Trip 4 & 12

Mexican Porphyry Cu-Mo Deposits: La Caridad, Pilares, Cananea, Maria, Mariquita, Milpillas

October, 1994

Bootprints Along the Cordillera

Porphyry Copper Deposits from Alaska to Chile

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Dear Field Trip Participants:

On behalf of the **Arizona Geological Society, Society for Mining, Metallurgy and Exploration Inc., and the U. S. Geological Survey**, we bid you welcome to the Bootprints Along the Cordillera field trip program. We have assembled a collection of field trips that portray the geologic and mineralogic diversity that exists along the cordillera of North and South America.

We wish to thank all of the field trip leaders who volunteered their time, effort, and expertise to organize their individual trips. We also want to thank collectively, all of the mining companies and staff who graciously allowed us to visit their properties. Without their cooperation, this program would not have occurred. A special thanks goes to Kathie Harrigan of Asarco for her help in the compilation of the field trip guides. We also want to thank Tucson Blueprint who underwrote the complete reproduction cost of the guides.

Mark Miller and Jim Briscoe
Field Trip Co-Chairmen
October 2, 1994

September 19, 1994

Dear Participants:

Welcome to Mexico and Sonora. I hope this trip will be pleasant and beneficial to you. Your guides will try to make this so.

This field trip "Mexican Porphyry Cu-Mo Deposits: La Caridad, Pilares, Cananea, Maria, Mariquita, Milpillas" is intended to be a brief introduction to the porphyry and breccia copper-molybdenum deposits of northern Sonora. It will point out the salient features of various working deposits and the physical aspects of undeveloped copper prospects, which will become mines in the near future.

The trip will start out at La Caridad on the southern most end and finish with Milpillas, the northern most known copper resource, of a northwesterly trend that extends into Arizona.

We wish to acknowledge management of Mexicana de Cobre, S.A. de C.V., Mexicana de Cananea, S. A. de C.V., Empresas Frisco, S.A. de C.V., Mineral Constelacion, S. A. de C.V. and Servicios Cyprus, S. A. de C.V. without whose cooperation this trip would not have been possible.

Sincerely,

Remigio Martinez Muller

Muller.rem

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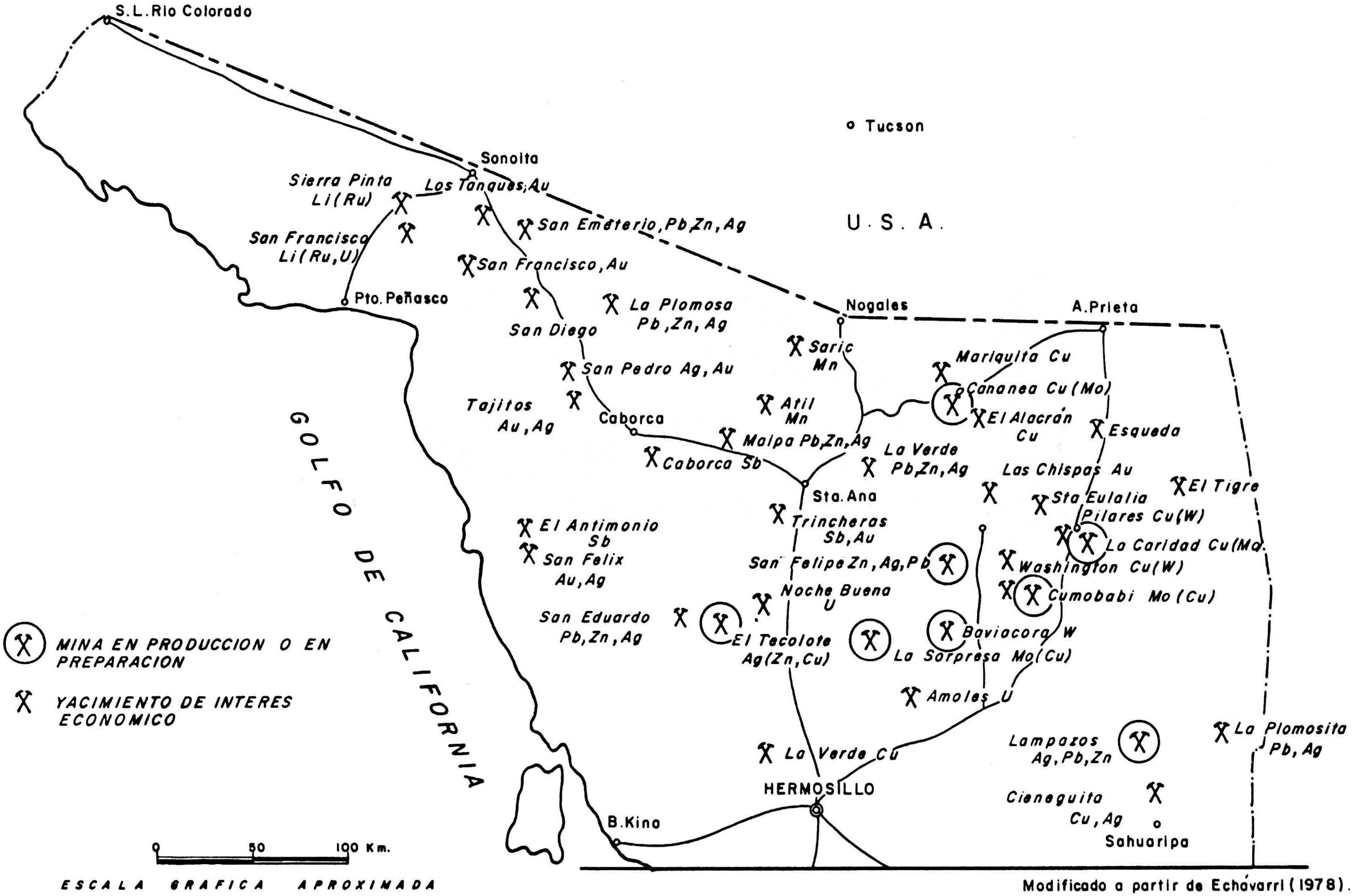
Figura I - LOCALIZACION APROXIMADA DE LOS PRINCIPALES YACIMIENTOS EN LA PORCION NORTE DEL ESTADO DE SONORA, MEXICO.



Modificado a partir de Echávarri (1978).

From Anderson, T.H., and Roldan-Quintana, J., 1979, Geological Society of America Field Trip 27

ROADLOG - FROM TUCSON TO TOMBSTONE TO BISBEE TO DOUGLAS

0.0 Palo Verde entrance to Interstate 10. Start road log! 3.3

3.3 Exit 268. Craycroft Road 2.8

6.1 Water tank at 3:00 just as we pass over the ramp is at the site of a small community previously known as Galeyville. Exxon drilled a deep stratigraphic test into the Tucson basin about 2 miles south of here. The upper 7,277 ft. is sand, gravel and clay, filling Basin and Range grabens formed after 12 Ma. From 7,277 to 9,000 ft. the hole penetrated a volcanic section of tuff, andesite and rhyolite. Selected cuttings from a tuff at 7,940 to 7,960 ft. yielded a K - Ar age of 23.4 Ma. Below the volcanic section from 9,000 to 9,500 ft. reddish brown conglomerates were encountered. At 9,500 to 10,000 ft. another volcanic unit was found which yielded K - Ar ages of 16.1 and 18.0 Ma. This was interpreted to be an intrusive dike or sill. From 10,000 to 12,000 ft. more reddish brown conglomerates, slits and shales were drilled. At 12,000 ft. was a quartz monzonite dated at 61 Ma by K- Ar and 120 Ma by Rb - Sr methods. Eberly and Stanley (1978) regard the section from 7,277 to

12,000 ft. as deposited after the Eocene and before the Basin and Range faulting at about 13 Ma. 0.4

6.5 At 3:00 are the Santa Rita Mountains. 2.1

8.6 Exit 273. Rita Road. 1.0

9.6 Milepost 274. I-10 traverses an aggradational surface on Plio-Pleistocene valley fill. The upper red clay-rich (argillic) horizons have been stripped away, exposing a thick caliche horizon. This stripping has occurred over most of the Tucson basin and demonstrates that the red soils are not of modern origin. 1.4

11.0 Exit 275. Houghton Road and turn-off to Colossal Cave and Pima County Fairgrounds. 1.1

12.1 Milepost 276.5. Broad domal physiography of the Rincon Mountains is seen from 9:00 to 11:30.

The large rounded peak at 10:00 in the Rincon Mountains is Mica Mountain (8,666 ft.). The conspicuous ridge trending west-south-west from Mica Mountain is Tanque Verde Ridge or the Tanque Verde Mountains. Cow Head Saddle separates Tanque

Verde Ridge from Mica Mountain. The top of Tanque Verde Ridge gently plunges southwestward and generally marks the culmination of a large, antiformal foliation arch in mylonitic gneisses. Mica Mountain is separated from Rincon Peak (8,482 ft. at 10.30) by Happy Valley Saddle. The small peak north of the cuesta-like peak and south of Rincon Peak is Wrong Mountain which hosts the Wrong Mountain quartz monzonite crops out extensively throughout the Rincon Mountains

Layers of mylonite schist commonly separate layers of Wrong Mountain Quartz Monzonite from the darker layers of deformed Continental Granodiorite. These schistose lenses have been correlated with Pinal Schist by Drewes (1977).

Low foothills at 3:30 in middle distance are underlain by Paleozoic rocks. Colossal Cave, a local tourist attraction, is in the foothills at 9:30. Paleozoic rocks in the Agua Verde-Colossal Cave area are part of a series of deformed Phanerozoic rocks that also occur at Martinez ranch at the base of the Rincon Mountains in the Loma Alta area at the southern base of Tanque Verde Ridge, and in the Saguaro National Monument area just northeast of the base of Tanque Verde ridge at 9:00. A large pediment in Rincon Valley between Loma Alta and Colossal Cave is cut on Precambrian Rincon Valley Granodiorite.

The Precambrian and Paleozoics are in the upper plate of the major, low-angle, Santa Catalina fault, which is located at the break in slope between the main Rincon massif and the foothill block. The Santa Catalina fault separates the unmetamorphosed, but highly deformed, upper plate rocks from lineated mylonites of the metamorphic core in the main Rincon Mountain mass. Inevitably these complicated geometric relationships have several interpretations. Davis (1975) analyzed fold geometries in Paleozoic and Mesozoic rocks of the upper plate and concluded that they represented a period of major gravitational sliding of the cover down the Santa Catalina fault surface in mid-Tertiary time. Drewes (1977) recognized this mid-Tertiary gravity-induced movement, but also suggested that the low-angle fault was older and represented former thrusts which were emplaced at about 73 Ma via regional north-east-southwest compression of Laramide age. These faults were reactivated in Oligocene time (25 Ma) during arching of the mylonite rocks of the metamorphic core. 1.5

13.6 Milepost 278. Northern Santa Rita Mountains from 2:00 to 3:00. Mount Fagin at 2:00 consists of Late Cretaceous Salero Volcanics which unconformably overlie folded Bisbee Group. A defunct limestone quarry is the prominent scar on the hillside at 3:00. 1.3

14.9 Exit 279. Vail and Wentworth roads to Colossal Cave and Saguaro National Monument. 2.1

17.0 Exit 281. Arizona 83 south to Sonoita. The R. W. Webb Winery is the building at 10:00 when we first see the Exit 281 sign. The building at 11:00 houses Mountain States R&D International's assay and metallurgical research lab. 1.6

18.6 Milepost 283. Northern Empire Mountains are at 1:30. The oldest rocks in the Empires are Precambrian Pinal schist and gneiss which occur immediately south of I-10 for about three miles. These units are mantled by outward dipping and overturned Cretaceous Bisbee Group. Further south, near Martinez Ranch, a Laramide quartz monzonite intrudes Pennsylvanian carbonates that are overlain by Bisbee Group sediments and slightly younger Salero volcanics. 2.0

19.6 Milepost 284. Angular unconformity between Pliocene Valley fill and lower fanglomerate member of Oligocene Pantano Formation in roadcuts on either side of the highway. 0.4

20.0 Bridge over Davidson Canyon. Roadcuts east of Davidson Canyon are in lower fanglomerate member of Pantano Formation with pronounced eastward dips. The Pantano Formation south of the Rincon Mountains generally exhibits a uniform, moderately east to northeast inclination throughout a thickness of over 10,000 ft. 0.7

20.7 Milepost 285. Roadcut in Turkey Track Andesite flow that dips east at 45° at the top of the lower fanglomerate member. This volcanic unit takes its name from clusters of large (±1" long), elongate plagioclase phenocrysts. Roadcuts ahead are in the claystone member of the Pantano Formation. The lower half of the Pantano Formation is 28 Ma to 36 Ma on the basis of several radiometric dates (Keith & Wilt, 1978). Reddish clastics similar to Pantano

Formation are widespread throughout southeastern Arizona. They may represent basin-ward facies shed from time-equivalent Oligocene ignimbrite piles. They may in some way be linked with the late Oligocene (28 to 22 Ma) activity in the metamorphic areas. They may also be linked to synclinal fold basins formed at the margins of mid-Tertiary basement uplifts, as in the Tortilla Mountains north of the Catalina Mountains. The 28 to 36 Ma dates of the Pantano Formation in this area are slightly older than the cooling ages (22 to 28 Ma) in the Rincon-Catalina metamorphic complex to the north.

Drewes (1977) suggested that parts of the Rincon Mountains were a structural basin through which the underlying metamorphic terrain was arched. Thus, the 22 to 28 Ma cooling ages of the metamorphic rocks represent the time of uplift and not necessarily the time of metamorphism, which is older by an unspecified amount. This metamorphism could have been Laramide in age, Precambrian (Mazatzal orogeny) in age, or a combination of both. For Drewes the profound lineation and accompanying metamorphic event of Laramide time would have been coincident with major low-angle thrusting during the Piman phase of the Laramide orogeny (Drewes, 1972, 1976a, 1978).

Others (Coney, 1978) suggest that the Pantano Formation is syntectonic with the development of extensive mid-Tertiary lineation and metamorphism. The lineation represents an extreme attenuation or thinning of the crust. This would have created a basin into which thick Pantano clastics were deposited. Rebound of the crust following the attenuation event would arch the metamorphic rocks through their Pantano cover. The Pantano Formation would then accumulate around the uplifted metamorphic terrain as large, gravity-slide blocks, which record a tectonic denudation of the dome during its arching from 22 to 28 Ma.

Gneiss clasts are conspicuous by their absence in the fanglomerate member of the Pantano Formation although every other pre-Tertiary rock is represented (Brennan, 1957; Finnel, 1970b). Imbrication directions as determined from aligned tabular clasts consistently indicate stream transport direction from the east and southeast. 0.4

21.1 Roadcuts here and ahead are in upturned, nearly vertical, east-striking, mid-Cretaceous, Bisbee Group strata. These are in fault contact with the claystone member of the Pantano Formation to the west. This deformation in Bisbee Group strata is part of the east-west belt of the Late Cretaceous deformation which extends from the north end of the Whetstone Mountains through the north end of the Empire Mountains and disappears under pediment alluvium at the north end of the northern Santa Rita Mountains. This block of Bisbee Group also represents a north-trending, upthrown horst block bounded by normal faults that developed after deposition of the Pantano. Perhaps this horst is a part of the late Miocene-Pliocene Basin and Range faulting episode. 0.9

22.0 Roadcuts in lower fanglomerate member of Pantano Formation, which is in fault contact with north-trending Bisbee horst to the west. This fault is well-exposed in the west-bound lane of I-10. Note the steep eastward dips in the fanglomerates. This tilting is at right angles to the east-west tectonic zone in the Bisbee Group horst. Deformation in the Bisbee and Pantano has been truncated by an extensive pediment, upon which rests a veneer of Plio-Pleistocene gravels. 0.2

22.2 Rhyolite tuff unit (29.4 Ma) within the lower fanglomerate member of the Pantano Formation is exposed in low roadcuts on either side of the highway and is better exposed in west-bound lane. 0.5.

22.7 Roadcuts in lower fanglomerate member. Fault within this member separates finer grained from coarser grained units. Turkey Track Andesite flow in roadcut on right is faulted against finer grained material. Note that the Turkey Track unit is completely faulted out in the roadcut on left side of highway. Numerous faults cut Pantano Formation in roadcuts ahead. 1.1

23.6 Milepost 287. Quarry at 9:00 is in red colored sandy, argillaceous Pantano units that contain intercalated 1 1/2" thick gypsum beds. These beds are overlain unconformably by a green-colored brecciated argillite. 0.2

23.8 Fault contact between claystone member (in roadcuts ahead) and fanglomerate member. The Turkey Track Andesite marker unit is faulted out here.

Claystone member ahead is angularly overlain by Plio Pleistocene gravels. Further east and northeast claystone member is overlain by upper fanglomerate member of Pantano Formation (Drewes, 1977). 1.0

24.8 Cienega Creek bridge. Highway ascends onto a post-mid-Miocene aggradational surface on Plio-Pleistocene gravels for the next several miles.

25.4 Exit 289; Marsh Sta Road. 0.2

25.6 Milepost 290. Whetstone Mountains (1:00) on skyline contain southwest-dipping Bisbee Group strata. A fuller description of the Whetstones is given later in this log. At 2:00 in the middle distance are relatively flat-lying conglomerates in upper fanglomerate member of Pantano Formation. They may also be Miocene Nogales Formation which Drewes (1977) mapped south of the Rincon Mountains and north of I-10.

Total Wreck Ridge (3:30) in the northeastern Empire Mountains contains Concha Limestone and Rain Valley Formation. East of Total Wreck Ridge a thick (to 5,000 ft.) southward-thinning, fanglomerate wedge of Glance Conglomerate represents a clastic wedge that was shed southward from an uplifted block exposing older Precambrian granite and Pinal Schist in Early Cretaceous time (Finnel, 1971; Bilodeau, 1978). South of the east-west tectonic belt (which I-10 is in), the southwest-dipping strata in the central Whetstone Mountains and southeast-dipping layers in the Empire Mountains form a broad, south-southwest-plunging syncline. 2.6

28.2 Exit 292; Bell Road to Empirita Ranch and vicinity. 0.4

28.6 Low hills ahead and at 2:00 are in narrow, north-trending, Basin and Range horst block containing east-trending, north-dipping, overturned, tight folds of Bisbee Group strata with subordinate Pennsylvanian carbonates and Precambrian felsic gneisses. This is a relatively upthrown continuation of the east-trending, Late Cretaceous structural zone. 1.2

29.8 Roadcuts here and ahead for next mile are in deformed, east-striking, nearly vertical, Bisbee Group overlain by flat-lying gravels veneering the pediment. At 9:00 steep, topographic scarps on the east side of the Rincons mark a large Basin and Range fault which is continuous with the east boundary of the horst block now being crossed by I-10. 0.8

30.6 Milepost 295. Fault contact between late Miocene-Pliocene basin-filling alluvium (post-Pantano Formation) and Bisbee Group. The fault is excellently exposed in roadcut on right. This fault strikes north, dips 70 to 75 degrees east, and is a continuation of the fault which marks the eastern boundary of the Rincon metamorphic range massif to the west. The Happy Valley block of eastern Rincon Mountain area has been dropped down a minimum of 5,000 ft. to the east on this fault zone. It is significant that this faulting post-dates the metamorphic events and the low-angle fault phenomena which are associated with the development of the Rincon-Catalina-Tortolita metamorphic complex. Many people now interpret the age of this metamorphic complex to be of late Oligocene (22 to 28 Ma). This roadcut is an excellent example of Basin and Range faulting which in southeast Arizona is generally younger than 14 Ma and possibly younger than 10 Ma. Most of the Basin and Range faulting had terminated by about 5

Ma, although some has lingered to the present day.

The low rounded ridge ahead is underlain by valley fill. 1.2

31.8 Entering Cochise County. El Paso Natural Gas compressor station on left. Happy Valley area at 8:30; Little Rincon Mountains at 9:00. Johnny Lyon Hills (10:00) are backed by the Winchester Mountains and the southern Galiuro Mountains in far distance. The Little Dragoon Mountains are at 11:30 with the "big" Dragoon Mountains at 12:00. 0.8

32.6 Exit 297. Mescal-J Six Ranch Road. Roads north from this exit lead to Happy Valley, an area of very complex structure related to the Rincon metamorphic complex to the west. 1.0

33.6 Road continues across a mid-Pleistocene surface which now slopes toward San Pedro Valley and extends to the foot of the northern Whetstone Mountains at 2:30, where it merges with a Pliocene pediment cut on 1,400 Ma Precambrian granite. 1.2

34.8 Exit 299. Skyline road. 0.8

35.6 Milepost 300. The Johnny Lyon Hills (1:30 to 12:30) consist of an oblong, north-trending structural block which is separated from the southern Galiuro Mountains by the west-northwest-striking Antelope Tank fault zone at 9:30. The Antelope Tank fault zone was thought to be an element of the Texas lineament by Cooper and Silver (1964).

The east border of the Johnny Lyon Hills block is marked by a series of arcuate, north-to-northwest-trending ridges which extend northward from Sheep Camp Ridge (10:00) and are backed by the Winchester Mountains at 9:45 on the skyline. These ridges consist of east-and northeast-dipping, younger Precambrian Apache Group and Paleozoic strata. These strata unconformably rest on 1,625 Ma Johnny Lyon Granodiorite and 1,680 Ma Pinal Schist; they form an extensive pediment west of the low ridges. Relationships of the older Precambrian rocks in the Johnny Lyon Hills allowed Silver and Deutsch (1963) to date what they regarded the Mazatzal orogeny of Wilson (1939). Pinal Schist was deformed into north-east-trending isoclines. This deformed terrain was intruded by the postdeformational, Johnny Lyon Granodiorite, bracketing the Mazatzal tectonic event between 1,680 and 1,625 Ma.

East-dipping Paleozoic and Apache Group strata, Pinal Schist and Johnny Lyon Granodiorite are truncated by several low-angle faults, which contain Paleozoic strata and some Apache Group strata in the upper plate. These plates are thought to be northeast-directed Laramide thrusts. These strata occupy the high area around Keith Peak (10:5), Sheep Camp Ridge and Javelina Hill (to the northeast behind Keith Peak). The low-angle faults are intruded by Tertiary lamprophyre and rhyolite dikes (Copper and Silver, 1964). 1.0

36.6 Milepost 301. The southern Galiuro Mountains appear in the far distance behind the east end of the Little Rincons at 9:00. The southern Galiuro Mountains are mostly 28-22 Ma old ignimbrites which unconformably overlie pre-Tertiary rocks. See Creasey and Krieger (1978) for a discussion of volcanic stratigraphy in the northern Galiuro Mountains. 1.2

37.8 Exit 302. Arizona 90 south to Fort Huachuca and Sierra Vista. 4.0

41.8 Exit I-10 to Benson. The San Pedro Valley in front of you has extensive exposures of valley-fill sediments, named the St. David Formations by Gray (1967). Three divisions of the St. David Formations include the upper carbonate soil-forming division, a middle carbonate-enriched division, and the lower red-bed division.

Rancholabreau fossils occur in overlying alluvial deposits. The Irvingtonian fossils occur in the lower part of the soil-forming units and in the upper part of the middle carbonate. Blancan fossils are common in the middle carbonate-enriched beds. The lower red-beds have no fossils.

The redefined Pliocene-Pleistocene boundary is readily identified in the San Pedro Valley using the magneto-stratigraphic sequence established by Johnson and others (1975). 2.0

43.8 Leaving Benson and turning onto State Route 86. 2.0

45.8	Milepost 295. On right is the Post Ranch amphitheater where the Benson fauna was reported. The Post Ranch ash containing the Benson fauna is dated at 3.1 Ma by fission tracks in zireon. 5.7
51.5	Cross the San Pedro River north of St. David. The rugged exposed granites to the east beyond St. David is the site of the Cochise Stronghold, the favorite campgrounds of the Chiricahus Apache Indian of times past. (Watch for these out your windows!) 1.0
52.5	Saint David. The artesian wells in the vicinity of St. David provide a good supply of water for the many ponds we pass by. 6.2
58.7	Curtis Ranch Amphitheater on left. The fossils at Curtis Ranch include bats, rabbits, gophers, jaguar, three-toed horse, and llama. 7.8
66.5	Junction of State Route 86 with State Route 82 from the west. 3.8
70.3	Tombstone - Home of Big Nose Kate
	(Note: San Pedro Valley portion is excerpt from

Lindsay, E.H., et. al, 1987, Late Cenozoic deposits, vertebrate faunas, and magnetostratigraphy of southeastern Arizona, p. 227-237 in Arizona Geological Society Special Paper 5.)

ROADLOG - TOMBSTONE TO BISBEE

Modified from the log of Stanley B. Keith and Jan C. Wilt that was prepared for the New Mexico Geological Society Guide Book "Land of Cochise", 1978. This road log commences at milepost 318 on the south side of Tombstone, driving southeast.

0.0 Milepost 318. Recommence road log driving southeast from Tombstone. For next mile, roadcuts are in Plio-Pleistocene alluvium overlying bedrock pediment cut on upturned Bisbee Group. The Tombstone Hills at 3:00 are separated from the Dragoon Mountains at 9:00 by a broad valley about 8 mi. wide which marks the position of a northwest-trending Basin and Range graben of unknown depth. Note cut and fill aspect of coarse terrace alluvium which overlies finer-grained valley fill in roadcuts. Also note locally thick caliche layers in roadcuts. 1.4

1.5 Roadcuts on right are in Bisbee Group within downthrown block north of east-striking Prompter fault. Ridge to south at 1:00 to 2:00 is north-dipping Horquilla Limestone in block south of Prompter fault which is intruded by 61 Ma rhyolite porphyry. 0.6

2.0 Milepost 320. Hills at 9:00 to 10:00 are Miocene to Upper Oligocene andesites and dacites (Turkey Track equivalents ± 26 Ma). East of these hills the low-lying topography is underlain by the Jurassic Glesson quartz monzonite that hosts gold in quartz vein stockworks at Gold Camp currently being drill evaluated. 1.0

3.0 Milepost 321. Hills to left are Horquilla and Earp formations with complicated bedding attitudes. Davis Road turn-off east to Gleeson. 1.0

4.0 Roadcuts on right and left for next 0.2 miles are in Martin and Escabrosa units at top of the hill and in Colina Limestone near bottom of hill. These units are intruded in this area by a number of small bodies of Laramide age felsic porphyries (latites and dacites). Note fault and drag fold in roadcut on right at first road cut. Numerous small faults are exposed in the roadcuts that are not obvious in the outcropping section. 1.0

5.0 Milepost 323. Intricate bedding attitudes in Paleozoic strata west of road indicate complicated structural history of Tombstone Hills. They were mapped and described by Gilluly (1956) who argued for the presence of two orogenies. The first orogeny formed east-trending folds and reverse faults related to a north-south to north-northeast/south-southwest compression after deposition of the Bisbee Group and before deposition of the Bronco Volcanics.

The first orogeny was followed by widespread deformation, intrusion (72 Ma) and mineralization from a second orogeny. This orogeny caused north-trending folds, north-striking reverse faults, and strike-slip movement on east-west faults near and after 72 Ma. His second orogeny has been correlated by many workers with the Laramide.

Davis (1981) views the Tombstone Hills as a comparatively undeformed block in a large, northwest-trending, basement-cored uplift. Its structural margins are in the Dragoon Mountains to the northeast and the Huachuca Mountains to the southwest. Jones (1966) offered another interpretation; "that in Laramide time rising magmas; (a) broadly domed the area of the Tombstone Hills causing local compressional features of diverse trends but primarily causing normal faulting, (b) pushed up the Precambrian granite, (c) permitted access to the surface of various extrusive rocks, and (d) concluded their active rise by intruding some of the faults and the solidifying in the near surface rocks."

Prominent unnamed hill at 4:00 consists of Colina Limestone intruded by a conspicuous light colored 62 Ma old rhyolite. Note small, sharp kink fold in cliff-forming ledges of Colina Limestone above rhyolite intrusion. 1.0

5.0 Between mileposts 323 and 324 look to the west for a view of the southern Tombstone Hills. The distinctive ridge is Colina Ridge and contains the type section of Permian Colina Limestone on the western slopes near the north end. Epitaph Gulch at the west end and the eastern slopes of the north end of Colina Ridge contain the type section of the Permian Epitaph Dolomite. Horquilla Peak (high peak at 10:00) contains the type section of the Pennsylvanian Horquilla Limestone.

Regionally the Horquilla disconformably overlies Black Prince Limestone and is gradational into the overlying Earp Formation. On Horquilla Peak the eroded Horquilla is 1,000 ft. thick and consists of a series of thin-bedded, blue-gray limestones (pinkish gray on fresh fracture) with a few thicker beds which form ledges and a few reddish-weathering shaly limestones near the top.

The Earp Formation is 595 ft. thick here (Gilluly and others, 1954). It generally forms gentle slopes and low areas because of the greater percentage of shales (particularly in the lower part) and clastics than in either the gradationally underlying Horquilla Limestone or the gradationally overlying Colina Limestone.

The Colina is 633 ft. thick on Colina Ridge, but is 947 ft. thick on the unnamed ridge extending southeast from Horquilla Peak from at 3:00 only a mile from Colina Ridge (Wilt, 1969). The variation in thickness is probably attributable to the varying downward extent to diagenetic dolomitization in the Epitaph (Patch, 1969), as the same bed can be raced from undolomitized Colina into dolomitized Epitaph. The Colina Limestone is dominantly a dark-gray, thick-bedded limestone that forms cliffs characterized by massive ledges and steep slopes only slightly less precipitous than the Escabrosa. On fresh fracture the limestones are very dark gray to black and have a fetid odor.

The lower contact of the Epitaph Dolomite is taken as the first massive dolomite above the transitional zone of partially dolomitized limestone at the top of the Colina. The lowest member is 200 ft. of medium-to light-gray to yellow and buff, medium-bedded dolomite containing silica nodules weathering as knots on the surface. It is exposed as the dip slope on the east side of Colina ridge. The middle part of the Epitaph is exposed in the saddle at 3:00 and 4:00 between Colina Ridge and the low foreground hill. The middle part of the Epitaph consists of about 250 ft. of poorly exposed, reddish, sandy limestone or limy sandstone containing shallow water indicators such as crossbedding, ripple marks and intraformational breccias, and a higher proportion of maroon shale and less dolomite. The upper part of the Epitaph, also exposed in the same hill, consists of over 100 ft. of bluish-gray, thin-bedded limestone.

The Epitaph is unconformably overlain by Glance Conglomerate containing boulders and pebbles of dolomite, limestone, granite, rhyolite and quartzite with an angular discordance of about 15 degrees and with an erosion surface with relief exceeding 20 ft. in 300 ft. (Gilluly and others, 1954).

The large hill at 10:00 is Government Butte which is described after milepost 328. The Huachuca Mountains are on the skyline from 12:00 to 2:00. 1.0

6.0 Milepost 324. Hill to left at 2:00 contains well-exposed, slope-forming Earp Formation in lower slopes. The Earp is in fault contact with Colina Limestone which is anticlinally folded. 1.0

7.0 Milepost 325. Bridge over Government Draw. 2.0

9.0 Milepost 327. From milepost 327 to milepost 329 Government Butte is the large hill on the east side of the road. Government Butte consists of upper Paleozoic strata, the type sections of which were measured in the Tombstone Hills. A controversial east-west structural zone is visible at the southern end of Government Butte. This structure is related to complex "Laramide" structural development here and in the southern Tombstone Hills. 2.0

11.0 Milepost 329. Hills from 9:00 to 11:00 are the Mule Mountains which here are composed of subhorizontal, Cretaceous Bisbee Group sediments. 1.5

12.5 Hill at 9:00 is Devonian Martin Formation. 0.1

12.6 Bridge. Outcrops in arroyo are Escabrosa Limestone. 0.4

13.0 Milepost 331. Low hill at 3:00 is Horquilla Limestone. Juniper Flat granite (Jurassic) intrudes the Martin in low ridge at 12:00 to 2:00. Outcrops of the granite are next to the road on the west side. Low ridge to left is Cambrian Abrigo and Bolsa quartzite which are cut by granophyre dikes, presumably of Juniper Flat granite. 1.0

14.0 Milepost 332. Roadcut in east-and northeast-striking fault slices of aphanitic dolomites of Martin Limestone, Juniper Flat Granite, and Percha Shale. Strike-slip, oblige-slip and dip-slip slickensides indicate a complicated movement history. Note brittle aspect of this deformation.

0.3

14.3 Junction of U. S. 80 and Arizona 92. Hill at 3:00 is capped by crinoidal Escabrosa Limestone. At the base of the Escabrosa cliff is a well-vegetated slope-forming unit that is probably olive-green mud-shales of Percha Formation. The yellowish-gray ledge below the presumed Percha Shale is probably a sandy dolomite in the upper Martin Limestone.

Both Martin and Escabrosa are cut by granophyre dike apophyses of Juniper Flat Granite. Note west-striking fault which offsets these Paleozoic strata.

After the road junction, U. S. 80 swings to the southeast and follows a valley that is the trace of the Dividend Fault. This fault separates Juniper Flat granite, that is much of the area on the left of the road, from Precambrian Pinal schist, which is on the right of the road, the south side. The Pinal is unconformably overlain by Paleozoic sediments. 02.

14.5 Roadcut on right is southwest-dipping lower Abrigo Formation with numerous faults. 0.5

15.0 Milepost 333. Roadcuts on left side of road are in middle carbonate member of the Cambrian Abrigo Formation.

15.2 Bridge across Banning Creek.

16.0 Milepost 334. Roadcuts are in southwest-dipping Bolsa Quartzite overlain conformably by Abrigo Formation. These are intruded at the southeast end of cut by a dike of Juniper Flat Granite.

From Milepost 334. Numerous roadcuts on the left of the road expose cobble-boulder colluvium which unconformably overlies Juniper Flat Granite and sheared Pinal Schist. The sheared schist may represent gouge related to the Dividend fault or deformation related to intrusion of the Juniper Flat Granite. For about 3 miles the highway nearly parallels the contact between Juniper Flat Granite and Pinal Schits. High ridge to left is Escabrosa Ridge. For the next four miles roadcuts are in locally mineralized and altered Juniper Flat Granite and sheared Pinal Schist. 5.0

21.0 Milepost 339. As we top the ridge, Juniper Flat Granite crops out in immediate vicinity. Visible terrain to the southwest is mostly Pinal Schist intruded by dikes presumably related to the Juniper Flat Granite. Some of the ridge tops are capped by Bolsa Quartzite resting unconformably on Pinal Schist.

Mule Pass tunnel cuts through drainage divide. Tombstone Canyon drains eastward to Sulphur Springs Valley and Banning Creek drains northwest to San Pedro Valley. 0.6

21.4 U. S. 80 Bisbee business loop intersects from the left. 02.

21.5 Bridge. Roadcuts ahead in Juniper Flat Granite. Turnoff to Bisbee and Tombstone Canyon on right. 0.1

21.6 Roadcuts ahead will be in Pinal Schist for 0.8 mi. Note extremely deformed character of Pinal Schist, which is probably related to motions along Dividend fault. The Dividend fault is difficult to trace northwest of these roadcuts. Its projected trace has been a matter of considerable speculation. 0.8

22.4 Pinal Schist with thermal alteration. Pinal Schist is here separated from Abrigo Formation by a northeast-striking fault strand of the Quarry fault. 04.

22.8 Bolsa Quartzite in roadcuts on both sides of road. Note numerous faults within the relatively competent Bolsa. The contrasting deformation styles in Bolsa Quartzite and Abrigo Formation illustrate the response to stress of rocks of differing ductilities. 0.1

22.9 Abrigo Formation in roadcuts on both sides of highway. Note numerous kink folds in the comparatively incompetent strata of Abrigo Formation. Also note distinctive "graham cracker" texture and ribbed "tire track" aspect of carbonate beds within this part of the Abrigo. 0.1

23.0 Milepost 341. Covered area to left conceals Martin Limestone and much of the Abrigo Formation. 0.4

23.4 Escabrosa Limestone on left. Castle Rock, the conspicuous terreted crag which overlooks downtown Bisbee is down and to the right of the highway. Castle Rock is mainly composed of Escabrosa Limestone and Martin Limestone which are in fault contact with the Dividend fault to the north.

Excellent views overlooking Tombstone Canyon and Bisbee (to the right) for the next mile. 0.2

23.6 Road to right to business section of Bisbee and the picturesque Brewery Gulch section. Bisbee, one of the more colorful mining towns in the American Southwest, was named for Judge DeWitt Bisbee of San Francisco, a shareholder and father-in-law of one of the promoters in the Copper Queen Consolidated Mining Company. Judge Bisbee never visited the town which bore his name.

To the right is the Copper Queen mine; worthwhile mine tours are offered daily. Within the underground workings of the Copper Queen mine, some of the world's finest examples of secondary copper minerals have been found. The Warren district is particularly famous for its stalacitic and crystallized specimens of azurite and malachite. It is said that high school proms and Bisbee town council meetings were held in underground caverns adorned with spectacular malachite stalacitites locally covered with crystallized rosettes of azurite. To the left just beyond the Copper Queen is a small amount of Martin Formation of Devonian age. 0.6

24.2 Sacramento Hill, what is left of it, is on the right. Along this stretch of road are spectacular roadcuts of alteration related to porphyry copper mineralization in alkali granite of the Jurassic Sacramento stock. The surfaces of hills in this vicinity are covered by a bright red oxidized zone which follows the contours of the hills. This constitutes the classic oxidized zone present over many porphyry copper sulfide systems.

Below the oxidized zone is hypogene (primary quartz-sericite-pyrite) alteration in the Sacramento stock. Note how the upper oxidized zone extends down into primary altered rock along fractures. The red iron oxide cap was the flag that initially drew many of the old prospectors into what are now major porphyry copper districts. 0.2

24.4 Turn left from Lavender Pit overview on U. S. 80.

The Lavender Pit is one of the smaller open pit porphyry copper mines in the United States. To the right are the remains of Sacramento Hill. Across the pit one can see where the pit intersected old underground workings. The power house at 10:00 is at the head of major slumpage.

The Lavender Pit, which began stripping in 1954, included the Sacramento Pit, initiated in 1913 at what is now the northwest end of the pit. The Lavender Pit was named for Harrison Lavender, who became mine superintendent of the Copper Queen Mine in 1931, having started as a miner, and became general manager in 1937 for Phelps Dodge.

The head frames across the pit at 10:00 are the Campbell shafts. This mine was the main underground producer in the Warren district, extending 3,600 ft. deep and supplying three-fourths of the total district production. The ore bodies consisted of rich lead-zinc-copper replacement bodies in Escabrosa, Martin and Abrigo formations.

The Warren mining district was named after George Warren, a prospector grubstaked by the army scout John Dunn, who had noticed rich ore in 1877 while camping in Mule Pass in pursuit of Apaches. Warren and Dunn owned the Copper Queen which merged with

Phelps Dodge after 1880.

The upper benches of the southeast pit wall (9:30 to 11:30) are in maroon outcrops of Glance Conglomerte containing over 90% Pinal Schist-clasts. The Glance rests depositionally on the Jurassic Sacramento stock in the greenish brown outcrops of the lower benches (11:00 to 1:00). Glance Conglomerate here contains mineralized clasts of Pinal Schist. The southwest pit wall (12:00 to 2:30) is contact-altered Horquilla Limestone, Earp Formation and Colina Limestone (upper benches, which are overlain at 12:00 by Glance Conglomerate. The entire south wall of Lavender Pit has been downfaulted along the west-northwest-striking Dividend fault which traces through the center of the pit. The north wall of the pit is in upthrown Pinal Schist and is intruded by the Sacramento stock, named for Sacramento Hill at 3:00. Behind the ridge north of the road, Pinal chist is overlain by Glance Conglomerate (50-200 ft. thick). Thus 5,000 to 6,000 ft. of Paleozoic section has been removed from the north block in Triassic-Jurassic time by activity along the Dividend fault. Bisbee is anomalous in that it is the only known Jurassic porphyry copper deposit in southeastern

Arizona.

The Bolsa Quartzite, Abrigo, Martin, Escabrosa, Horquilla and Colina limestones were intruded by the Jurassic Sacramento stock along the Dividend fault. The initial stage of mineralization was intense silicification and pyritization of limestone, schist and porphyry. An extension of the Mule Fault and leaves the southern end of the Mule Mountains.

4.9 Elfrida-Double Adobe turn off on left. Upturned Bisbee Group at 2:00 comprises a sharp west-northwest-trending, moneclinal flexture on trend with the Dividend fault. This monocline is overturned locally and probably reflects reactivation of the Dividend fault during post-Bisbee Group orogenic movements (probably Laramide). 2.9

7.8 Light-colored low ridges (2:00) at foot of Mule Mountains are Mural Limestone overlying the Morita Formation. 3.0

10.8 Milepost 354. Mural Limestone outcrops to left and right. 0.8

11.6 Gold Hill road on right. Paul Speer lime quarry at 2:00. 1.7

13.3 Paul Speer road and lime plant on right. 0.7

14.0 Start of 4-lane highway. 0.9

14.9 Cochise College on left. 0.9

15.8 San Jose Peak in Mexico at 3:00, as are the prominent inclined hogback cliffs (2:30) in the Sierradaelos ajos, of Mural Limestone which thickens southward in Mexico. 5.3

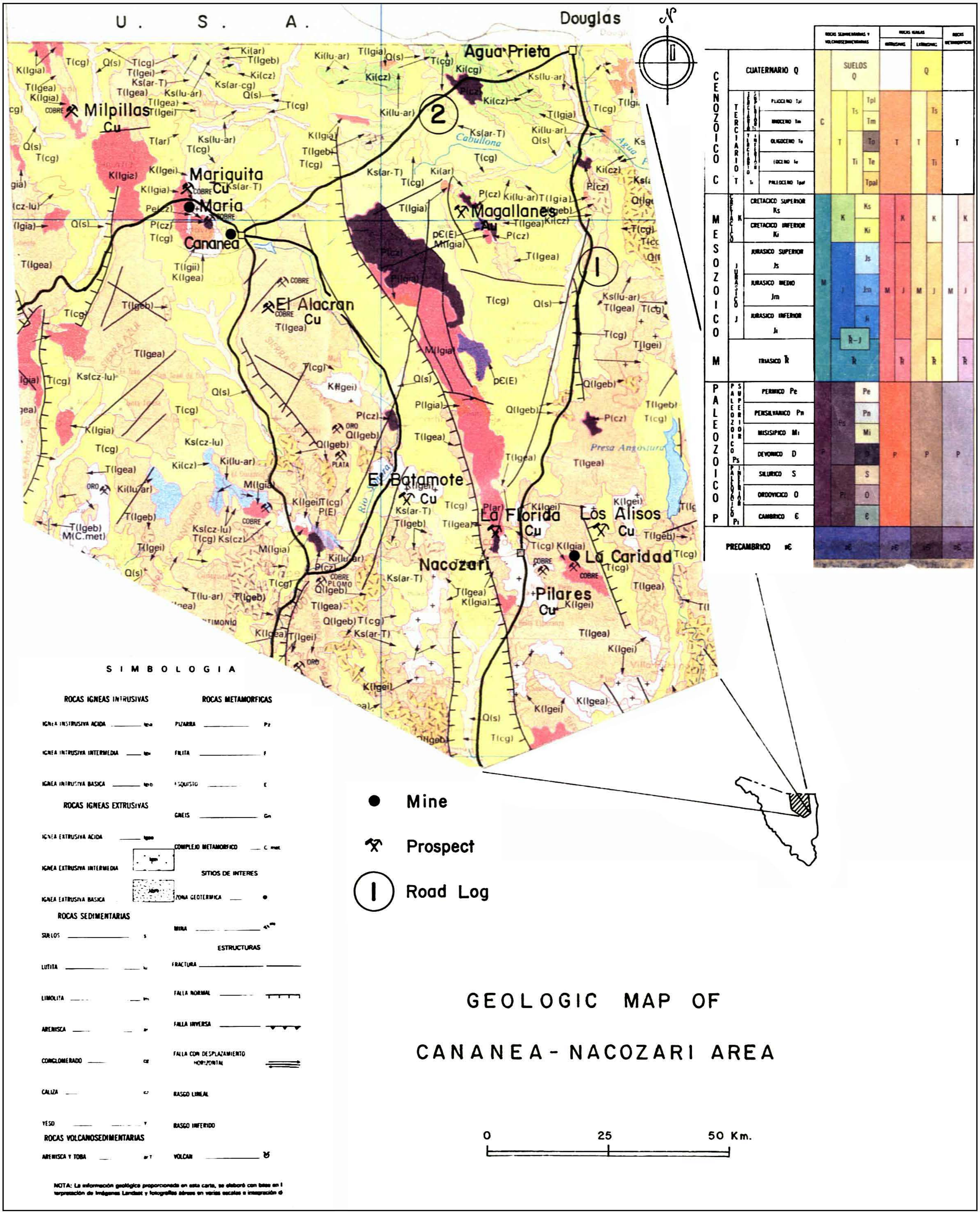
21.1 Bridge over Whitewater Draw, which drains south to Rio San Bernardino and the Gulf of California by the Rio Yaqui. 0.3

21.4 U.S. 666 to Willcox on left. City of Douglas straight ahead. 0.4

21.8 Milepost 365. Former site of Phelps Dodge Corporation's Douglas smelter on right. Douglas was founded in 1901 and named for Dr. James Douglas, who established the smelter here for the Bisbee ores. 2.1

23.9 Douglas city limits. Turning south to cross the International Border for start of your Mexico trip.

RODLOG.2



GEOLOGIC MAP OF CANANEA-NACOZARI AREA

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ROAD LOG 1

ROAD LOG FROM AGUA PRIETA TO LA CARIDAD MINE

SUNDAY OCTOBER 2 AND SATURDAY OCTOBER 8, 1994

Driving distance:	124.8 Km.
Driving time:	2:30 Hours
Departure:	9:00 A.M. (From Agua Prieta)
Leader:	Remigio Martinez Muller

SUMMARY

This trip starting at Agua Prieta takes one through Cretaceous sedimentary rocks near Agua Prieta to Tertiary Volcanics and intrusive rocks in the vicinity of La Caridad Mine.

Cumulative
Distance
Km.

0.0	International crossing, initiate trip on Panamerican Avenue.
0.5	Turn left on Calle 6.
0.7	Turn left on Avenida 6.
2.4	Intersection with the Imuris-Janos Highway.
4.8	Intersection with Agua Prieta-Nacozari Highway.
10.8	On the right, road that leads to airport and to Mexicana de Cobre's lime plant. This plant produces lime for the La Caridad Concentrator from

the Cretaceous Mural limestone which is a patch reef deposit.

16.8 On the right, Sierra Anibacachi, which is composed of Cretaceous limestones, shales, and sandstones. On the left, Sierra La Ceniza composed of sandstones.

24.8 Immigration and Customs check point. Have your papers ready.

25.3 Cabullona creek.

32.1 On the left, Sierra de Cabullona made of Paleozoic limestones and Cretaceous shales and sandstones.

45.0 Ejido 47. Farming community.

50.0 Town of Fronteras with population of 1,500 founded in 1645.
Elevation of 1,129 m. above sea level.

67.0 On the left, old foundations of the Flour Esqueda mill. Esqueda was founded in 1902 has 6,000 inhabitants and elevation of 1,201 m. We are in a valley but have entered the Tertiary volcanic terrain. The hills to the left represent this lithologic units.

92.2 Left turn off to Mexicana de Cobre installations. Main highway leads to Nacozari.

93.0 Mexicana de Cobre check point.

96.0 On the left the smelter.

98.1 On the right, the airport.

106.8 Road cuts with quartz veins in rhyolitic volcanic rocks.

107.8 On the right, Mexicana vein. Produces silica flux with gold and silver values.

114.2 Left turn leads to El Globo townsite.

115.8 Intersection with La Caridad-Nacozari access road.

119.0 Check point to enter the Mine and Concentrator installations.

124.0 Check point to enter the open pit mine.

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GEOLOGIC SUMMARY OF THE NACOZARI MINING DISTRICT

The Nacozari Mining District covers an area of approximately 200 square kilometers located in northeastern Sonora, 120 kilometers South of Douglas, Arizona and 80 kilometers southeast of Cananea, Sonora (Figure 1). The rocks in this area consist of Mesozoic and Tertiary sediments and volcanics which are intruded by felsic to intermediate porphyry stocks. The mineralization in the district consists of precious metal veins, copper tungsten-bearing breccia pipes, and porphyry copper. The La Caridad Porphyry Deposit is by far the most important mineral deposit in the district.

Figure 2 shows the geology of the district. The rocks in the district are, from younger to older:

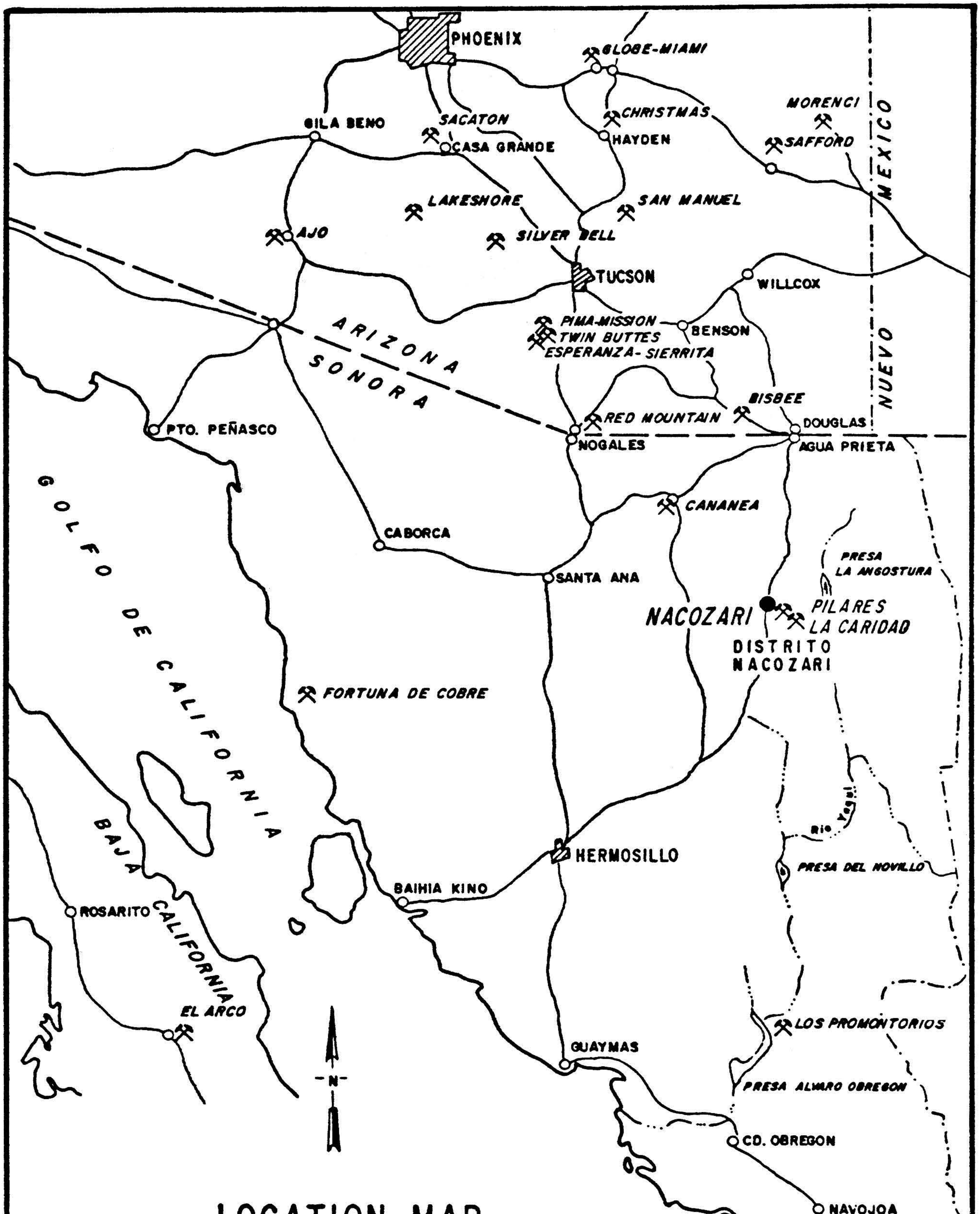
El Globo Rhyolite
Mineralization Breccias
Porvenir Andesite
Paulina Latite
La Caridad Intrusive complex
Grandiorite
Undiferenciated Andesitic rocks

The rocks in the La Caridad deposit (Figure 3) are pegmatite, quartz monzonite porphyry, granodiorite and diorite. The alteration consists of phylic, argillic and propylitic (Figure 4) with some tourmalinization. The mineralization is composed primarily of pyrite, chalcocite and chalcopyrite with lesser amounts of molybdenite, galena and sphalerite. Economic mineralization consists of mostly chalcocite which is in blanket-like enrichment zone (Figure 5).

The Pilares Breccia pipe is a pipe where collapse affects the Paulina Latite, Porvenir Andesite, a diorite porphyry and dacite tuff, (Figure 6). Mineralization consists of chalcopyrite, pyrite, hematite and sheelite. Economic copper mineralization is located mostly on the "noses' and the periphery of the breccia, but always within the breccia. Chalcopyrite is the most important copper mineral, chalcocite is present only in a small portion of the upper part of the breccia.

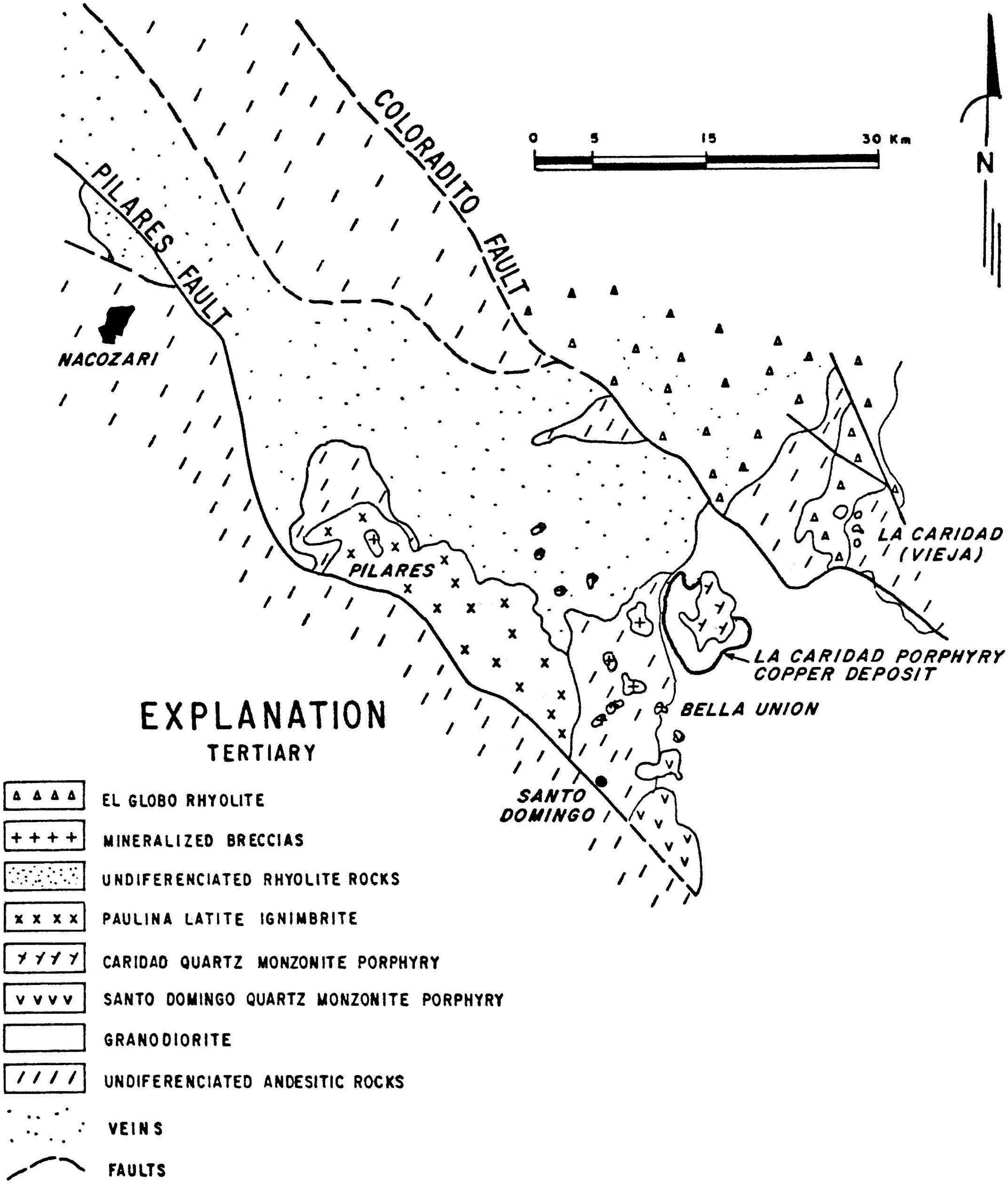
Figure 7 is a geologic composite map of the benches that are being mined. Our visit to the mine will start at the lowest bench (1530) and proceed outward.

FIGURE 1



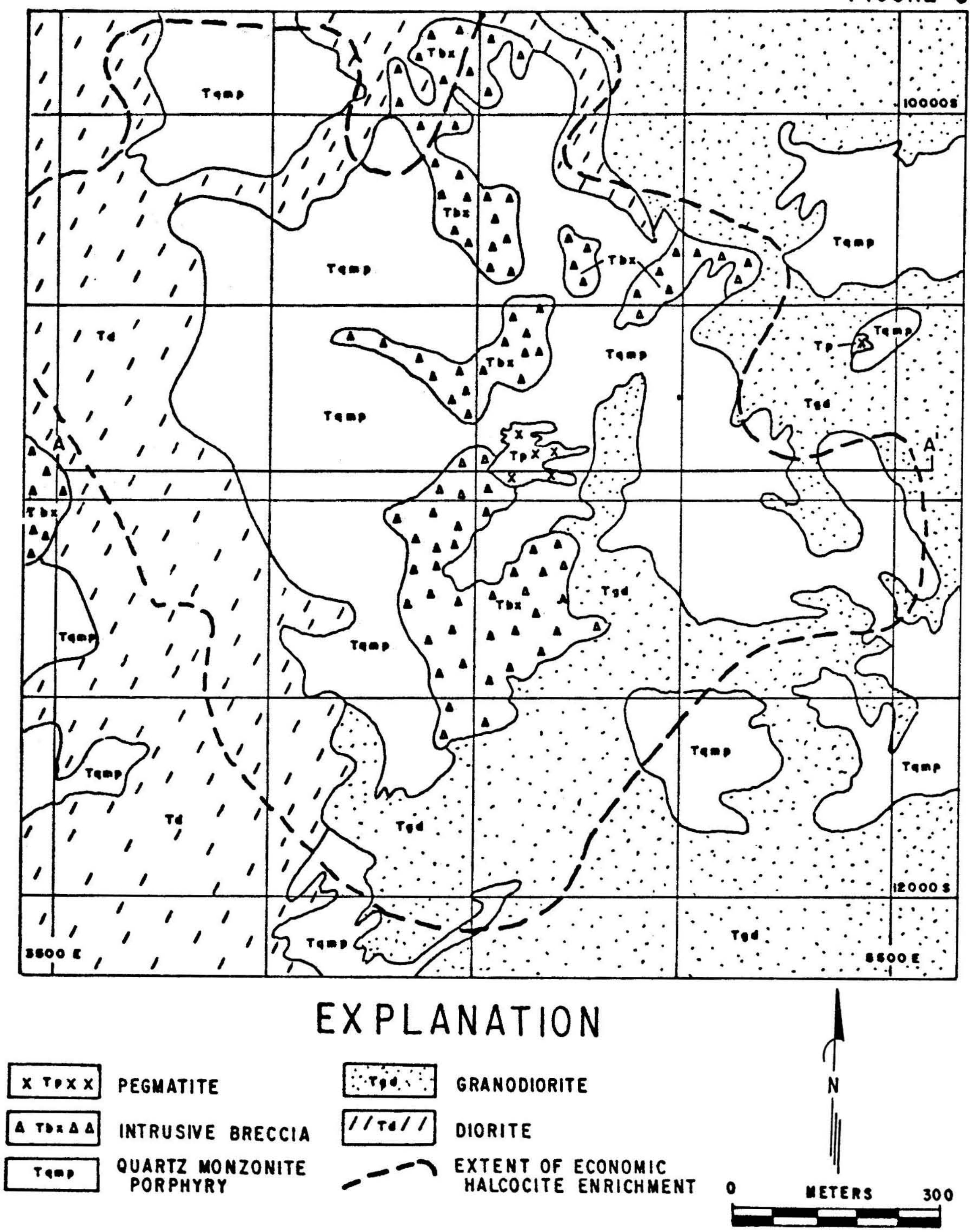
LOCATION MAP
NACOZARI SONORA, MEXICO
SCALE 1: 3,500.000

FIGURE 2



GEOLOGY OF THE NACOZARI DISTRICT

FIGURE 3



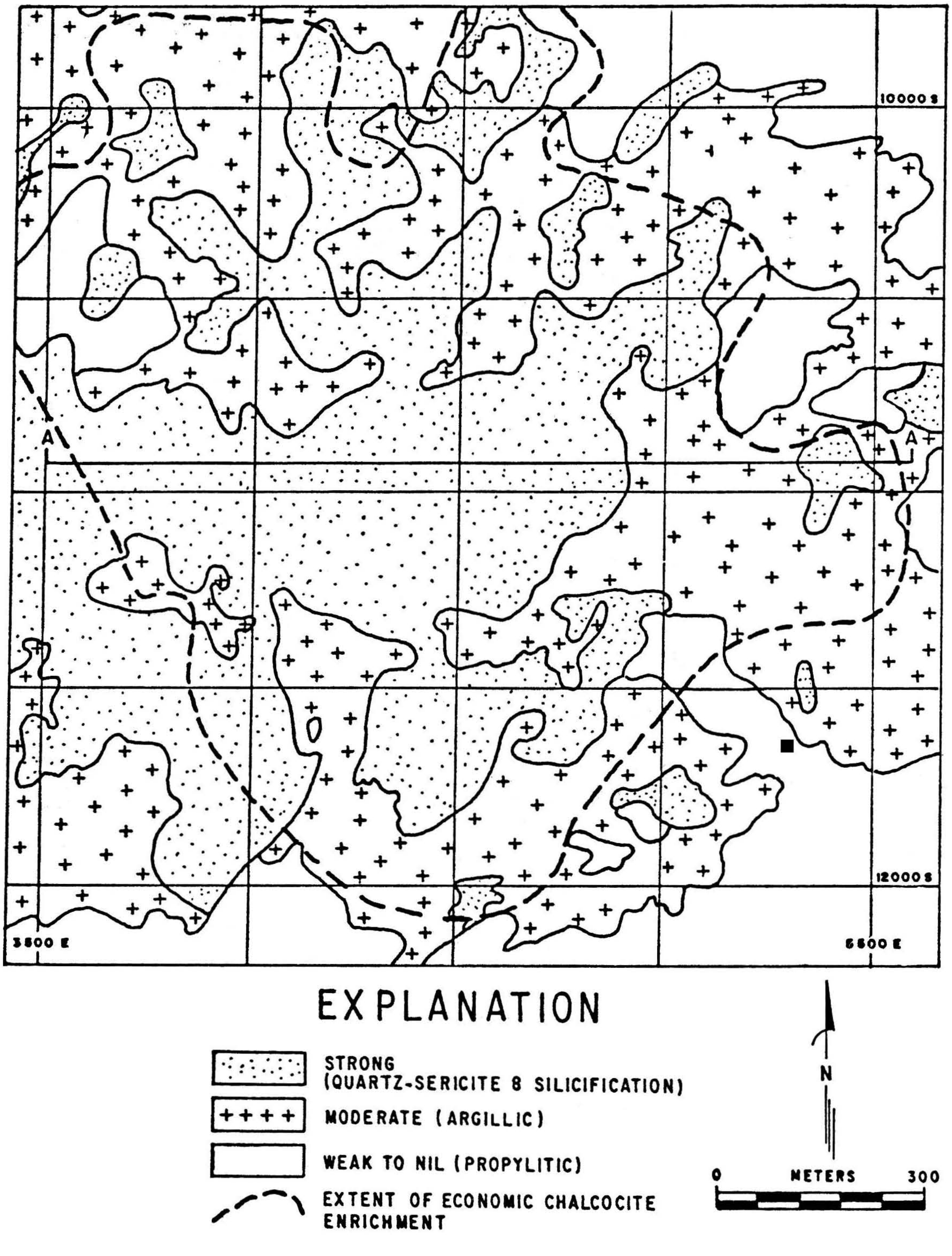
GENERALIZED SURFACE GEOLOGY

LA CARIDAD PORPHYRY COPPER

NACOZARI, SONORA

AFTER SAEGART, SELL, 8 KILPATRICK

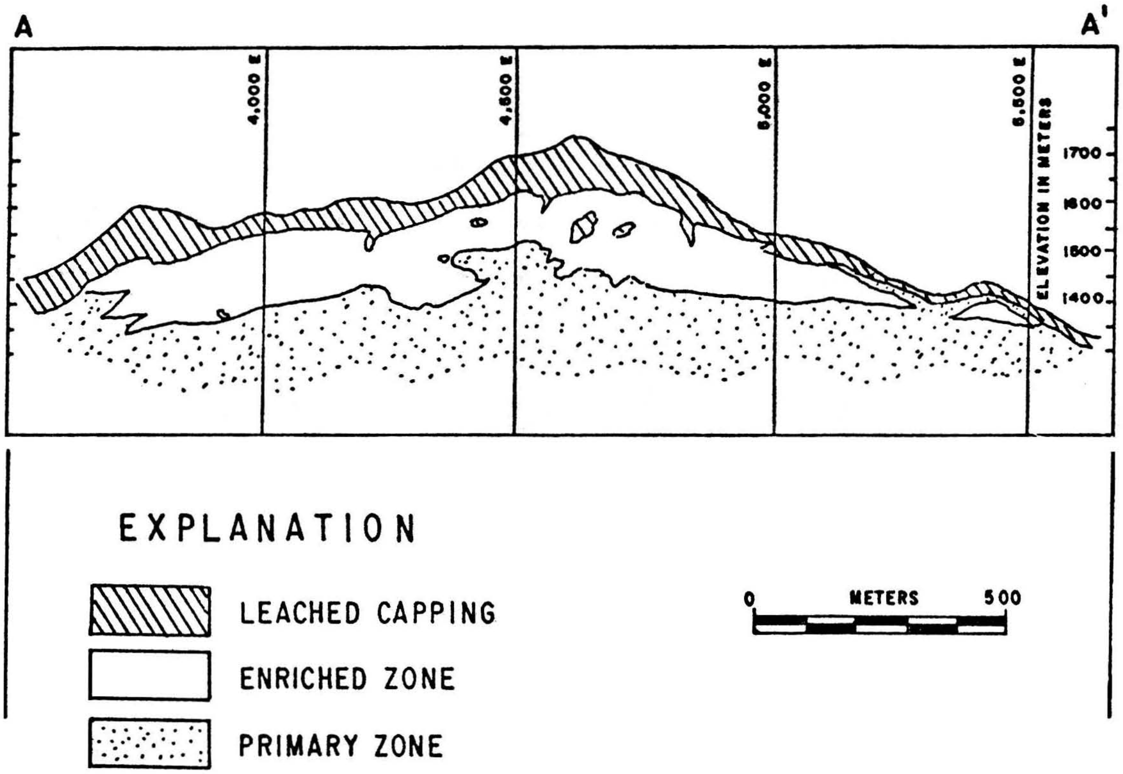
FIGURE 4



SURFACE ALTERATION MAP
LA CARIDAD PORPHYRY COPPER
NACOZARI, SONORA

AFTER SAEGART, SELL, 8 KILPATRICK

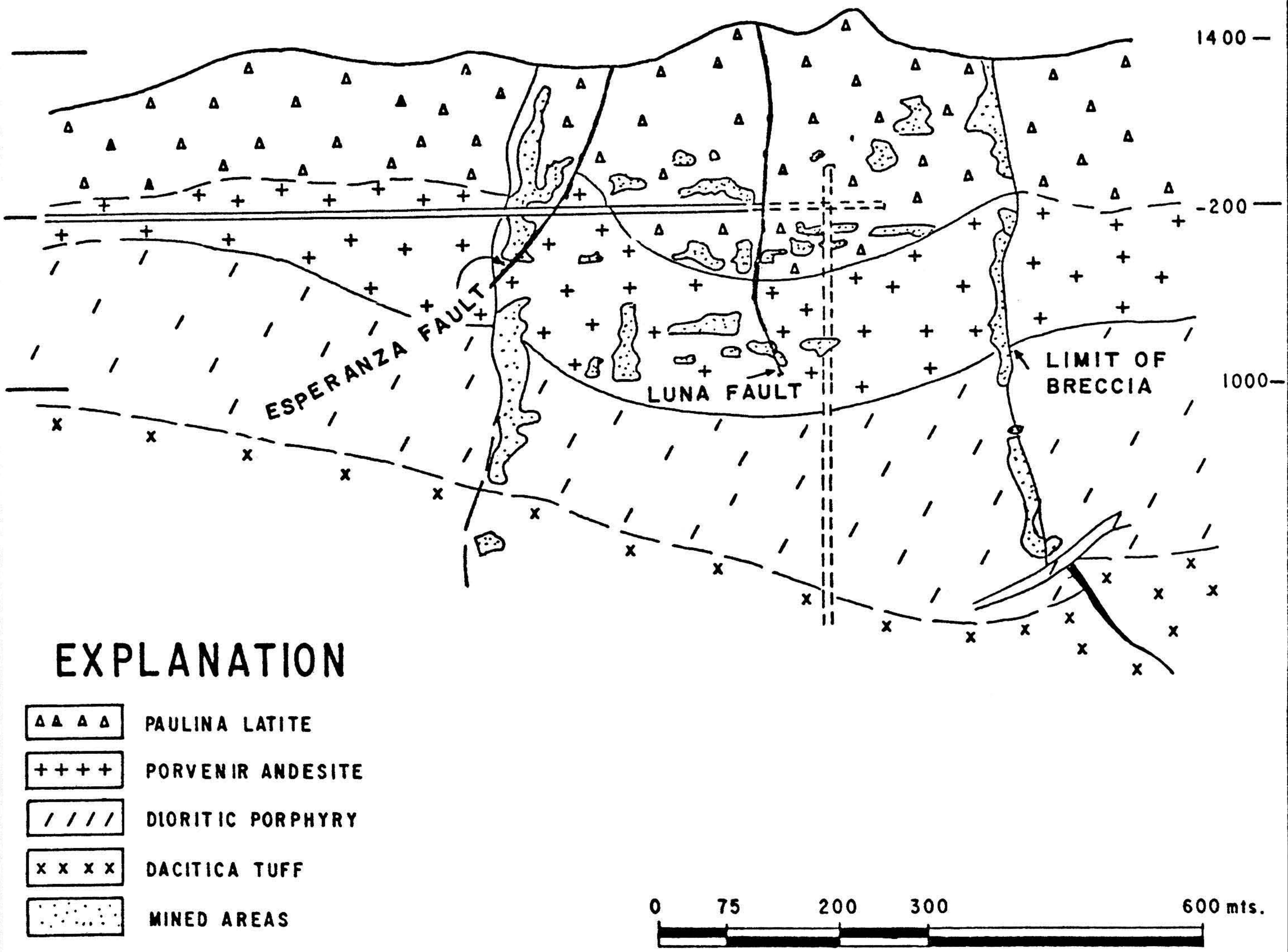
FIGURE 5



SECTION A - A'
VERTICAL DISTRIBUTION OF MINERALIZATION
NACOZARI, SONORA

AFTER SAEGART, SELL, & KILPATRICK

FIGURE 6



SECTION A - A'

PILARES MINE

NACOZARI, SONORA

ROAD LOG 2

ROAD LOG NACOZARI TURN OFF TO CANANEA
MONDAY OCTOBER 3 AND SUNDAY OCTOBER 9, 1994

Driving distance:	80 Km.
Driving time:	1:30 Hours
Departure: (from Nacozari)	9:00 A.M.
Leader:	Ramon Ayala Fontes

SUMMARY

This road log starts at the junction of the Nacozari-Agua Prieta Highway with the Imuris-Janos Highway. From this point we drive through Cretaceous sedimentary rocks, valley gravels and at Cananea, volcanic, sedimentary and intrusive rocks. (This log is modified after Roldan, Clark and Schmitt).

Cumulative

Distance

Km.

0.0	Imuris-Janos Highway.
15.0	Turn off to Ocotillo Microwave Station.
18.0	Lower Cretaceous strata dipping northeast forming cuestas.
25.0	Road passes between hills: Cerro La Muela to the north and Sierra Anibacachi to the south, both part of the Bisbee Group.

31.0 Outcrop of the Upper Cretaceous Cabullona Group.

33.7 Dirt road at left leads to Cerro Magallanes, a rhyolite dome. East, light-colored beds of Mural limestone. North, Sierra San Jose.

35.0 Right turn leads to the border town of Naco. The Mule Mountain of southern Arizona to the northwest.

40.3 To the right, the Magallanes rhyolite dome, which contains a disseminated gold prospect.

41.5 At right, Cuauhtemoc Hill capped by basaltic rocks.

42.5 At left, Ejido Cuauhtemoc. (Cattle grazing community)

53.0 Contact between gravels and Upper Cretaceous sequence of the Cabullona Group.

54.1 Arroyo Claro bridge.

56.0 Cananea in plain view to the southwest.

57.4 To the left, Sierra de Los Ajos, to the right at the distance, the Huachuca Mountains of Arizona.

76.0 Cananea City limits.

GENERAL GEOLOGY OF THE CANANEA MINING DISTRICT

Ramon Ayala-Fontes

Mexicana de Cananea. S.A. C.V.

The geology of the Cananea mining district, located in north central Sonora, Mexico, 40 Km from the International border, consists of a Pre-Cambrian granitic basement, overlain by a Cambrian quartzite and a series of upper Cambrian to Carboniferous limestones, uncomfortably overlain by a thick sequence of volcanic rocks, occurring as interbedded flows, breccias, lahars and pyroclastic facies. The entire lithologic sequence was invaded along lines of structural weakness by deep seated granitic rocks with final intrusive differentiates of diabase and quartz porphyry. This extended period of igneous activity lasted from late Jurassic to early Tertiary time.

Hydrothermal alteration and mineralization occupies an area of about 30 Km^2. The major axis of the district coincides with the northwest-southeast trend of the intrusive rocks, as well as with the main regional evidence of uplift, along which Paleozoic sediments were raised, folded and faulted, with relation to the volcanic rocks that flank the uplifted block. Major evidence of faulting is of pre-intrusive age or resultant from the emplacement of deep seated and shallow intrusives. Minor post mineral faulting, complements the complex structural setting in the district.

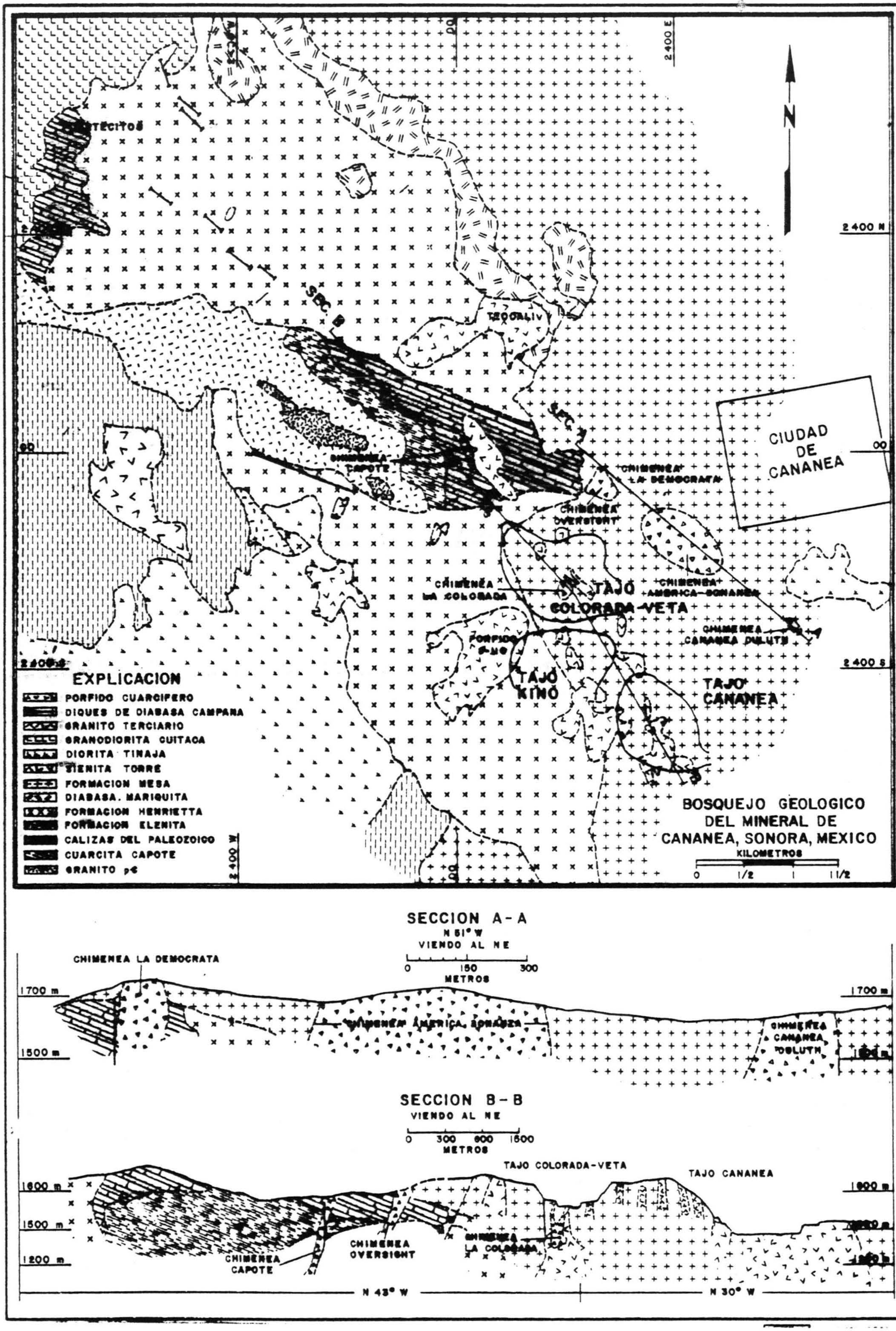
The most productive mineral deposits have been localized within more or less vertical pipe-like breccia structures, namely "El Capote", "Cananea-Duluth", "La Democrata", and "La Colorado". The district is quite unique for the occurrence of mineralized breccias. It is possible that these breccias acted as primary roots or feeders for the overlying mineral concentrations, trapped in structurally favorable conditions. Likewise, they may have provided the channelways for the mineralizing solutions that affected the host rocks. The breccias are isolated, sharply defined, usually oval or circular in plan and apparently not connected laterally with throughgoing fissures.

Important economic mineral deposits of the disseminated porphyry type, occur associated with the porphyritic intrusive rocks, adjacent volcanics and brecciated areas. The mineralization, closely related to nearly vertical quartz monzonite porphyry plugs, consists of a stockwork of quartz and sulfide veinlets in a strongly shattered and fractured zones, resulting from the forceful emplacement of the intrusives into pre-existing volcanic rocks. Chalcopyrite is the principal disseminated primary mineral, commonly associated with pyrite and quartz, occasionally with molybdenite. Supergene mineral concentrations have constituted an important source of copper in the district. The supergene zone extensively overlies the primary zone, and the principal sulfide mineral is chalcocite with minor covelite. A hematite-goethitejarosite development caps the enrichment zone of the major disseminated deposit.

Mineralization occurred in several stages. An early pegmatitic event, associated with bornite-chalcopyrite-molybdenite in the breccia structures, followed by a widespread flooding of hydrothermal solutions, accompanying extensive quartz-pyrite-chalcopyrite assemblages. A late and distinct pyrite-quartz introduction, envelopes and closes the mineralization sequence. An intense hydrothermal alteration episode is evident in a pervasive, feldspar destructive, sericitic and argillic products which are present throughout the district's igneous complex.

Skarn associated mineral deposits also occur in the central and northwestern portions of the district. Copper-zinc-silver, manto type replacement deposits in metamorphosed limestones, tend to follow favorable horizons or occur related to crosscutting brecciation. Calc-silicate mineral assemblages are typically present in these skarn type mineral deposits.


Arizona
Tucson
Cananea
Hermosillo
Sonora
200 km


BOSQUEJO GEOLOGICO
DEL MINERAL DE
CANANEA, SONORA, MEXICO
KILOMETROS
0
1/2
1
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N
2400 E
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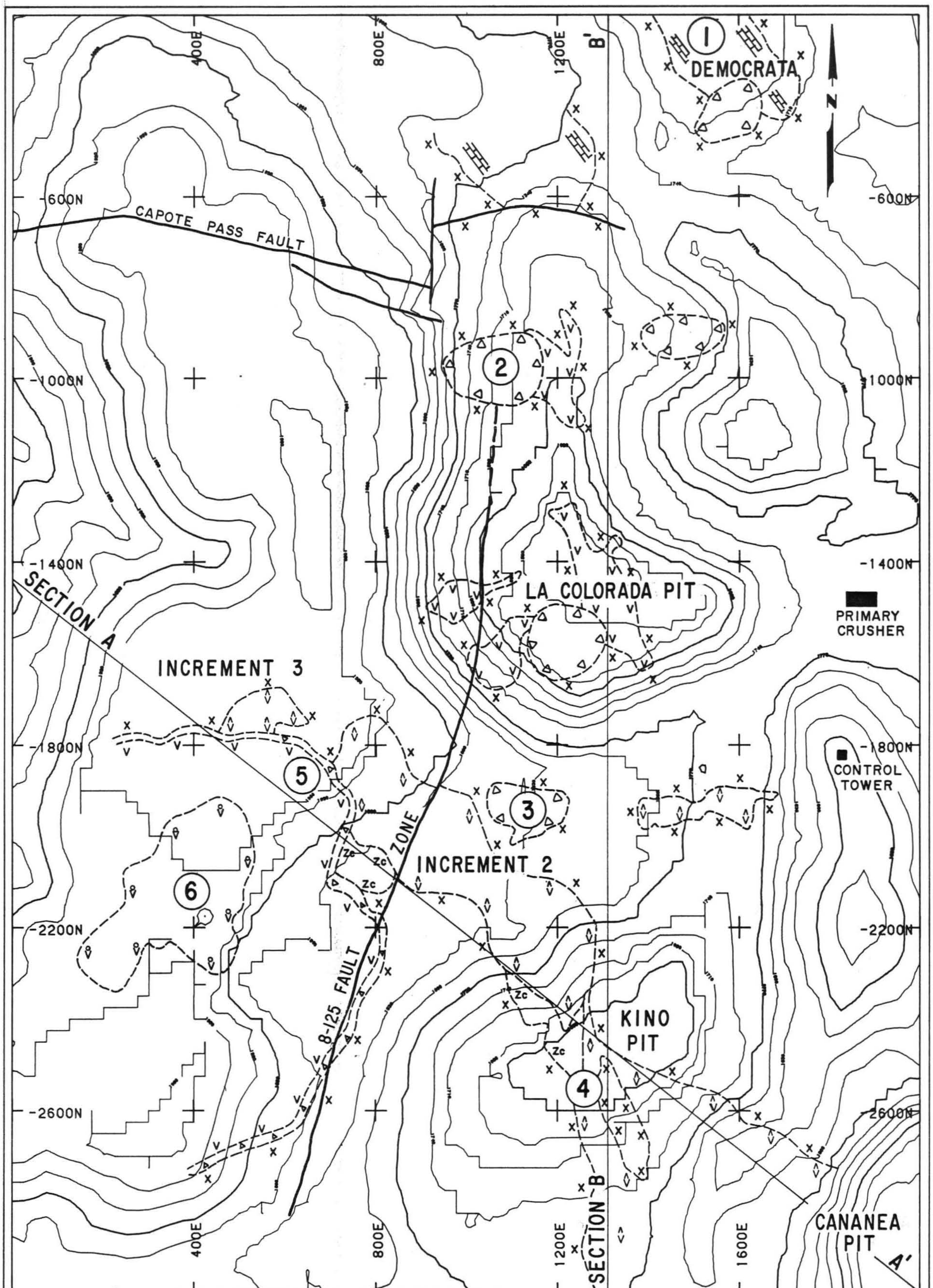
00
CIUDAD
DE
CANANEA
TECOALI
SEC. B
SEC. A
CHIMENEA CAPOTE
CHIMENEA LA DEMOCRATA
CHIMENEA OVERSIGHT
CHIMENEA LA COLORADA
CHIMENEA AMERICA-SONANZA
CHIMENEA CANANEA DULUTH
TAJO
COLORADA-VETA
PORFIDO
TAJO
KINO
TAJO
CANANEA
EXPLICACION
PORFIDO CUARCIFERO
DIQUES DE DIABASA CAMPANA
GRANITO TERCIARIO
GRANODIORITA CUITACA
DIORITA TINAJA
SIENITA TORRE
FORMACION MESA
DIABASA. MARIQUITA
FORMACION HENRIETTA
FORMACION ELENITA
CALIZAS DEL PALEOZOICO
CUARCITA CAPOTE
GRANITO p€
SECCION A-A
N 51° W
VIENDO AL NE
0
150
300
METROS
CHIMENEA LA DEMOCRATA
1700 m
1500 m
CHIMENEA AMERICA, SONANZA
CHIMENEA
CANANEA
DULUTH
SECCION B-B
VIENDO AL NE
0
300
600
1500
METROS
TAJO COLORADA-VETA
TAJO CANANEA
1600 m
1500 m
1200 m
CHIMENEA
CAPOTE
CHIMENEA
OVERSIGHT
CHIMENEA
LA COLORADA
N 43° W
N 30° W



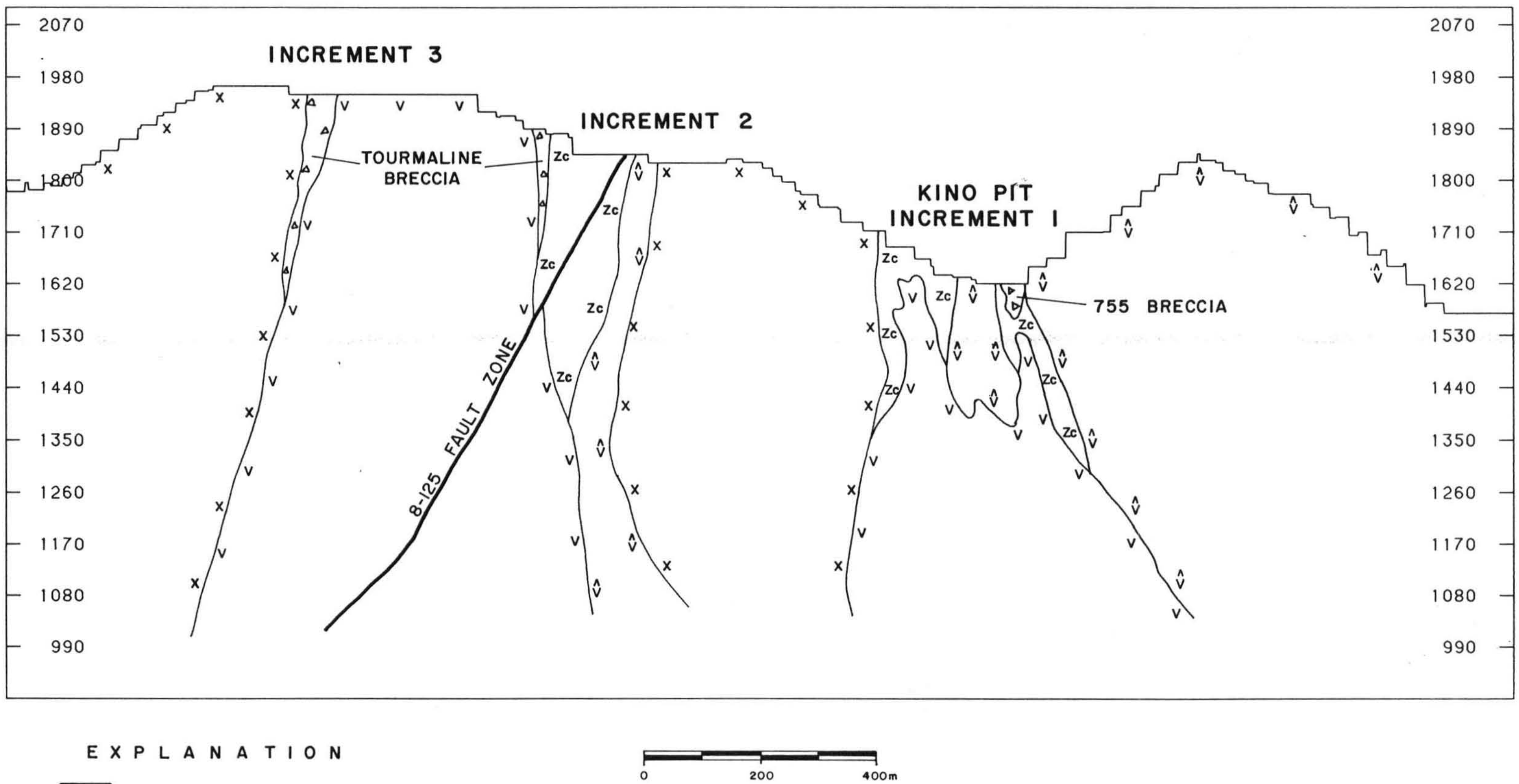
0 200 400 m

CANANEA OPEN PIT MINE AREA
GENERAL GEOLOGY

SCALE 1: 10000

EXPLANATION

△	BRECCIA	Zc	CONTACT ZONE		CONTOUR LINE
	COARSE Q-F PORPHYRY	x	VOLCANIC ROCK	x v	GEOLOGIC CONTACT
v	QUARTZ FELD. PORPHYRY		LIMESTONE AND SEDIMENTARY ROCKS		FAULT
	FELDESPATIC PORPHYRY				



EXPLANATION

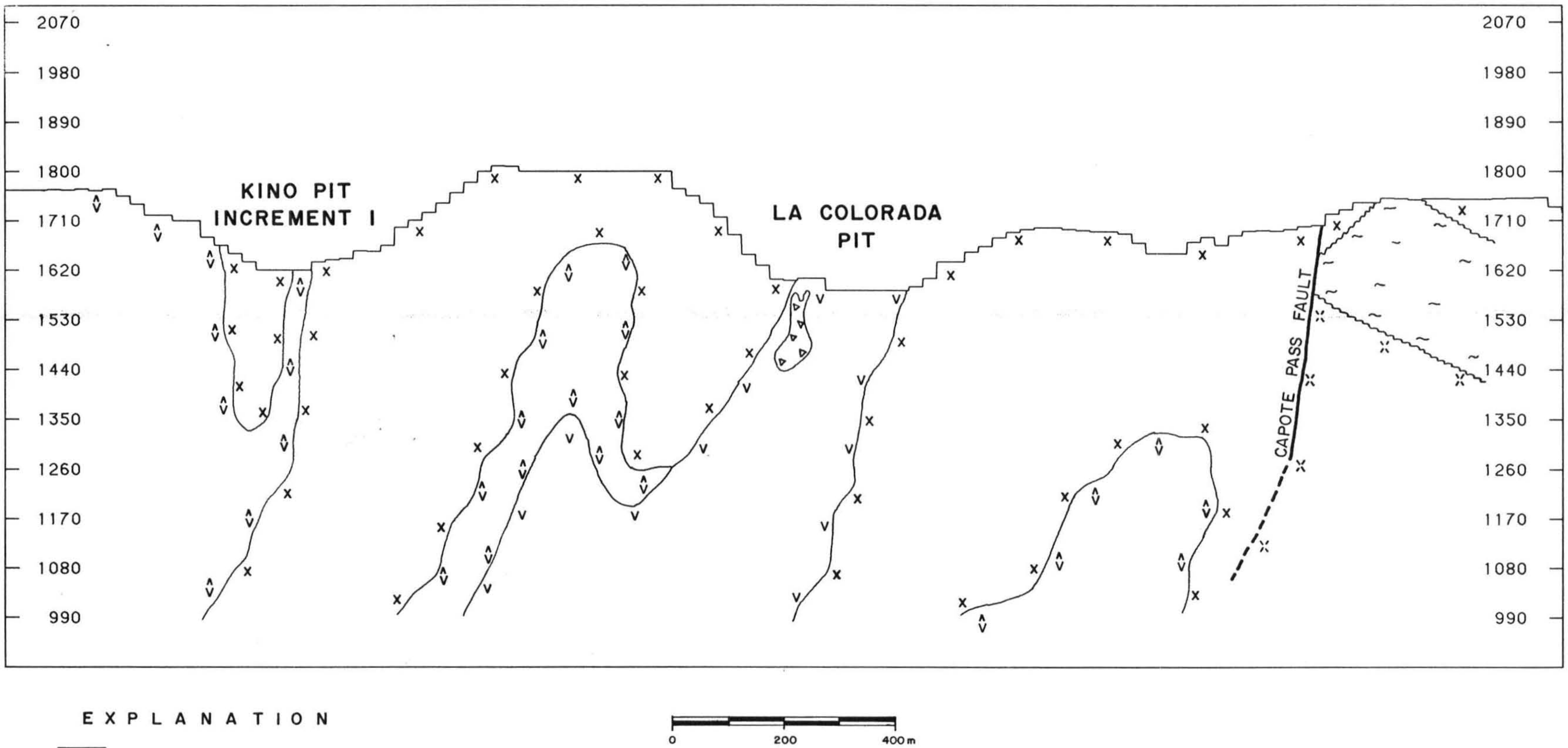
- Δ BRECCIAS
- V QUARTZ-FELDESPAR PORPHYRY
- Zc CONTACT ZONE
- FELDESPAR PORPHYRY
- X VOLCANICS

MEXICANA DE CANANEA, S.A. de C.V.
GEOLOGICAL DEPARTMENT

SECTION A-A'

N 38° W — Looking N E

Scale 1: 10,000 — 1994



EXPLANATION

- △ LA COLORADA BRECCIA
- V QUARTZ-FELDESPAR PORPHYRY
- ◊ FELDESPAR PORPHYRY
- X VOLCANICS
- ~ QUARTZITE
- ⁑ CANANEA GRANITE

MEXICANA DE CANANEA, S.A. de C.V.
GEOLOGICAL DEPARTMENT

SECTION B - B'

N - S Looking WEST
Scale 1: 10,000 1994

ROAD LOG

ROAD LOG: CANANEA TO IMURIS TO NOGALES

Monday October 3 and Sunday October 9, 1994

Driving Distance: 143 Km.

Departure: From Cananea

SUMMARY

The mine visit sites are within the continuation of the basin-and-range topography with Cretaceous sediments intruded by batholithic granite-granodiorite and overlain by Tertiary flows and volcaniclastic sediments. Westward, Jurassic arc volcanic-sediments series become involved in detachment and strike-slip tectonics and the rise of metamorphic core complex suites. (This log modified after Clark, Roldan, and Schmitt, 1992).

Cumulative Distance, Km:

0.0 Cananea *Glorieta*, traffic circle. Locomotive monument. Travel northwest on Highway 2 toward Imuris.

0.3 Railroad tracks.

0.8 Conglomerates overlying volcaniclastic units. Next ten kilometers, passing through Upper Cretaceous (Kus) sandstones, shales and conglomerate; Lower Volcanic (K-Tlu) units of andesite flows and tuffs with intercalated sediments; and the intrusive (K-Tig) Sonoran batholithic complex, here called the Cuitaca Granodiorite.

11.0 Turn of Highway, visit the Mina Maria and return to Highway 2.

11.6 Crest of range.

13.6 At 12:00 is Sierra Mariquita, part of the Sonoran Batholithic suite intruding the Lower Volcanics. Turn off Highway to visit Mina Mariquita porphyry copper deposit located on the west flank of the Sierra. Return to Highway 2.

15.5 Weathered and oxidized intrusive.

16.7 Possible fault contact between conglomerate and granodiorite.

23.5 Road cuts in pediment conglomerate.

24.4 Bridge: *Ejido* Vincente Guerrero.

24.9 Altered intrusive outcrops on left.

29.8 Rounded forms developed on granodiorite.

34.8 Km post 118. Bridge. *Aduana* check point. (Road north 35 km to Projecto Milpillas. Deposit under 1000 meters of post-mineral cover.)

40.3 Alluvial filled and cultivated Cocospera valley with flanking terraces.

40.6 Road to right to *Mision de Nuestra Senora del Pilar y Santiago de Cocospera.* This old church was reconstructed by *Padre Kino* during 1703-1704, and 290 years later it again needs additional work.

49.6 Crossing *Sierra El Pinito* consisting of Lower-Middle Jurassic volcanic arc assemblage and Upper Jurassic-Lower Cretaceous sedimentary units.

55.5 Large roadcuts in Cretaceous Glance Conglomerate.

59.6 A detachment-type fault contact between Jurassic volcanic arc rocks and Cretaceous conglomerates and sandstones. Note the color and topographic change along the fault trace.

62.2 Road side exposure of Jurassic metamorphosed rhyolite porphyry with oxidized pyrite grains.

65.6 Steeply inclined units of Jurassic sandstone, graywacke, and conglomerate overlies the rhyolite porphyry of Lower-Middle Jurassic age.

67.4 Road dropping through conglomerates, with younger Tertiary over Late Jurassic-Early Cretaceous Glance Conglomerate equivalent on north side of road.

78.0 Approaching Imuris. Hills and ranges to south and west are underlain by schist and orthogneiss of the Magdalena metamorphic core complex.

78.4 Imuris. Take right fork to Nogales on Highway 15. Travel along the drainage basin of the Rio Magdalena. Freeway is mostly along Neogene conglomerates and alluvium with several roadcuts of rhyolite porphyry near La Casita. Ranges to west are Jurassic age rhyolite porphyry, granite porphyry, silicic tuff,and conglomerate. High range to east is predominantly Tertiary rhyolite to the north with Jurassic volcanic arc units on the south.

142.5 Heroica Nogales.

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FIELD TRIP

HANDOUTS

CANANEA MINE VISIT

STOP 1

- Cananea-Sonora Hill Pits view point. Over 100 million tons of ore were mined from these pits. Presently is being used as a reservoir for copper pregnant solutions for the SXEW Plants.

- On the road cut behind the view point, we see a exposure of an example of near surface gossan in the form of hematite-jarosite-goethite development along veinlets and disseminated. The rock is the quartz feldspar porphyry

STOP 2 BENCH 1920

- Coarse quartz-feldspar porphyry with abundant medium to large quartz and feldspar phenocrysts in a siliceous matrix. The mineralization consists of fine disseminated pyrite and chalcocite. Some quartz, and alunite, veinlets and iron oxide in fractures.

STOP 3 BENCH 1920

- Quartz porphyry facies with abundant small to medium size quartz phenocrysts and small feldspars in a sericitized matrix with some clay minerals. Abundant, fine disseminations of pyrite and chalcocite, occasional quartz veinlets with molybdenum and others with chalcocite-pyrite-quartz assemblage. Avarage grade 0.55% Cu.

STOP 4 BENCH 1830

- Contact between quartz-feldspar porphyry and a tourmaline breccia. We can also observe to the NE the contact between the tourmaline breccia and the Mesa volcanic rocks. A mixture of oxide and sulfide veinlets (stockwork) are also present. A northeast and north west fracture pattern is noticeable on the bench.

CANANEA MINE VISIT

STOP 5 BENCH 1815

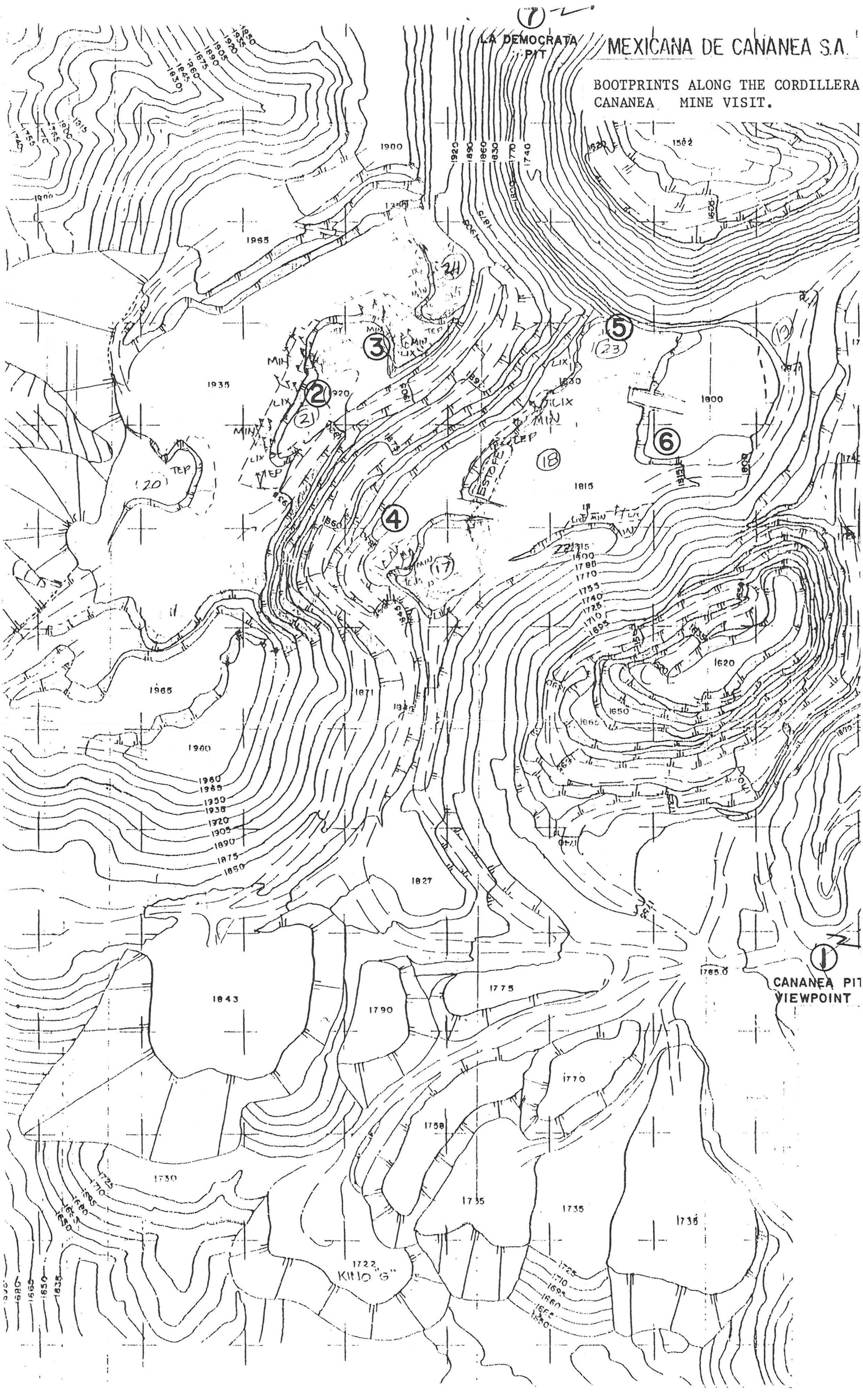
- Panoramic view of the La Colorada Pit. This pit was initially worked in the forties and later from the mid seventies to 1991. About 65 million tons of ore averaging 0.78% Cu were mined during this time. The world famous La Colorada breccia pipe was mined below the pit bottom. (7 million tons 6.0% Cu, 0.4% Mo). The geology of the pit consists of porphyry and volcanic rocks, contact zones between these two rocks and brecciated areas. Mineralization consisted of dissemination and veinlets stockwork of pyrite, chalcocite, molybdenite and quartz.

STOP 6 BENCH 1800

- 244 mineralized breccia consisting of high massive sulfides principally pyrite associated with quartz. The dimensions of the breccia are 190 by 120 meters. The cementing sulfides also contain up to 2.0% Cu locally. The fragments vary in size from centimeters to up to 2 meters in size mostly volcanic rock fragments are present with some feldspar porphyry. Brecciation is irregular and is not deeprooted. Average grade of the breccia is about 0.3% Cu.

STOP 7 LA DEMOCRATA PIT (BENCH 1665)

- Skarn type mineralization is exposed in La Democrata pit consisting of chalcopyrite-bornite-pyrite-sphalerite mineralization hosted by calc-silicated rocks with calcite, epidote, pyroxene and chlorite alteration. The vuggy texture is common in the La Democrata pit exposures which are locally associated with La Democrata breccia pipe.


MEXICANA DE CANANEA S.A.
BOOTPRINTS ALONG THE CORDILLERA
CANANEA MINE VISIT.
LA DEMOCRATA PIT
CANANEA PIT VIEWPOINT
KINO "G"
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1900
1965
1935
1920
1800
1815
1860
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