,000
Phase III	Exploration to identify the position and attitude of the porphyry center. This will include geology and Quantitative Alteration Mapping, biogeochemical, soil and rock chip geochemical sampling, electrical geophysics and ground magnetics and data compilation, interpretation and Phase IV design.	$68,248
Phase IV	"Scout" drilling - one hole to 2,000 feet	$30,000
	Total for Phase I through IV	$139,248

Robbers' Roost Breccia Pipe (Block 5)

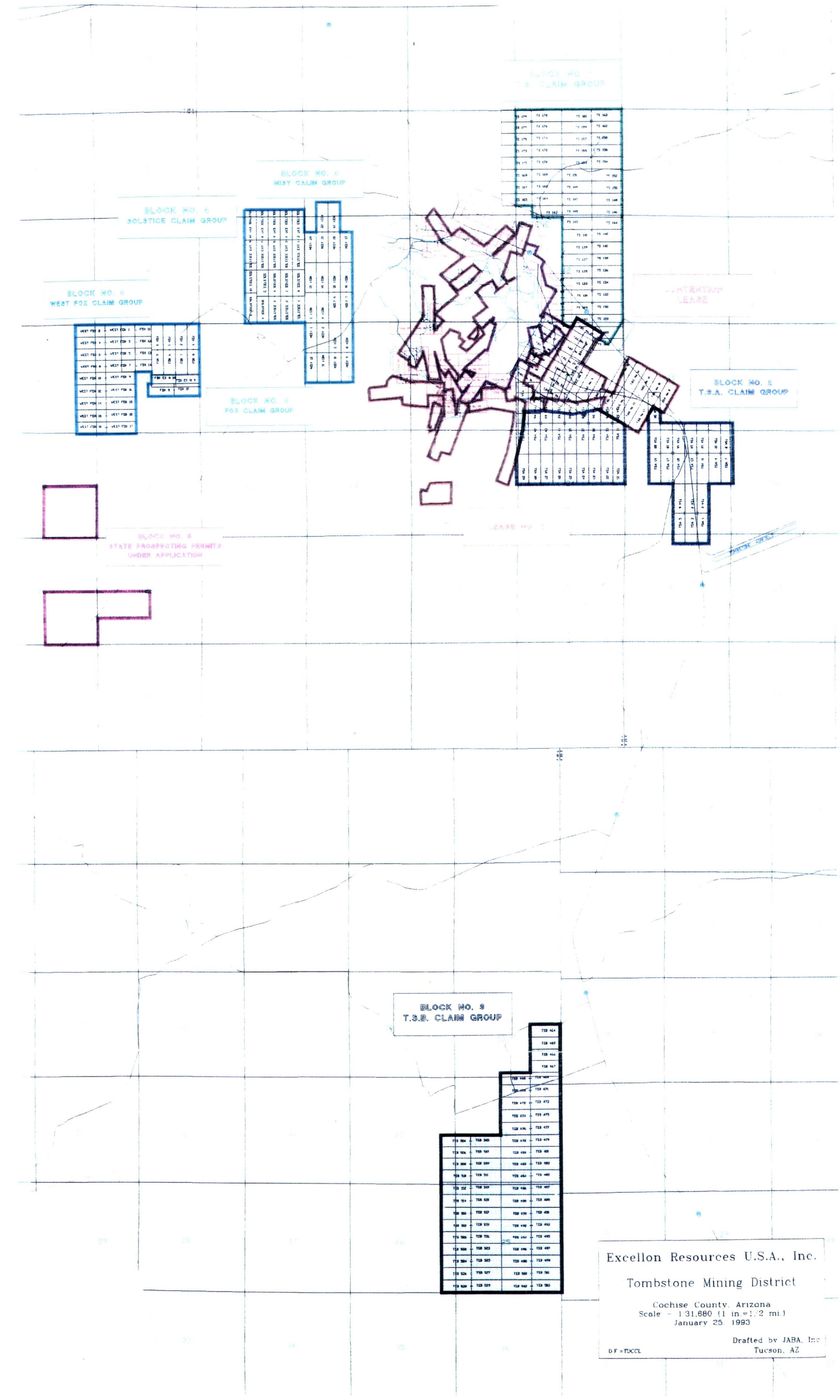
The Robbers' Roost breccia pipe is relatively well exposed along Robbers' Roost wash, but alteration plunges beneath shallow cover in all directions except west along the wash. The old ASARCO drill hole logs need to be studied and the remaining core re-logged, using Quantitative Alteration Mapping techniques. The geochemistry of the surrounding thinly covered areas must be determined using biogeochemistry and soil sampling. Closely spaced (250 foot centers) rock chip sampling should be done in the outcrop areas. Detailed geology, Quantitative Alteration Mapping and leached capping interpretation mapping should be performed in the areas of outcrop to determine the lateral position of the outcrop in relation to the porphyry center, as well as pinpointing drill locations to test for chalcocite blanket mineralization. Though leached capping after sulfide minerals can be clearly seen in outcrop, electrical geophysical and ground magnetic mapping might aid in pinpointing contact areas, overall geometry, and deep drilling targets.

The following budget for Phase I, II, III, IV and V programs is:

Phase I	Surface geologic, Quantitative Alteration, and leached capping interpretative mapping, rock chip geochemistry, compilation of existing data and re-logging of remaining ASARCO core, interpretation and design of shallow drill program.	$22,331
Phase II	Shallow drill test for a chalcocite blanket - five 400 foot holes.	$24,000
Phase III	Broad biogeochemical and soil sampling to define the position of porphyry copper metal zoning and determine the potential presence of a distal gold zone.	$ 9,722
Phase IV	Electrical geophysics and ground magnetics	$22,000
Phase V	Deep "Scout" drilling - one hole to 2,000 feet.	$30,000
	Total for Phase I through V	$108,103

TOTAL FOR ALL PHASES OF ALL 5 BLOCKS **$694,954**

This includes 30,500 feet of drilling at an all inclusive cost average of $22.79 per foot.



BLOCK NO.
T.S. CLAIM GROUP
BLOCK NO.
MISY CALIM GROUP
BLOCK NO.
SOLSTICE CLAIM GROUP
BLOCK NO.
WEST FOX CLAIM GROUP
BLOCK NO.
FOX CLAIM GROUP
LEASE
BLOCK NO. 2
T.S.A. CLAIM GROUP
BLOCK NO. 3
T.S.B. CLAIM GROUP
Excellon Resources U.S.A., Inc.
Tombstone Mining District
Cochise County, Arizona
Scale - 1:31,680 (1 in.=1/2 mi.)
January 25 1993
Drafted by JABA, Inc.
Tucson, AZ
D F =TDCCL

TOMBSTONE MINING DISTRICT
COCHISE COUNTY, ARIZONA
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