CONTACT INFORMATION
Mining Records Curator
Arizona Geological Survey
416 W. Congress St., Suite 100
Tucson, Arizona 85701
520-770-3500
http://www.azgs.az.gov
inquiries@azgs.az.gov

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ASARCO

Southwestern Exploration Division

July 19, 1984

To R. L. Brown

Some Porphyry Copper History

Under existing dismal market conditions, I'm sure you will agree that porphyry copper tales make something less than exciting reading. This is the final installment.

PART III

22. BAGDAD

Gila Conglomerate capped by basaltic flows covered the Bagdad porphyry copper deposit late in the Tertiary period. These units were truncated by modern erosion, exposing sizeable areas of leached capping, as well as the southern edge of the enriched zone (Figs. 61 A & B). Early day miners were attracted by rich accumulations of oxide copper in outcrop (derived from chalcocite in sub-outcrop) and eventually dug their way deep into the blanket, which ran in part well over 2.0% Cu. This discovery, made in 1905, was followed up later by churn drill exploration. A reserve of some 13 million tons of 1.68% Cu was reported in 1917. Over subsequent years, during which small but richer portions of the ore were mined and milled, Asarco made several evaluations and at one time almost "took the plunge," but in 1940 H. A. Guess* terminated negotiations, advising Loerpabel** by telegram that, "15¢ market necessary for capital outlay on 20 million tons, 1.0% ore body. Outlook for 15¢ copper over 20 year period not bright and enterprise risky."

Three years later, having obtained an RFC loan, the Bagdad Company started block-cave mining at 2500 tpd. Plagued by ore dilution, largely due to ineffective draw control, the cave system was replaced by open pit mining (4000 tpd) in 1947. By 1956, nearly 14 million tons grading .98% Cu had

* V.P. and Manager of Mines, N.Y.

** Manager of Southwest Mining Department.

been milled (most of the concentrates shipped to Asarco smelters), but with little return to Bagdad stockholders. With the operation in a somewhat precarious state financially, Asarco undertook yet another evaluation*. This effort involved extensive studies of the drilling and sampling, ore reserves, metallurgy, exploration possibilities, water, power, etc. By this time most of the chalcocite "cream had been skimmed," but chances looked fairly good for a substantial tonnage of .60 to .70% primary ore. This potential appeared to lie within the projected "zone of stronger copper mineralization," as shown on the small-scale plan (Fig. 62). Also outlined is the ore body as indicated by drilling, extent of alteration, lava-capping and the then existing pit perimeter.

In brief, the estimated reserve, including both "indicated" and "inferred," was reported (65) as follows:

Cutoff	Tons (Millions)	% Cu Total	W/O Ratio
.40% Cu	101	.68	1.63/1
.50% Cu	69	.77	2.73/1

It was also pointed out (65A) that "considering the possibility of eventual commercial interest in deposits averaging around .5% Cu, it should be emphasized, we believe, that Bagdad has a huge tonnage potential in material of that grade."

Bagdad capping contained an unusual amount of copper as oxide. To provide the required acid, an alternative to the conventional smelting of concentrates was investigated. This process, proposed by Dick Vincent**, required fluosolid (fluid bed) roasting of concentrates***, producing cement copper, with the resulting acid used for calcine leaching as well as heap leaching. Based on

* Earlier, in 1952, J.G. Pearcey of the Mining Dept. had calculated a reserve of 16.5 million tons at .77% Cu.

** Asst. Chief Milling Engineer, Asarco

*** At the time, Bagdad was treating 5 tpd of flotation concentrates in a pilot fluosolids plant, producing cathode copper by solvent extraction - electrowinning.

a rate of 10,000 tpd (.5% Cutoff), less capital was required, but operating costs were higher than conventional treatment; however, the operating profit per ton was also higher (over 20%) than conventional treatment. At 31¢ copper the roast-leach process looked modestly attractive with an operating margin of $1.65 per ton, exclusive of proceeds from dump leach. But this was 2¢ over Asarco's forecast price ---- and viability of the process, including production of acid for dump leaching, was questioned. The project failed to reach the negotiating stage. Four years earlier the price of J.C. Lincoln's* 56% of the stock was $6 million.

The mine continued production and in 1973 merged with Cyprus**, forming the Cyprus Bagdad Copper Company. Asarco terminated its smelter contract the following year and in 1977 the flotation plant was expanded from 6000 to 40,000 tpd. Reported ore reserves: 303 million tons at .49% Cu, .03 Mo. All of Cyprus' holdings were taken over by Standard Oil of Indiana in 1979 and in 1981 Bagdad's production rate was increased to 54,000 tpd. In 1982 the mill processed 19.2 million tons, recovering 8.4 lbs Cu per ton ---- plus 6,500 tons of cathode copper from dump leach. In Dec. 1983 production was 56,000 tpd and reserves, 400 million tons of .46% Cu and .02% Mo.

C. A. Anderson (65B) was the first to recognize potassic alteration at Bagdad (1950). He found that dark granular textured rocks that had been called diorite were originally quartz monzonite porphyries. Abundant brown leafy biotite had replaced book biotite and hornblende, and albite had replaced plagioclase accompanied by an increase in orthoclase and quartz. Occurring principally as narrow ribs (in outcrop), quartz-orthoclase-sericite was considered the second of two alteration facies.

* President of Bagdad Copper and majority stockholder.

** Cyprus operated the Bruce Mine, a nearby Cu-Zn massive sulphide deposit.

Anderson noted that hydrothermal biotite and/or orthoclase occurred in some other deposits (Ajo, San Manuel, Ely and Bingham), but "sericitic alteration appeared to be common to all the porphyry coppers."

Progress was being made, but potassic alteration was still regarded as the exception rather than the rule, and its close association with relatively strong hypogene copper mineralization not generally recognized ---- not until 1970, when the Lowell-Guilbert paper on alteration-mineralization zoning in porphyry copper deposits was published (66).

23. MT. TOLMAN (San Poil)

You no doubt will recall a 1957 expedition to the San Poil prospect* on the Washington State Colville Indian Reservation, where we sampled dumps and mapped occasional outcrops of porphyry copper alteration on primitive air photos borrowed from the U.S.G.S. ---- and, the old gun-toting prospector who ran us off his claim on the southeast slope of Mt. Tolman. Down slope, disseminated sulphides exposed at shallow depth in old workings, contained appreciable value in moly (.04%), but only a few hundredths copper. Although the areal extent of the zone did not appear very large, a more thorough investigation was considered warranted (67); however, no action was taken by the Northwest Mining Dept.

Several years later, after Bear Creek moved in and drilled Mt. Tolman, it became painfully apparent that our San Poil prospect area covered only a minor southeastern prong of a substantial-sized zone of porphyry copper-moly mineralization ---- around 200 million tons grading .12% Cu and .08% Mo (Fig. 63). The rock chip sample map (Fig. 64) shows the area sampled in 1957 and the extent of Bear Creek's geochem moly anomaly.

* Dug out of Northwest Mining Dept. files and literature.

In 1976, under pressure from the Indians, Kennecott gave up their lease. Two years later several other mining companies were invited to submit bids on the property. A rising moly market had by that time elevated the Mt. Tolman deposit from marginal to potentially profitable. And, in view of the exploration possibilities also existing, the property was considered worth going after [68]. Based on a production rate of 20,000 tpd, 63¢ copper, $4.60 moly and 20% of net proceeds royalty, an R.O.I. of 12% was estimated [69]. However, the risk of investing plus $100 million in a deposit with a substantially lower grade* than that of the larger moly operations was adjudged too high by management and a bid was not submitted [70]. Eventually AMAX won out by giving the tribe what was likely the most lucrative deal ever negotiated by Indians anywhere ---- $8.5 million (bonus and advances) on signing, another $8.5 million in two years (1980) and, after recovery of capital, 50% of net revenues.

AMAX proceeded with a large drilling program, resulting in a much greater tonnage (900 million) at a much lower grade (.06% Mo, .09% Cu)**. Initial preparations for a 60,000 tpd open pit operation had gotten underway; however, moly demand continued its decline and the project was abandoned in Dec.1981.

24. BATTLE MOUNTAIN

At a public auction back around 1959, Asarco acquired some secondhand milling machinery as well as large mining claim blocks in the Copper Canyon and Copper Basin areas covering two separate zones*** of porphyry copper mineralization-alteration (Fig. 65), all for the sum of $125,000. The auction was held by the Small Business Administration which had foreclosed on a loan to the Copper Canyon Mining Co. In years past, Anaconda dredged placer gold

* Including copper as moly equivalent, the Mt. Tolman grade would approximate .12% Mo (Henderson ---- .24% Mo, Climax ---- .17% Mo).

** Form 10K, 1979 Annual Report

*** Excepting a few key claims in Copper Canyon held by H.B. Chesser.

and mined primary copper in the Canyon area and chalcocite ores in the Basin.

Following purchase of the property, the Salt Lake City staff carried out mapping in both areas, and had drilled a few holes in Copper Canyon when (in 1960) the Salt Lake exploration office was closed and direction of the project shifted to Tucson. Incidentally, our first look at their maps revealed surprisingly attractive exploration possibilities, indicated by old churn drill results, particularly in the Basin area. It later became apparent, however, that this was an illusion which had been created simply by leaving off the maps those holes in waste or low grade!! (71)

After much digging through the files, a more complete picture was finally assembled. It was evident that ore-grade chalcocite enrichment was generally confined to narrow zones in Paleozoic clastics (argillite, limey shale, sandstone) adjacent to the porphyry intrusives which contained for the most part only low grade primary copper. (Sizeable areas of green-stained porphyry in the Canyon area outcrops, averaging around .50% Cu, were initially considered to hold the principal exploration potential (72).)

Eventually, we concluded that (quoting from the report (73)) "The odds against discovery of a large ore body are quite heavy; however, the chances of developing several small deposits, the aggregate of which could amount to a commercial tonnage ---- sufficient to support a 5000 tpd operation, or, say 5000 tons of concentrate per month ---- are regarded as fair." This potential included an estimated 18 million tons of .77% Cu, .02 Au, .50 Ag at Copper Canyon which also had untested possibilities in a gold-bearing conglomerate running around $5.00 per ton (at $35.00). This reserve included the Chesser ground on which a lease had been obtained.

Our request of $65,000, principally for drilling, was turned down and later the property was leased to Duval Corp. on a royalty basis. Eventually (in 1967), they started both leaching and milling (4500 tpd) operations, but not before persuading Asarco to cancel the royalty and quit-claim the property

in return for payment of a modest sum (equivalent to Asarco's expenditures).

Silver began its upward price trend in '67, gold in '68. Copper started its long climb in '64, peaking out in 1980. However, over the years, leach-precipitation provided the principal source of profits for Duval, although both gold and silver contributed substantially to the value of the ore milled. Open pit gold mining commenced in '78; copper milling was discontinued the same year, the plant being modified for gold ore treatment.

At this time, Duval is milling 3200 tpd gold ore and treating dump-leach copper by solvent-extration-electrowinning. A new open pit gold deposit containing 16 million tons of .14 Au, .52 Ag is scheduled for production in 1985.

In a recent paper on Copper Canyon (74), 2 ore bodies* in sediments are shown occurring adjacent to a grandiorite porphyry. Strong potassic alteration, chiefly biotite, pervades the intrusive and spreads outward, encompassing the major part of the East deposit and all of the West deposit (Fig. 66). And, as indicated, less than 2% sulphides (pyrrhotite-pyrite-chalcopyrite) occur in the intrusive, although the eastern one-third of the mass contained over .40% Cu and was mined as leach ore. No mention is made by the authors of this green-stained porphyry (indicated on Fig. 66); however, it is worthy of note that early in the game we were puzzled by the apparent absence of sulphide cavities and iron oxides in this almost fresh-appearing rock ---- suggesting that the copper had been transported from another source. Petrographic studies at that time indicated that the copper was present as silicate, largely in the lattice of feldspars.

Although I have not visited the area since open pit mining began, it now seems probable that, (1) the copper in the porphyry occurred as very finely divided cpy and (2) during weathering, reactivity of the potassic

* The West ore body, a non-outcropping skarn deposit, was discovered by Duval.

alteration (plus a low iron-sulphide to cpy ratio) precipitated the copper as silicate with little or no transportation involved. What became of the iron is an unanswered question. Similar conditions existed at Yerington [75].

In respect to alteration, it is now obvious that the large zones originally mapped (Fig. 65) should be classed as weak argillic, and that significant copper mineralization was confined to relatively small zones of potassic alteration in the porphyry and the enclosing sedimentary rocks.

25. ROSEMONT

The Helvetia district, which had been known since the 1880's for its small production of direct-smelting copper ores, received considerable publicity in 1957 when the Lewisohn Copper Corporation drilled Peach Hill, finding 10 million tons of partially oxidized porphyry copper skarn running 0.80% total Cu. A few holes in the Elgin area adjacent indicated a possibly equal amount of mineralized skarn and porphyry with 0.70% Cu. Other occurrences included Broad Top, a very low-grade breccia pipe, and Rosemont (Fig. 67), a small area of skarn exposures assaying 1.0 to 2.0% Cu.

This, in brief, was the picture in 1958 when the Tucson office undertook an examination of the entire district. Several small, altered intrusive porphyries were mapped, but limonites in the leached outcrops indicated little more than weak primary copper, confining ore potential to the skarns. The Peach-Elgin Zone was found to be cut off at shallow depth by a low-angle, post mineral fault ---- its probable "roots" being in the sub-marginal copper mineralization of Broad Top. As for Rosemont, detailed mapping appeared to limit the extent of ore-grade skarn (derived from Paleozoic limestones) to a small area. Relatively weak copper mineralization occurred in Mesozoic clastics (hornfels) over a much larger area (Fig. 68). Also, there were 4 old diamond drill holes which had been collared east of the best showings. All cut barren or weakly mineralized shale, including one which was aimed directly

at the downward projection of ore-grade in outcrop. On the surface, steep westerly dipping shale beds suggested a possible overturned relationship with the Paleozoics. The maximum potential ---- 5 to 10 million tons at 1.0% Cu ---- was considered too small [76, 77] and we backed away.

Three years later, Banner Mining tied up the Lewisohn properties. Reportedly, they put down only one hole at Rosemont before closing a deal with Anaconda (in 1963) which included all of their holdings in the Helvetia, Twin Buttes and Pima districts. Some time later, word came around that Anaconda had a big drilling program going at Rosemont, and I well remember the day we took a charter flight over the area and observed a half dozen drill rigs strung out from the skarn prospect for over a half mile to the south ---- a disturbing sight, to say the least. Several years passed, during which very little information leaked out. Eventually, in 1973, speculation was put to rest somewhat by publication of the reserve (by Anamax) ---- 320 million tons at 0.64% Cu.

During the past year Asarco examined Rosemont data (the property being up for sale). As reported [78], the sulphide ore reserve, based on open pit mining plans, amounted to:

317 million tons at 0.58% Cu, W/O - 3.37 to 1.

The geologic reserve included .257 oz. Ag and .019% Mo. Sizeable zones of plus one percent copper are present, but most are too deep to be reached in the early years of open pit mining.

Although not anywhere near economic under present conditions, this sizeable copper bearing skarn deposit escaped detection earlier, being largely concealed by shales which had moved in on a low-angle, pre-mineral fault (Fig. 69).

26. TWIN BUTTES

Located 6 miles south of the Mission, the Twin Buttes pit started production at 25,000 tpd late in 1969. A reserve of 436 million tons at 0.63% Cu, 0.03% Mo, was reported by Anaconda, the operator. Our involvement in events preceeding Anaconda's discovery of this prophyry copper skarn deposit, concealed by 400 to 600' of gravel cover, is a story which ends in frustration.

Back in 1957, during the Mission drilling, it became apparent that the mineralized beds there were cut off in depth by a low angle, post-mineral fault, the so-called "San Xavier Thrust." We regarded the fault as a probable gravity slide, and since the dip was easterly (around 10°), the search for "roots" was first directed to the Sierrita Mts. on the west. However, mapping of the entire range failed to turn up any promising leads (79). Subsequently, studies of outcrops in the Twin Buttes area* revealed a fairly close correspondence to those in the Pima-Mission area, in respect to lithology and stratigraphy. The key ingredient, intrusive porphyry, was missing, but, it was concluded that such could be concealed by extensive gravel cover east of the Buttes. The cover on our new lead was, however, soon to be blown ---- by publication (June 1960) of Cooper's USGS Bulletin (80) wherein the Twin Buttes area was designated as the original location of the Pima-Mission zone of copper mineralization, prior to a 6½ mile northerly displacement on the "San Xavier Thrust."

Two days after delivery of the Bulletin, we had managed to stake 162 Federal claims in Cholla Flat on open ground immediately east of Banner Mining's claims (several years old) which covered part of the target area. We had expected the desert growth to be teeming with competitors, but none appeared ---- not until months later. After putting down 12 holes well into bedrock, overlain by 600 to 800' of gravel, it was apparent that Asarco's WG claim group covered, at best, only a piece of the eastern fringe of the

* Conducted by John E. Kinnison.

postulated zone of mineralization [81]. The probable limits of this zone, as drawn by Kinnison in April 1961, are shown on Figure 70 ---- essentially all within Banner ground.

Prior to this time, Alan Bowman of Banner had suggested a deal wherein Asarco could earn a 50% interest in their Twin Buttes property by spending one million dollars on exploration, subject to approval by the Banner Board of Directors. We were never able to make any progress on the deal and later, in July 1961, Bowman advised that they would drill a few holes before any further consideration of a joint venture [82]. Some time thereafter, Banner invited essentially all major companies except Asarco*, to examine their properties. An agreement**, presumably giving Banner everything they asked for, was completed with Anaconda in 1963. The ore deposit which Anaconda subsequently drilled out, obviously represented the "roots" of the Pima-Mission zone. The irony of this whole scenario was that Anaconda's top exploration personnel held from the beginning that the Eisenhower (and Pima-Mission) mineralization bottomed on an intrusive, rather than a fault contact***.

Eventually the WG group was turned over to Anaconda after they had completed sufficient drilling on the claims to rule out any appreciable ore potential.

* Asarco's business relations with Banner had deteriorated considerabley following collapse of negotiations involving their Eisenhower claims.

** Cash payment of $3.6 million ("lease bonus," etc.); 1965 thru 1976, $1.75 million advance royalty per year. Anaconda to provide all funds and recover capital investment over 12 year period, during which profits split 50-50.

*** Personal communications.

The open pit operation ran into serious trouble during the second year of production, when a plus 100 million ton slice of gravel forming the SW pit slope, started moving on fault planes. Attempts to hold the slide by cable bolting failed and a new pit was eventually excavated on the NE (Fig. 71) requiring a very large additional investment in stripping; also causing a sharp drop in ore grade and 10 months interruption in ore production.

In 1973 Amax acquired a 50% interest, forming a company named Anamax. Two years later an agitation leach-electrowinning oxide ore plant went into production at 10,000 tpd. In 1977 Atlantic Richfield acquired Anaconda.

Through 1982, sulphide ore production amounted to approximately 120 million tons at 0.92% Cu*.

At the end of 1981 reported ore reserves were 294 million tons of sulphide at 0.65% Cu, 0.03% Mo, 0.2 oz. Ag, and 37 million tons of oxide at 0.94% Cu. At the beginning of the same year, a total of 1.26 billion tons had been removed from the pit, 117 million tons of which was ore, sulphide plus oxide ---- a 10.7 to 1 W/O ratio!! As of January 1983, mining ceased in the Twin Buttes pit; however, milling continued on feed from the Eisenhower claims and the leach plant also continued operation on stockpiled oxide ore.

According to a 1982 publication [83], the principal ore-bearing rocks of the Twin Buttes deposit are steep-dipping Paleozoic limestones on either side of a Laramide intrusive complex (Figs. 72, 73). Lesser amounts of copper, mainly chalcopyrite, occur in the Mesozoic clastics, Laramide porphyries and Precambrian granite. As shown in Fig. 74, the best concentration (2.0% Cu) is present in garnet-diopside alteration of a 170' thick bed (Epitaph) of Permian carbonate. Next best is 1.5% Cu in 250' of Permian Concha.

* Compiled in part from annual reports showing only tons of ore and lbs. of copper (recovery estimated at 85%).

Many lithologic and mineralogic features of the Twin Buttes deposit, including porphyry age dates*, closely resemble those at Pima-Mission; however, there is essentially no match structurally. This is readily accounted for by probable deep, post-fault erosion in the Twin Buttes area (see section at bottom of Fig. 75). Oxidation is also relatively deep, ranging from 25' to 800' and averaging around 200' (?) below the bedrock surface.

27. SACATON

The Poston and Mineral Butte discoveries provided further evidence of the existence of a SW trending porphyry belt projecting across the major NW trend of continental extent. What became the Sacaton "discovery outcrop," a small knoll isolated by extensive alluvial cover, was found** near the intersection of the 2 trends (Figs. 76 & 76A). The search had been narrowed somewhat by a letter dug out of the files, which reported rich copper oxide in the bottom of a water well put down in 1919 "somewhere near Casa Grande." Attempts to locate the well were unsuccessful, however.

Viewed from a distance, the outcrop was inconspicuous, showing only a very pale yellow-brown tone. Quoting from the initial report of Feb. 12, 1961 (84):

"The rock on this small hill is pervasively sericitized and kaolinized granite, containing limonite after pyrite and traces of "live" limonite. An altered porphyry dike cuts the southern slope. The original total sulphide content is estimated to have been about 2%.

Although the capping exposed on this hill does not suggest that ore lies directly beneath it, it may be the pyritic portion of a larger porphyry copper deposit."

* 54 - 58 m.y.

** By John Kinnison and Art Blucher.

After obtaining options on the fee land and prospecting permits on the State land, the Geophysical Dept. ran siesmic, magnetometer and IP surveys. The seismic results were encouraging in that they indicated only 100-200' of cover in the area; however, it later became evident that the upper surface of a thick, post-mineral conglomerate had been interpreted as bedrock. IP measurements detected anomalous response, but the lateral extent of "significant sulphide mineralization" was limited to a 2000' diameter zone enclosing the discovery outcrop (Fig. 77).

The head office (New York) took a dim view of the prospect's porphyry copper potential, in view of the small areal extent of the IP anomaly. However, $30,000 for 6 holes was authorized with the implication that the project would have to "sink or swim" on this sum of money (85). The first 5 holes (Fig. 77) cut disseminated sulphides under the leached capping, but failed to find other than very short intercepts of ore grade. A heated debate took place in the Tucson office as to where No. 6 should be located ---- where to "shoot the last wad." Eventually No. 6 was drilled ---- not on the hypothesized NE trend, but NW of the outcrop (Fig. 77) hitting sufficient ore grade copper to keep the project going.

By late 1963, wide spaced (500-700') drilling had roughly defined 2 separate zones of chalcocite enrichment, the relatively shallow "West" deposit and the deep "East" deposit; the latter with an indicated reserve of 8.6 million tons at 1.40% Cu, the former with 13.3 million tons at 1.18% Cu. However, closer spaced drilling was not undertaken as the Mining Dept. considered the deposits non-economic at the then existing price of copper (30¢). Later, in 1968, the market improved and drilling was resumed to better define the reserves. Subsequently, results were reported (86)

as follows:

	Tons	% Cu	% Mo	Oz Au	Oz Ag	W/O
West, Open Pit*	22,400,000	.86	.016	.003	.13	6:1
East, Block-Cave	14,558,000	1.36	.028	.004	.07	

Statistical Analyses* indicated that there was sufficient drilling in the West deposit to consider it measured within acceptable limits [86].

Samples for metallurgical work consisted of 6" dia. cores recovered from 15 holes, the locations of which were determined by variations in ore mineralogy as indicated by the exploration drilling. Incidentally, this method provides overall a more representative sample than the underground approach which is limited (by cost) to only a portion of the whole porphyry copper ore body.

In 1972 pit plans were expanded to include a larger tonnage with a lower average grade and lower stripping ratio, as follows:

	Tons	% Cu	W/O
West, Open Pit	33 million	.76	4.8:1

The Sacaton ore bodies, in Laramide porphyries and Precambrian granite, were formed by supergene chalcocite enrichment of hypogene mineralization grading around .50% Cu. Relatively strong potassic alteration was no doubt associated with the better hypogene copper mineralization, but subsequent phyllic alteration has been effective in obscuring such a relationship**. As shown in cross-section (Fig. 78) in a recent publication [87], one body lies below sea level and the other well above. The author observes quite logically that prior to the development of the horst-graben structure, there was very likely just one more-or-less continuous chalcocite blanket. Later,

* By Carl E. Williams.

** Personal communication, R. B. Cummings.

the major post-mineral structural event took place ---- development of the Basement fault, which sliced off a piece of the East ore body (Fig. 79).

Being with the uplifted horst block, the West ore body suffered deep oxidation and leaching ---- in an irregular pattern which roughly coincides with the "pre-mineral breccia core" (Fig. 80). Some evidence of this chalcocite destruction was noted in drill cores, but the full extent was not apparent until mining was well under way.

Well along in the exploration drilling, it became evident that the entire Sacaton zone of alteration-mineralization was within a post-enrichment fault block which had probably moved a considerable distance, either to the NE, or SW.

Open pit mining commenced early in 1974, averaging 11,500 tpd milled over the years since. By the end of 1982 production amounted to 33.8 million tons at .66% Cu. The discrepancy (13%)* between predicted and mill head grade was primarily due to unforeseen "gaps" in the chalcocite blanket created by highly irregular zones of oxidation and leaching (mainly in the top 3 ore benches), only a small number of which were, by chance, hit in the surface drilling. In some instances, it was found in mining that the chalcocite ore in a drill hole was only an "island" surrounded largely by leached rock. The erratic pattern of ore-waste contacts, in general, caused more than the normal amount of mine dilution. Another factor was, as noted by J.J. Collins (86A), "...the mill was completed before the mine was fully developed; hence, the choice of mill feed was limited and the grade apparently suffered."

Work on the shaft sunk to develop the East ore body was discontinued in the fall of '81. The high cost of grouting to control water (±1200 gpm)

* The first 3 years' production was largely responsible for the 13% difference over a period of 9 years.

encountered beneath the Basement Fault was a major factor in the shutdown decision. The pit ore body was mined out and the operation closed down at the end of March 1984.

28. SANTA CRUZ

The search for the "roots" of the NE-SW elongated Sacaton fault block began on the NE, simply because the opposite direction led into the presumably much deeper cover of the Santa Cruz valley. This effort was unsuccessful. With essentially no other alternative, we started drilling to the SW (in July '64), on spacing comparable to that of wildcat oil exploration (initial hole locations being determined mainly by the positions of scattered State and Federal land parcels). The first hole, 1½ miles SW of the Sacaton deposits (Fig. 81), hit barren Precambrian schist bedrock at 2860'; the second at 4 miles, found very weakly altered and mineralized Precambrian granite at 2530'. The move to the 3rd hole proved to be "off the beam." The 4th (SC-4), 6 miles SW from Sacaton, hit what later was demonstrated to be well within the "root" zone ---- strongly altered, leached granite bedrock at 1380'. Although the capping contained moderate amounts of "live" limonite, only pyrite and very sparse cc was encountered below in less altered porphyry. There was some encouragement though ---- in finding relatively "shallow" bedrock below the valley bottom. However, SC-5 & 6, S and SW of SC-4, went down "over a cliff," cutting weakly altered granite bedrock at 3605' and 4150', respectively.*

Drilling continued (rotary with spot coring only) through SC-17 (Fig. 81), finding appreciable values in bedrock in but 3 holes (SE-12-13-14), the best oxide intercept being 37' of .98% Cu in SC-12 and the best chalcocite, 90' of .76% Cu in SC-14 at a depth of 2150'. SC-16 cut 90' of 1.4% Cu, but as exotic

* Our drilling engineer, Joe Wojcik, reported that this was no doubt a record depth for diamond bit coring in an uncased rotary hole in overburden. Kenyon Richard's comment was: "Records such as these, we don't need!"

oxide copper in a post-mineral conglomerate* underlain by very low values in porphyry bedrock. Nothing better than low grade primary (cpy) was encountered in any hole.

It was then concluded that extensive, post-enrichment oxidation-leaching had destroyed most of the chalcocite and that the chances of finding a deposit of sufficient size and grade to be mineable ---- at depths of plus 2000', and overlain by water-bearing valley alluvials ---- were too slim to warrant further exploration expenditures. The project was abandoned in July '65 (88), a move that was later demonstrated to be shortsighted, to say the least.

During that year the copper supply-demand imbalance increased sharply, driving the market price more-or-less steadily upward through 1970. Copper looked good, both short and long term. The decision to put Sacaton into production was made during this time and there were efforts to revive Santa Cruz. B.E. Kilpatrick restudied all data, including drill cores and sludges, and recommended 2 holes in the 4800' space between SC-13 and SC-14 (89). Later, W.L. Kurtz also called attention to the wide spacing of the Santa Cruz drilling, pointing out in effect that there was room for 2 or more Sacaton-sized ore bodies between holes showing significant copper mineralization. An authorization of $1,780,000 was requested for purchase of property and five 2500' drill holes (90). I find no record of action taken on this recommendation; however, property negotiations continued intermittently for some time, until in Aug. 1974 land acquisition commenced under terms of an Asarco-Freeport joint venture (50-50).

About the same time, J.D. Lowell, agent for Newmont-Hanna-Getty, started negotiating for land in the area. After the dust settled, Asarco-Freeport had acquired most all of the apparently critical ground, with the exception of the SE quarter of Section 13 (Fig. 81).

* Later logged as a "slide block" by H.G. Kreis.

Both groups commenced drilling in Nov. '74*. Two years later, Hanna-Getty (Newmont had dropped out early in the game) announced discovery of the "Casa Grande West" ore body containing 250 million tons of 1.0% Cu ---- situated largely in the SE quarter of Section 13 (Fig. ~~83~~ 81). As later evaluated [91], the deposit consisting of a partially oxidized chalcocite blanket underlain by chalcopyrite mineralization, contained (.60% Cu cut off) 220 million tons of 1.06% Cu. This reserve bottoms at a depth of 3200' and has horizontal dimension of 1000' by 4000'.

Asarco-Freeport drilling in the area adjacent encountered principally oxide copper ---- 200 million tons of .51% Cu. Two holes cut long columns of +.50% Cu primary and ample room existed for sizeable "ore-grade" sulphide deposits in "The Lands" area [91].

Exploration in the "Peripheral Lands" discovered a chalcocite blanket with an indicated reserve of 57 million tons of 1.12% Cu [92]. The deposit, rather severely disturbed by faulting, ranges from 2200' to 3200' in depth.

The original concept of the Sacaton upper plate was just one elongate fault block, terminating around ½ mile SW of the open pit ore body. However, later drilling found mineralized upper plate rock extending 2½ miles SW of the pit (Fig. ~~83~~ 82). Studies based on results of a few wide-spaced holes indicate a possible potential in the Parks-Salyer area, ranging up to 100 million tons of 1.5% Cu, as chalcocite, assuming the most favorable geologic conditions [93].

Figure 82 also shows the probable limits of "in place" alteration-mineralization (the "root zone"), encompassing an area 2 miles wide and 4 miles long. As described [91], the predominant host of the Santa Cruz sulphide system is Precambrian granite, with Laramide biotite-quartz-feldspar porphyry

* A detailed history of the project is included in a comprehensive report on Santa Cruz prepared by H.G. Kreis [91].

being the other principal rock unit. As in perhaps most porphyry coppers, potassic alteration characterizes zones of relatively high cpy-low py with later phyllic alteration predominating in low cpy-high py zones.

The Santa Cruz Project has been dormant since April 1981, awaiting a substantial improvement in the copper market.

29. MICHIQUILLAY

Around mid 1958, a Northern Peru Mining & Smelting geologist* was sent out to examine a lead-zinc prospect, the trail to which led up Michiquillay Creek, a headwater of the Amazon, 30 Km NE of Cajamarca in Northern Peru. Along the creek in an old prospect pit, he found disseminated sulphides with chalcocite in a pervasively altered porphyry ---- within an extensive area of leached capping. Existing denouncements were purchased for the sum of 100,000 Soles ($5,000). Later, the owner was to file suit for fraud on the part of NPMS.

A geologic map was prepared and in the following year 6 X-ray holes were drilled in, and somewhat above, the canyon bottom. This effort was not very successful as only 2 holes encountered a few meters of around 1.0% Cu and core recovery was under 50%. Subsequently, 9 holes were put down to depths varying from 100 to 200 mts with a skid mounted drill. Core recovery continued poor (average: 40%), but 7 of these cut chalcocite enrichment ranging in grade from 50 m of .62% Cu to 30 m of 2.05% Cu; the longest intercept, 91 m at .97% Cu.

Although essentially no limits to the deposit were defined, it was decided that its potential as a porphyry copper was relatively small (30-60 million tons of .80% Cu) and drilling was suspended.

* V.F. Hollister

During a 1961 tour of Peru and Chile, Kenyon Richard and I visited the property and concluded that exploration possibilities were sufficiently attractive to warrant a major-sized drilling program [94]. After much debate*, roads and a camp were built and drilling with truck-mounted rigs began in May 1963. By January 1965, 139 holes averaging 279 m depth had been completed. Results indicated a chalcocite blanket around 600 by 1200 m in plan (Fig. 83) underlain by a zone of fairly strong primary chalcopyrite mineralization extending below 600 mts in depth (Figs. 83A, 83B). Preliminary reserve estimates, based on several pit designs and grade cutoffs, ranged from 94 million short tons at 1.02% Cu to 464 million at .75% Cu, .012% Mo, .004 oz. Au and .08 oz. Ag.

Subsequently, other ore estimates were made by polygon and computer methods and all aspects of the project investigated ---- from the mine to port facilities for shipping blister. The latest outcome estimate (1969) in Tucson files [95], based on a reserve of 592 million short tons at .75% Cu, W/O 2 to 1, copper price 38.5¢, and a mill rate of 40,000 tpd, shows an initial capital cost of $230 million and a 9% ROI (10%, excluding smelter). Negotiations with Peruvian officials failed to achieve a reduction in taxes ---- they taking the position that the economic potential of the deposit was underrated**. Eventually, the Peruvian Government took over the property, without compensation. The Japanese moved in and, after an exhaustive investigation over 2 or more years, moved out.

The Michiquillay deposit [96] occurs principally in a quartz monzonite porphyry which intruded a Cretaceous series of shale, quartzite and limestone (Fig. 84). Primary mineralization, py and cpy, is present as stockworks of

* As to whether or not the prospect's potential warranted the cost of a large scale, well equipped project.

** The Toquepala "Bilateral Agreement" called for relatively low Peruvian taxes, but the operation proved to be far more profitable than S.P.C.C. projections (due principally to higher than anticipated copper prices).

veinlets and as discrete grains and is closely associated with strong phyllic alteration. Relatively minor amounts of ore-grade skarn mineralization occur in the sediments near porphyry contacts. According to a Spanish language publication [97], the primary ore body probably is in the potassic zone, although only minor amounts of hydrothermal K-spar and biotite were identified*. Also, the age of the porphyry intrusive was determined to be 20 m.y. (K-Ar).

Compared to other porphyry coppers with similar py to cpy ratios, supergene enrichment is relatively weak. Positioned at 3500-3800 m elevation just over on the wet side of the Andes (60" rainfall), the water table is presently at, or near surface. Obviously, at some time in the past, the climate shifted from dry to wet, resulting in a premature interruption of the leaching and enrichment processes. Except for the upper 2 or 3 m, the chalcocite blanket represents less than a two-fold increase in the primary grade.

Prior to drill road construction, essentially no color anomaly was apparent over the mineralized zone. Outcrops had pale gray, lichen-covered rock surfaces ---- from which practically all of the limonite had been removed, either chemically or mechanically, by the heavy rainfall. This removal of the limonites (and contained copper) is evident in the results of geochem sampling [98]. As shown in Fig. 85, outcrop samples generally ran lower in copper than drill cores or cuttings of capping. However, as is commonly the case, the moly anomaly more closely reflected the ore body than the copper anomaly (Fig. 85A).

Limonites in outcrop (revealed by vigorous use of the rock hammer) were mainly goethites. Hematite (after chalcocite) occurred sparsely over an area much larger than that of the underlying ore-grade enrichment [99].

* Perhaps another case of near obliteration of potassic minerals by later phyllic alteration.

In aerial reconnaissance, essentially the only observable clues to this porphyry copper occurrence were craggy, cavernous prominences, formed by the erosion-resistant siliceous vein stockworks ---- from which most of the clay-sericite had been removed by weathering.

. . . . . .

In the fall of 1966, Asarco's SW Exploration Department undertook a search for porphyry copper deposits in Western Mexico, and as in previous programs, file and literature studies preceded air and ground reconnaissance. A large area (150 by 300 Km)of Northern Sonora had been designated as a National Copper Reserve and withdrawn; however, the program (terminated early in 1969) turned up a number of prospects elsewhere ---- some of which were drilled (by ASARCO Mexicana under our supervision). The more significant "finds" are described briefly below.

30. MALPICA

My first look at this prospect, located 30 Km east of Mazatlan in southern Sinaloa, was in 1954*. It was at that time readily recognizable as a porphyry type occurrence in granodiorite. The best copper values seemed to be in tourmaline breccias, as evidenced by exposures in shallow pits and short adits. Dumps contained oxide copper and disseminated sulphides, principally pyrite and chalcopyrite. There appeared to have been only minor chalcocite enrichment. Outcrops displayed mostly the brown-to-orange colors of goethite-jarosite limonites. Surface chip samples averaged around 1.0% Cu and 1.0 g/t Au. Although the areal extent of mineralized outcrops was rather limited, jungle-like vegetation covered a possibly much larger zone. Mapping and drilling

* Examination requested by T.P. Clendinen, Chief Geol., ASARCO Mexicana.

were recommended [100], but no action was taken by the Mexican Mining Dept.

Two years later, Hanna Mining Co. put down 11 churn drill holes on the prospect. Surprisingly, only 4 of these were collared in the mineralized breccias; the best hole (CDH 11) contained 92 mts. of .85% Cu [Fig. 86]. Ten years later, interest in the prospect was revived [101] and subsequently the drill program recommended [102] was carried out. Results of the 14 diamond drill holes completed indicated 2 separate, rather small ore zones, containing a total of perhaps 15 million tons of .70% Cu ---- approximately half of which occurs as oxide copper [Fig. 87], or partially oxidized sulphides.

Although the drill cores were not assayed for gold, the average probably runs between .5 and 1.0 grs. per ton, considering the results of previously taken outcrop samples. I am not aware of any further development on the prospect; however, at the existing gold price its potential should be quite attractive.

31. MARGARITA

Mapping of this prospect* outlined a zone of alteration-mineralization 1 x 4 Km in extent, with possible continuations beneath post-mineral cover on two sides. Alteration in the intrusives varied from moderate argillic to strong phyllic with indigenous limonites after both chalcopyrite and chalcocite. Locally, oxide copper minerals were present in outcrop. It was concluded that the prospect offered sufficient potential to warrant drilling [103]; however, the property owners and ASARCO Mexicana failed to agree on terms and this project "died on the vine."

* First spotted during aerial recon.; later found to be privately held.

32. SANTO TOMAS

Located in the extreme north end of Sinaloa, the largest exposed area here of porphyry type alteration-mineralization was around 150 by 300 mts.* Including the possible extent under alluvial cover, the zone was perhaps double that size. Silicate copper was fairly abundant in outcrop, but little or no limonite-after-chalcocite. Other smaller shows, including mineralized skarns, occurred to the south, along a belt about 3 Km in length.

The drilling recommended (8 holes) was confined to the northern occurrence; results were not spectacular ---- .2 to .3% Cu as oxide, underlain by .5% Cu as primary cpy. Subsequently, ASARCO Mexicana took over direction of the exploration and 2 years later reported (104) a reserve of 87 million metric tons of .52% Cu, 5.32:1 strip ratio.

33. EL ARCO

The earliest information in our file is a 1968 "Porphyry Copper Note" by W.E. Saegart (105) accompanied by a sketch map (Fig. 88) showing an area of alteration-mineralization about 300 x 400 m in extent as observed on the ground**. As seen from the air, the zone covered an area of about 1000 m in diameter. Outcrop and prospect pit samples averaged about .50% Cu, principally as chrysocolla. Limonites were mostly after cpy and py, suggesting little cc enrichment. After mapping and further sampling, it was concluded (106) (107) that substantial extensions of the zone could exist under cover and that down-the-hole hammer drilling should be undertaken.

* Property submitted to ASARCO Mexicana by owners.

** This prospect was first brought to our attention by C. L. Burdick, a semi-retired prospector residing in Tucson.

The results of the subsequent drilling (15 holes, plus-or-minus 130 m in depth) indicated 60 million tons .57% Cu as oxide with an equivalent tonnage at .49% Cu in the underlying sulphides. Acquisition of adjacent claims, covering prospective ground, and diamond drilling was recommended [108].

About this time, ASARCO Mexicana took over the project and subsequently, after much urging, purchased the claims and proceeded with drilling. Later, as stated in a paper written for publication [109], (received in Tucson, 8-26-74) "geologic reserves" amount to over 600 million tons of .60% Cu as primary and 70 million tons as oxide and mixed oxide-sulphide grading .65% Cu. As outlined on the surface geologic map (Fig. 89), the ore body has a somewhat irregular shape, 1300 to 1700 m in diameter. The cross-section (Fig. 90) shows 3 flat-lying zones ---- oxide, transition (oxides and sulphides with minor cc enrichment) and sulphide (cpy and py). Presumably the dashed, undulating line near sea level represents the lower limit of plus .40% Cu, but no explanation is given in the text.

A major part of the copper mineralization (60%) occurs in a granodiorite porphyry (93 my, K-Ar) with a lesser amount in diorite (40%) closely associated with abundant hydrothermal feldspar [109]. Propylitic alteration encompasses and in part overlaps the central potassic zone; there is no recognized phyllic zone (Fig. 91). Obviously, the reactive gangue and low pyrite content were responsible for the lack of appreciable supergene sulphide enrichment. Lateral zoning of sulphides is evident in that the py-cpy ratio increases from less than 1:1 within the "ore" body to greater than 1:10 around its periphery (Fig. 92).

In respect to host rock type and alteration, the deposit more closely resembles those in British Columbia and the Philippines, rather than other porphyry coppers of the SW.

The El Arco project has been dormant for some time, although the deposit was potentially economic under the copper market prices which prevailed in the late seventies.

34. LA CARIDAD

Stream sediment geochem surveys, on "private" hunting grounds (Mexican National Copper Reserve) eventually led Consejo* and United Nations geologists to the La Caridad area. The best I.P. response and the highest geochem values (Cu-Mo) were found near the base of a prominent mountain of leached capping ---- where erosion had cut deep enough to expose sulphides in some outcrops. The UN drilled 11 widely scattered holes (starting late in 1966) on the IP-Geochem anomalies. All were in either low-grade or waste except for the 2nd hole which cut 55 meters of .70% Cu as chalcocite in a location that later proved to be outside the eastern fringe of the ore zone. And, resampling and assaying of the core by the Consejo, showed 43 meters of .43% Cu as cc (Fig. 93).

After the UN Contract expired, Consejo geologists proceeded to discover the La Caridad ore body by simply climbing the mountain and drilling the favorable appearing capping ---- an area of relatively low geochem values and low IP response. Fig. 93 shows the early concept of ore extent, Consejo drill holes and the nearest UN holes.

Incidentally, D.F. Coolbaugh's** version published in 1979 (110), reads as follows: "Although this discovery was the joint effort of various exploration disciplines, it can be stated that the reconnaissance geochemical survey was the first to pinpoint the favorable area. Both geochemical and induced polarization surveys were used to delineate the most favorable zone and were

* An organization of the Mexican Government.

** Headed UN exploration in Mexico; subsequently, Director of Exploration, ASARCO Mexicana.

instrumental in choosing the location of the first drill hole which confirmed a discovery. Later development drilling was guided by information obtained by geological investigations." Inaccuracies are underlined.

In May 1968, the SWED investigated the project which at the time had 7 holes in ore. W.E. Saegart reported (111): "...Based on drill results and our interpretation of the exposed leached capping, the inferred ore deposit has a potential of ±200 million tons averaging .75% Cu ... ASARCO Mexicana's participation, if invited, is strongly recommended."

It should be noted that Anaconda held a 180 hectare denouncement (Santa Rosa) near the center of the La Caridad deposit, which they purchased from claim holders in 1967, just after the UN drilling.

ASARCO Mexicana, given the nod by the Mexican Government, requested SWED's aid on the project. Their proposal was, in effect, that we assume responsibility for the drilling and evaluation of results, but function as advisors only ---- a role we declined to accept. The ensuing negotiations, which took place in the less-than-plush Nacozari Hotel, amounted to a prolonged endurance contest, but eventually we were conceded a measure of control over the so-called technical aspects of the project (112).

The deposit was drilled out on a 200 meter triangular grid, with some subsequent infilling on 100 meter spacing. A computer calculated reserve, run at the Tucson Office in 1974*, (including Santa Rosa) produced the following:

734 million metric tons - .70% Cu - W/O - 1.12:1

The average grade for the first 5 years of production (96 million tons) was estimated at .99% Cu. A later calculation in Tucson (1979) gave 537 million

* By C.E. Williams

tons at .74% Cu. The mine which commenced production at 18,000 tpd in mid 1979 (as Mexicana de Cobre, S.A.) reached 65,000 tpd by Nov. 1982. By April 1983, 67 million tons averaging .89% Cu had been milled* ---- indicating that the grade for the first 5 years was destined to fall somewhat short of the original projection.

As of early this year, reserves amounted to:

(1) 594 M metric tons at .60% Cu, .012% Mo, W/O .64 to 1 (.4% Cu cut off)

(2) at a .3% Cu cut off:

1,274 Billion tons at .42% Cu, .038% Mo, W/O .42 to 1

Asarco dropped out prior to the construction phase having declined to finance a smelter and refinery, as well as the mine, but later acquired an equity of around 5½% through IMMSA, formerly ASARCO Mexicana.

As described in a published paper [113], the deposit is genetically associated with a late Laramide quartz monzonite porphyry stock with intrusive breccias (Fig. 94). Phyllic alteration predominates in the central part, passing outward into argillic surrounded by a narrow propyllitic zone ---- a not unusual pattern. Potassic alteration is essentially absent, but the authors predict, logically, that such should occur at depth along with possible ore-grade mineralization.

As seen in section (Fig. 95), the chalcocite blanket conforms roughly to the topography. The primary zone below runs .2 - .3% Cu, as cpy. The capping thins to near zero on the east, due to erosion as previously noted. The most abundant hematite in the leached capping occurs over the south-central part of the ore body; elsewhere, goethite-jarosite predominates (Fig. 96). According to the authors [113], "one possible explanation (lies in) the py-cc ratio of

* Personal communication, AIME Geol. Div. meeting at La Caridad, 4-30-83.

the enriched blanket, which increased outward from the center of the deposit to its margins." In my opinion, this is the most probable explanation, as no evidence was found for other than a single cycle enrichment history. As in many other enriched porphyry coppers, moly content of the capping at La Caridad more closely reflects the ore below ---- than the copper anomalies which are highest in the peripheral areas. This is due, first to precipitation of the copper in the more reactive, less altered fringes of the deposit and second, to the relatively low mobility of molybdenite in acid solutions.

* * * * * * * * * * * * * * * * * *

This is the end of Part III and the end of the series covering projects initiated prior to 1970 ---- during the first 3 of 4 decades of uneven, but strong net growth in copper demand, a trend which peaked out (temporarily, we trust) in 1980.

J. H. Courtright

JHC:mek

J. H. Courtright

cc: R. L. Brown (2 extra)
J. C. Balla
R. E. Gale
R. S. Gray
D. D. Harper
W. L. Kurtz
J. D. Sell
D. M. Smith
P. G. Vikre
H. C. Williamson

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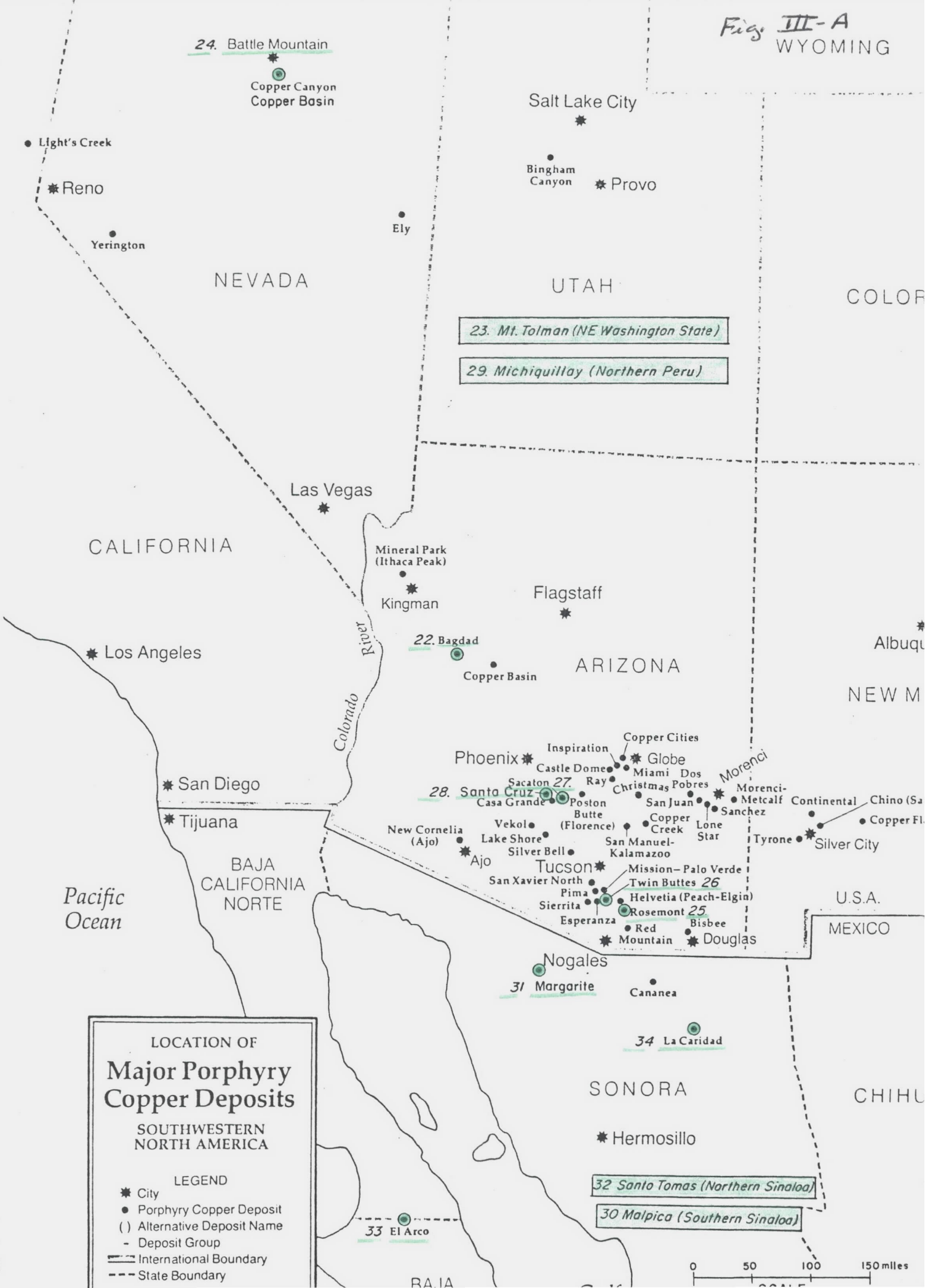
96.	La Caridad - Leached Capping Interpretation	1974

Fig. III-A


LOCATION OF
Major Porphyry Copper Deposits
SOUTHWESTERN NORTH AMERICA
LEGEND
City
Porphyry Copper Deposit
( ) Alternative Deposit Name
- Deposit Group
International Boundary
State Boundary
0 50 100 150 miles
WYOMING
NEVADA
UTAH
COLOR
CALIFORNIA
ARIZONA
NEW M
SONORA
CHIHU
BAJA CALIFORNIA NORTE
Pacific Ocean
U.S.A.
MEXICO
Colorado River
24. Battle Mountain
Copper Canyon
Copper Basin
Light's Creek
Reno
Yerington
Ely
Salt Lake City
Bingham Canyon
Provo
23. Mt. Tolman (NE Washington State)
29. Michiquillay (Northern Peru)
Las Vegas
Mineral Park (Ithaca Peak)
Kingman
Flagstaff
22. Bagdad
Copper Basin
Los Angeles
San Diego
Tijuana
Albuqu
Phoenix
Inspiration
Copper Cities
Globe
Castle Dome
Miami
Dos Pobres
Morenci
Ray
Christmas
Sacaton 27.
28. Santa Cruz
Casa Grande
Poston Butte (Florence)
San Juan
Morenci-Metcalf
Sanchez
Continental
Chino (Sa
Copper Fl
Copper Creek
Lone Star
Tyrone
Silver City
New Cornelia (Ajo)
Vekol
Lake Shore
Silver Bell
San Manuel-Kalamazoo
Ajo
Tucson
Mission–Palo Verde
San Xavier North
Twin Buttes 26
Pima
Helvetia (Peach-Elgin)
Sierrita
Rosemont 25
Esperanza
Bisbee
Red Mountain
Douglas
Nogales
31 Margarite
Cananea
34 La Caridad
Hermosillo
32 Santo Tomas (Northern Sinaloa)
30 Malpica (Southern Sinaloa)
33 El Arco

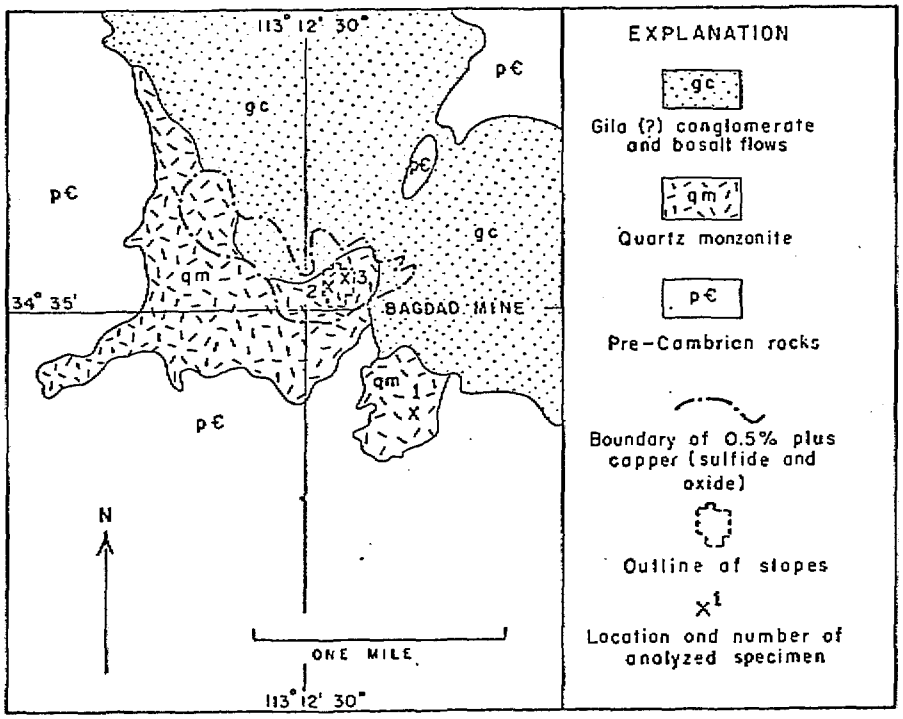


FIG. 2. Map showing quartz monzonite stock at Bagdad.

C.A. ANDERSON (1950)

FIGURE 61-B

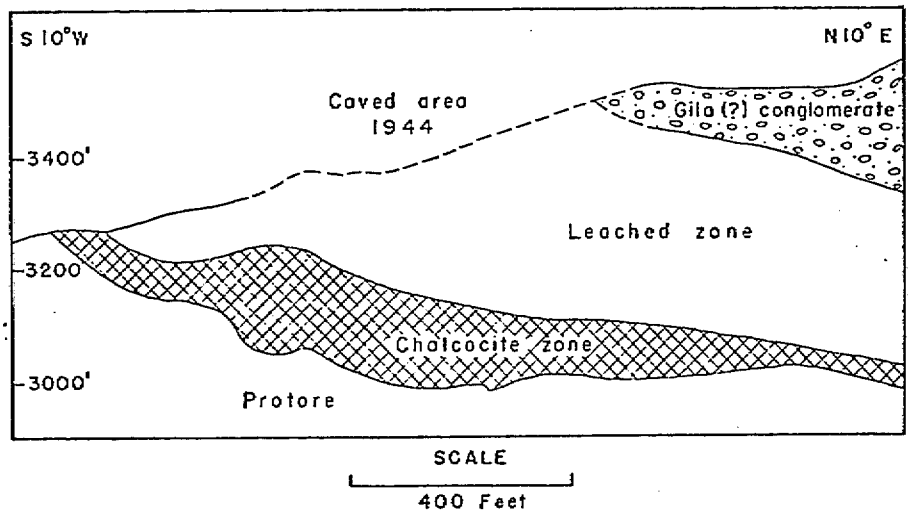
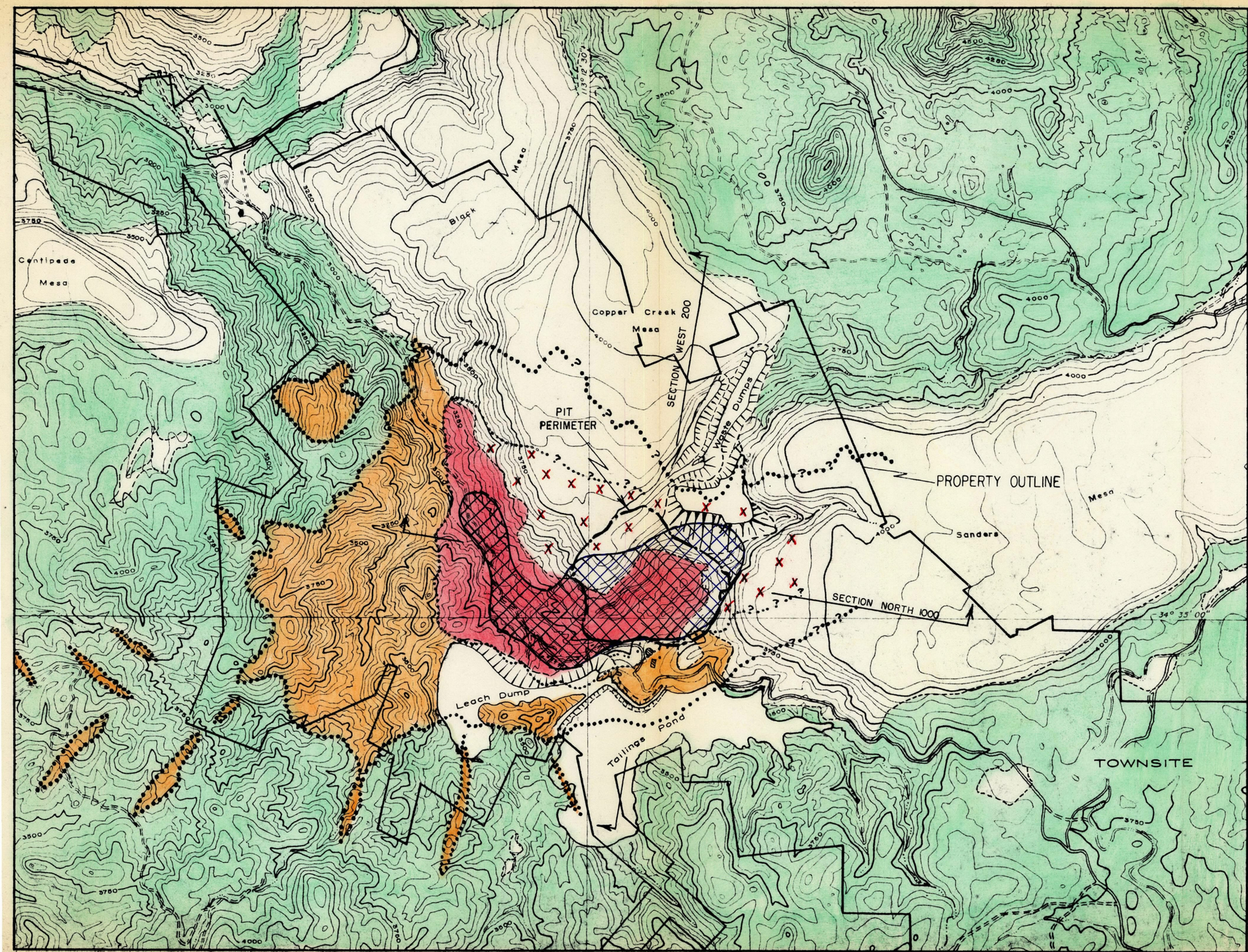


FIG. 7. Section west of Bagdad mine.

C.A. ANDERSON (1950)

FIGURE 62



EXPLANATION

- POST-ORE COVER (gravel and lava capping)
- UNALTERED ROCKS
- ZONE OF ALTERATION
- ZONE OF STRONGER COPPER MINERALIZATION

(UNALTERED ROCKS, ZONE OF ALTERATION, ZONE OF STRONGER COPPER MINERALIZATION: as indicated by outcrops)

- ZONE OF STRONGER COPPER MINERALIZATION (probable projection beneath post-ore cover)
- ORE BODY (as indicated by drill information)

AMERICAN SMELTING AND REFINING COMPANY

BAGDAD COPPER CORPORATION

Yavapai County, Arizona

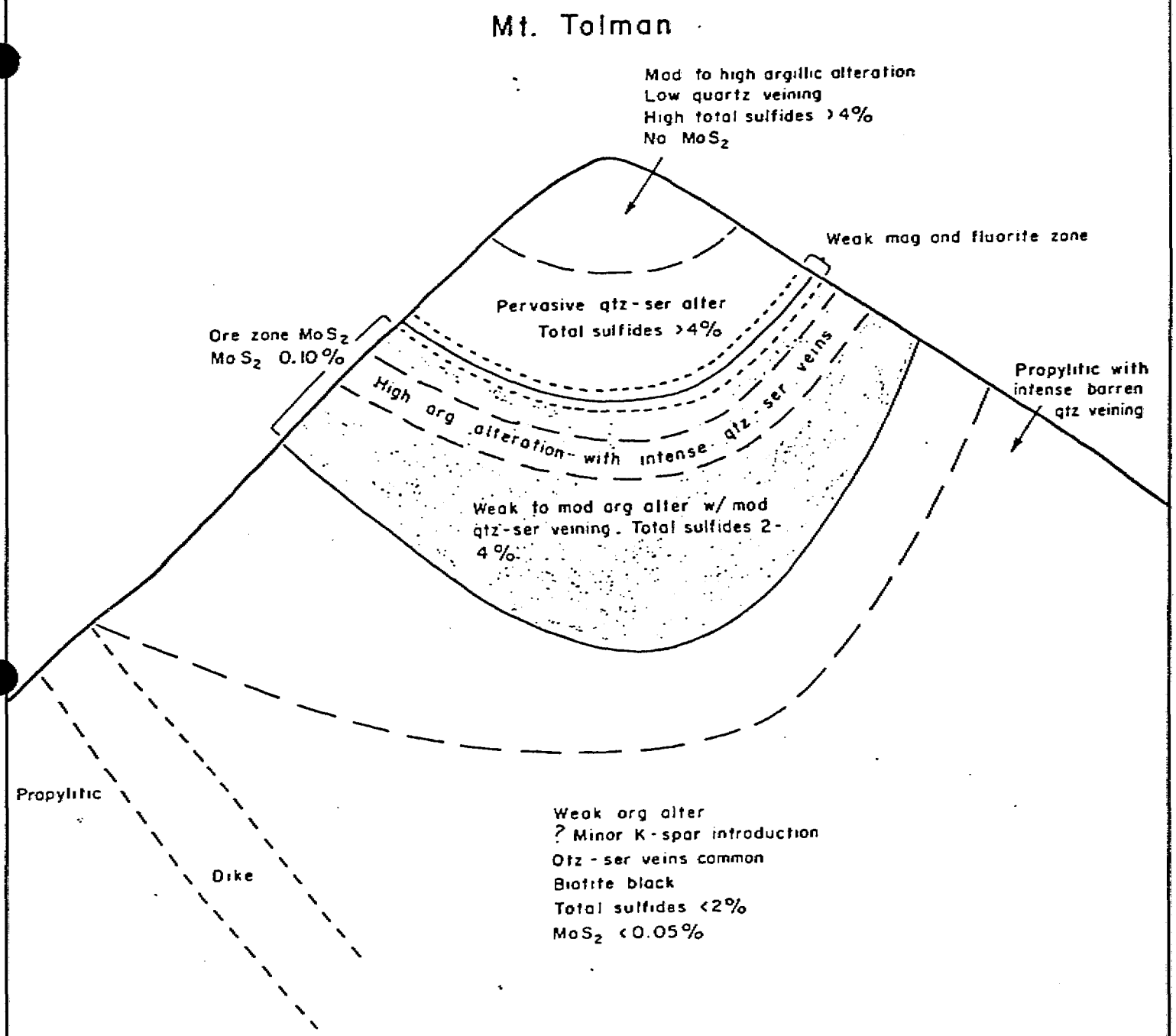
ALTERATION - MINERALIZATION MAP

SCALE 1: 20000

500 1000 2000 3000 FEET

K.E.R. & J.H.C. JUNE, 1956 MAP NO. 1351

FIGURE 63



LOOKING WEST

NO SCALE

ASARCO NORTHWEST EXPLORATION DIVISION

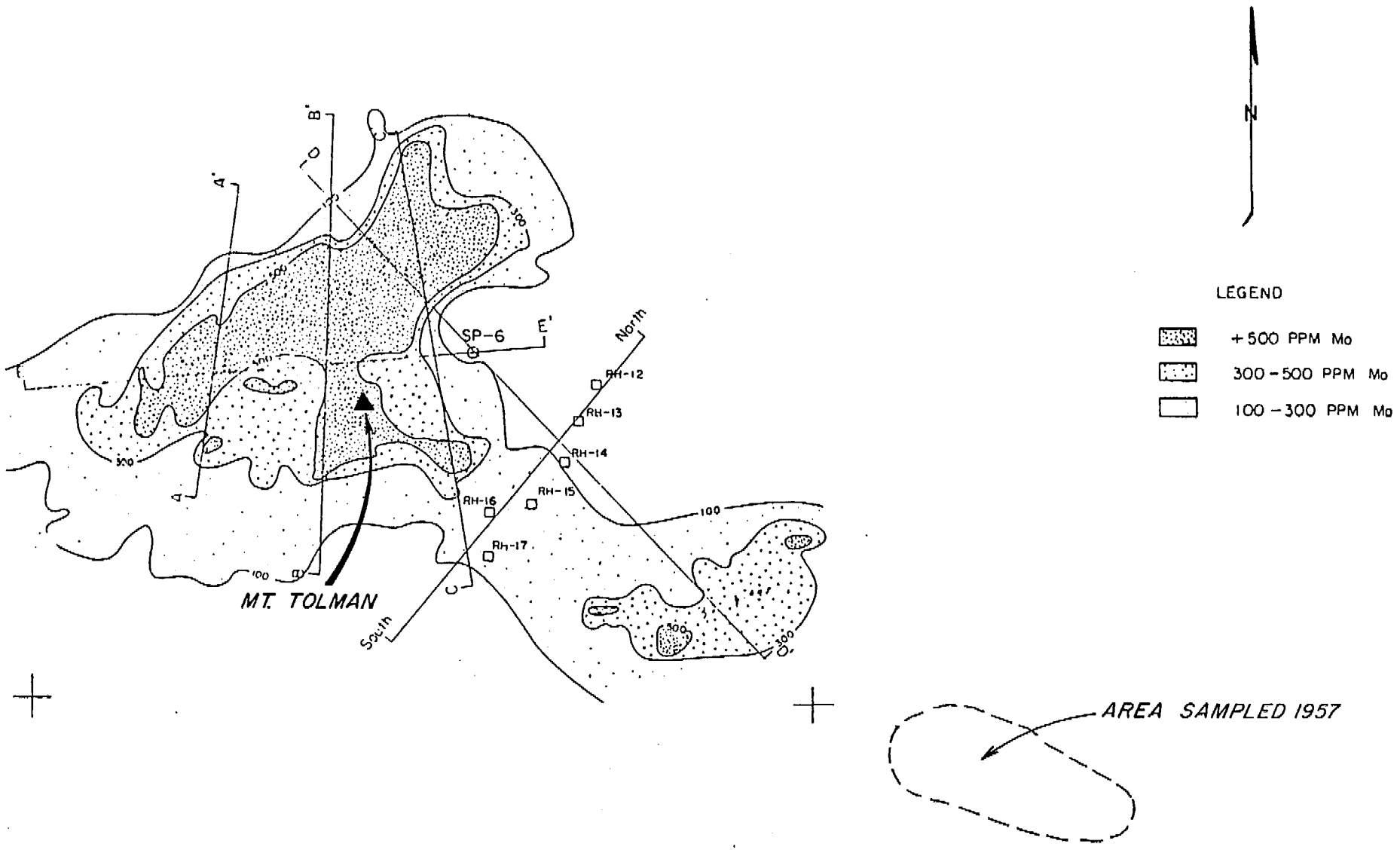
SAN POIL PROSPECT

IDEALIZED ALTERATION ZONES IN CROSS-SECTION

FERRY COUNTY, WASHINGTON

JAN. 1978

REDRAFTED FROM BEAR CREEK MINING CO'S SAN POIL REPORT, FEB., 1970

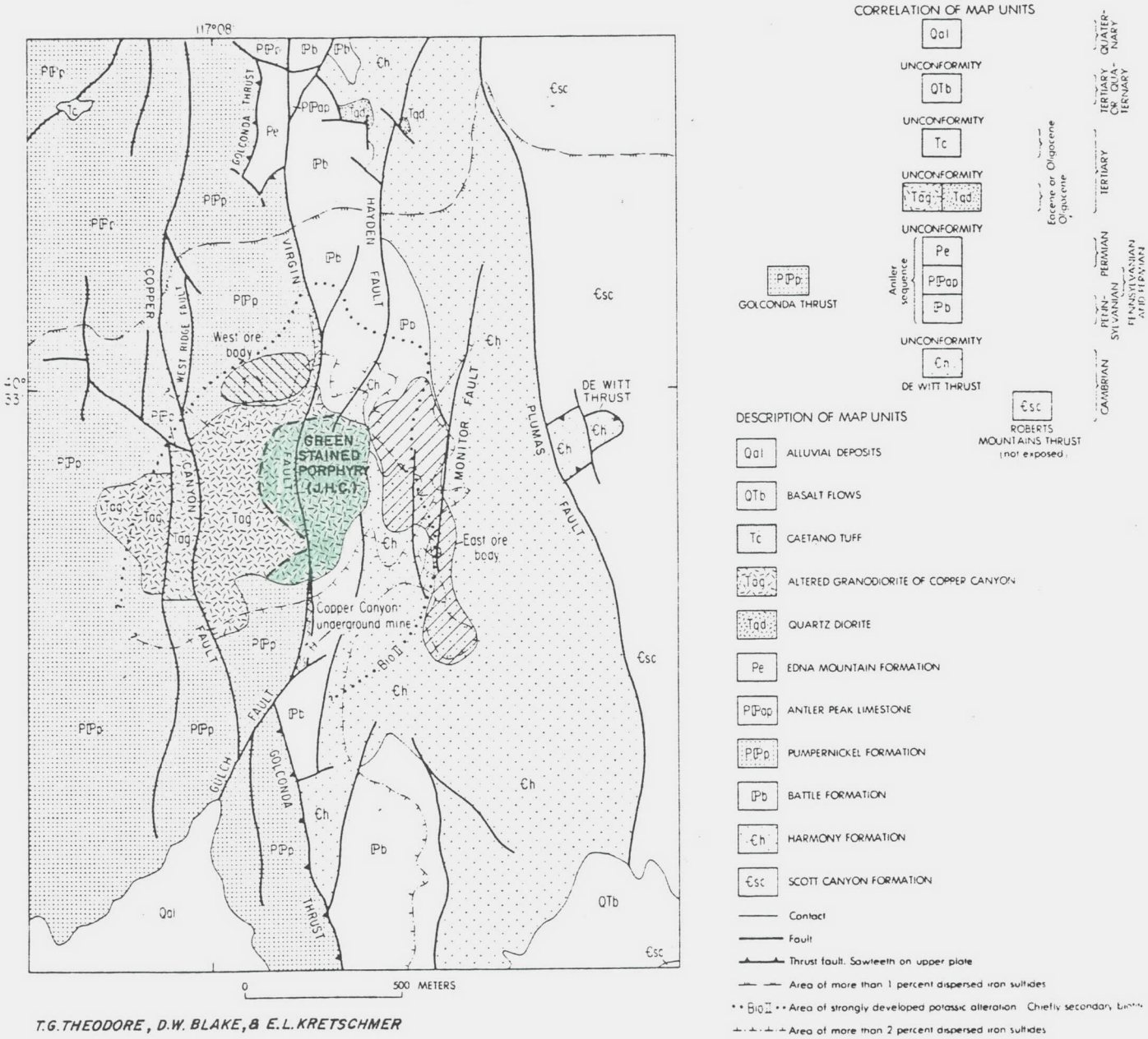


BEAR CREEK MINING COMPANY NORTHWEST DISTRICT	DATA BY: JCB	REVISED	SAN POIL MOLYBDENUM IN ROCK FERRY CO. WASH
SCALE: 1000 500 0 1000	DWN. BY: LLD		
	DATE: SEPT. 1968		

FIGURE 64

FIGURE 65

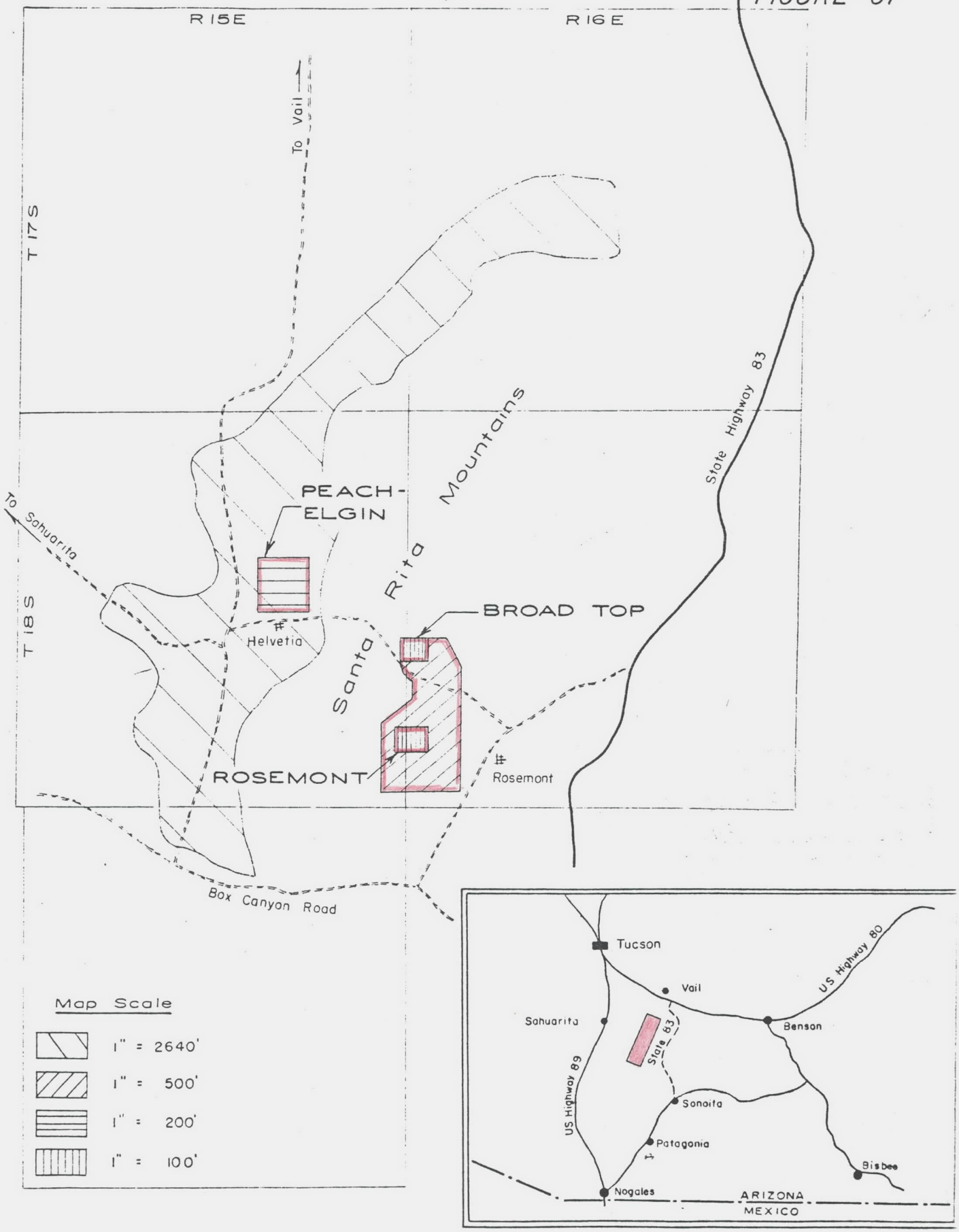
ATTACHMENT A
COPPER BASIN AREA
COPPER CANYON AREA
LONG CANYON
LITTLE COTTONWOOD CANYON
COTTONWOOD CANYON
GALENA CANYON
HUMBUG CANYON
BUTTE CANYON
IRON CANYON
PHILADELPHIA CANYON
WILLOW CREEK
T. 32 N.
T. 31 N.
R. 43 E.
R. 44 E.
Lucky Strike mine
Buckingham mine
CONTENTION
CHASE
BADGER
C.C. CAMP
CHESSHER LEASE
Julie wkgs.
Tom Boy mine
N
Canyons - U.S.G.S. Antler Peak Topog. sheet
Roads, highways & alluvium boundaries - U.S.G.S. Antler Peak Topog. sheet & W.P. Hewitt report Oct. 1960.
Altered areas - W.P. Hewitt report Oct. 1960 with additions by Kinnison, Alucher and Courtright - 1961.
Alluvium.
A.S.&R.Co. holdings.
A.S.&R.Co. drill holes.
Earlier drill holes.
TO ACCOMPANY Memo
DATED Oct. 18. 1961
BY J.H. Courtright
COPPER CANYON & COPPER BASIN AREAS
LANDER CO - NEVADA
1 IN = 1 MILE
Compiled July 1961.
J.H. Courtright
Oct. 1961
14-930



T.G.THEODORE, D.W. BLAKE, & E.L.KRETSCHMER

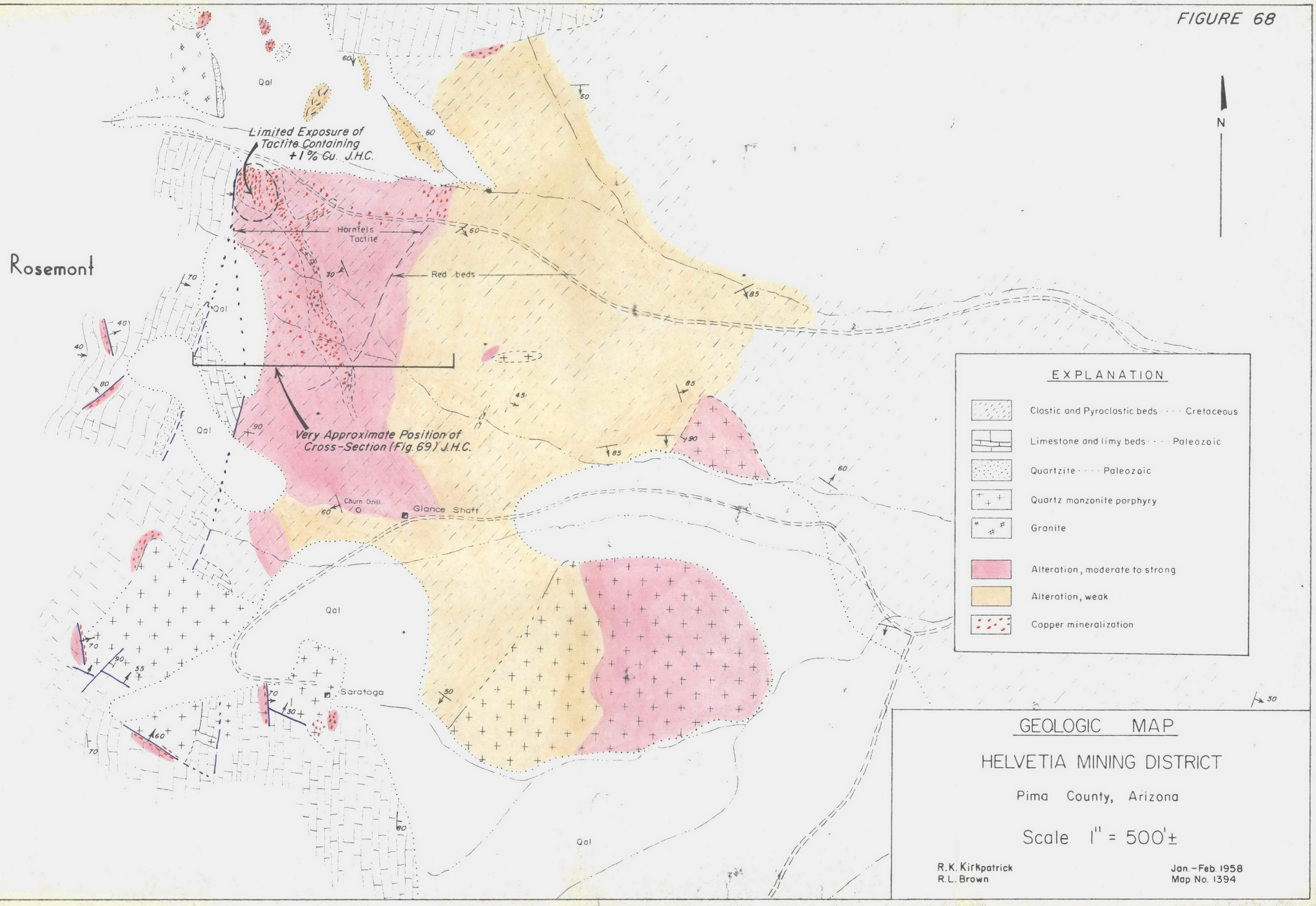
Figure 27.1. Geology of the Copper Canyon area, Lander County, Nevada

FIGURE-67

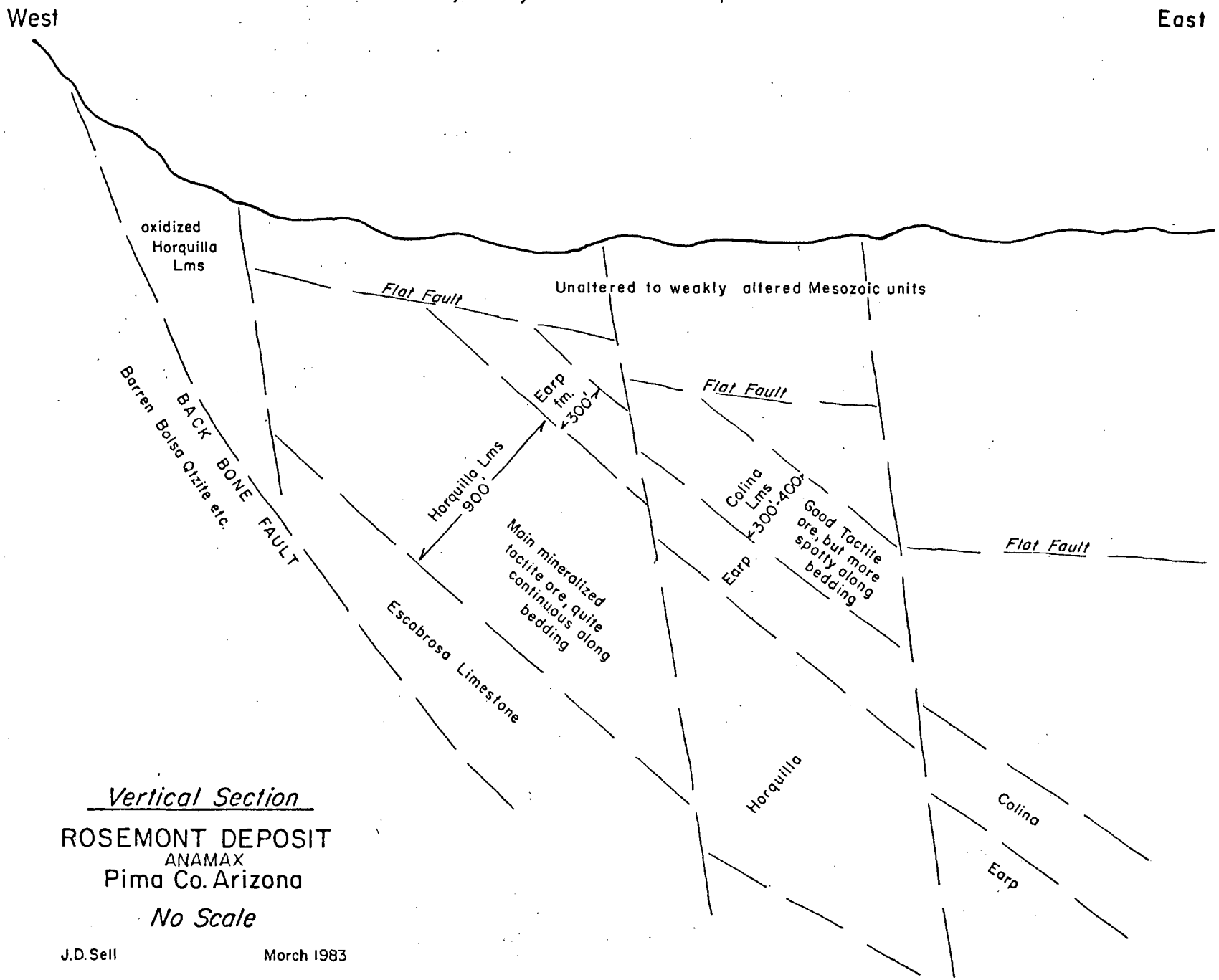


INDEX MAP
HELVETIA DISTRICT

FIGURE 68


Rosemont
Limited Exposure of Tactite Containing +1% Cu. J.H.C.
Hornfels Tactite
Red beds
Very Approximate Position of Cross-Section (Fig. 69) J.H.C.
Churn Drill
Glance Shaft
Saratoga
Qal
N
EXPLANATION
Clastic and Pyroclastic beds · · · · Cretaceous
Limestone and limy beds · · · · Paleozoic
Quartzite · · · · Paleozoic
Quartz monzonite porphyry
Granite
Alteration, moderate to strong
Alteration, weak
Copper mineralization
GEOLOGIC MAP
HELVETIA MINING DISTRICT
Pima County, Arizona
Scale 1" = 500'±
R.K. Kirkpatrick
R.L. Brown
Jan.-Feb. 1958
Map No. 1394

Sketch showing ore tactite units in Horquilla & Colina limestones covered by weakly to fresh rocks on top.



Vertical Section

ROSEMONT DEPOSIT
ANAMAX
Pima Co. Arizona

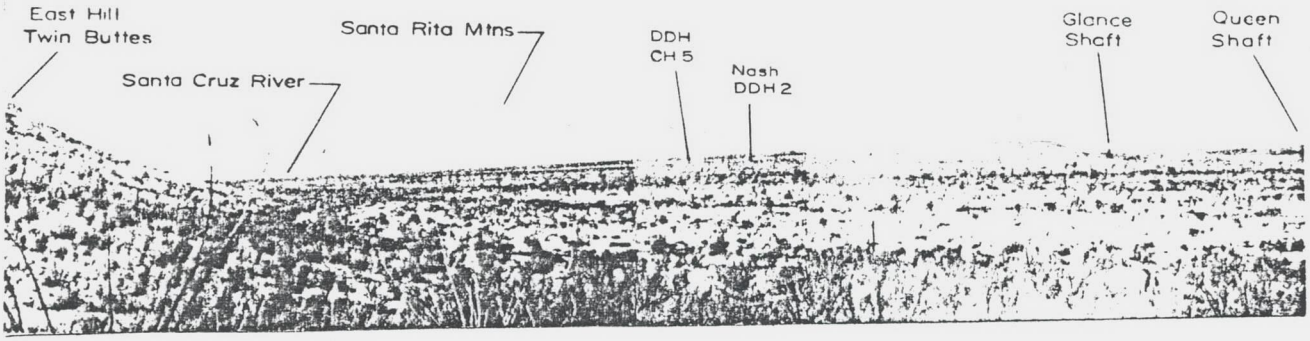
No Scale

J.D. Sell March 1983

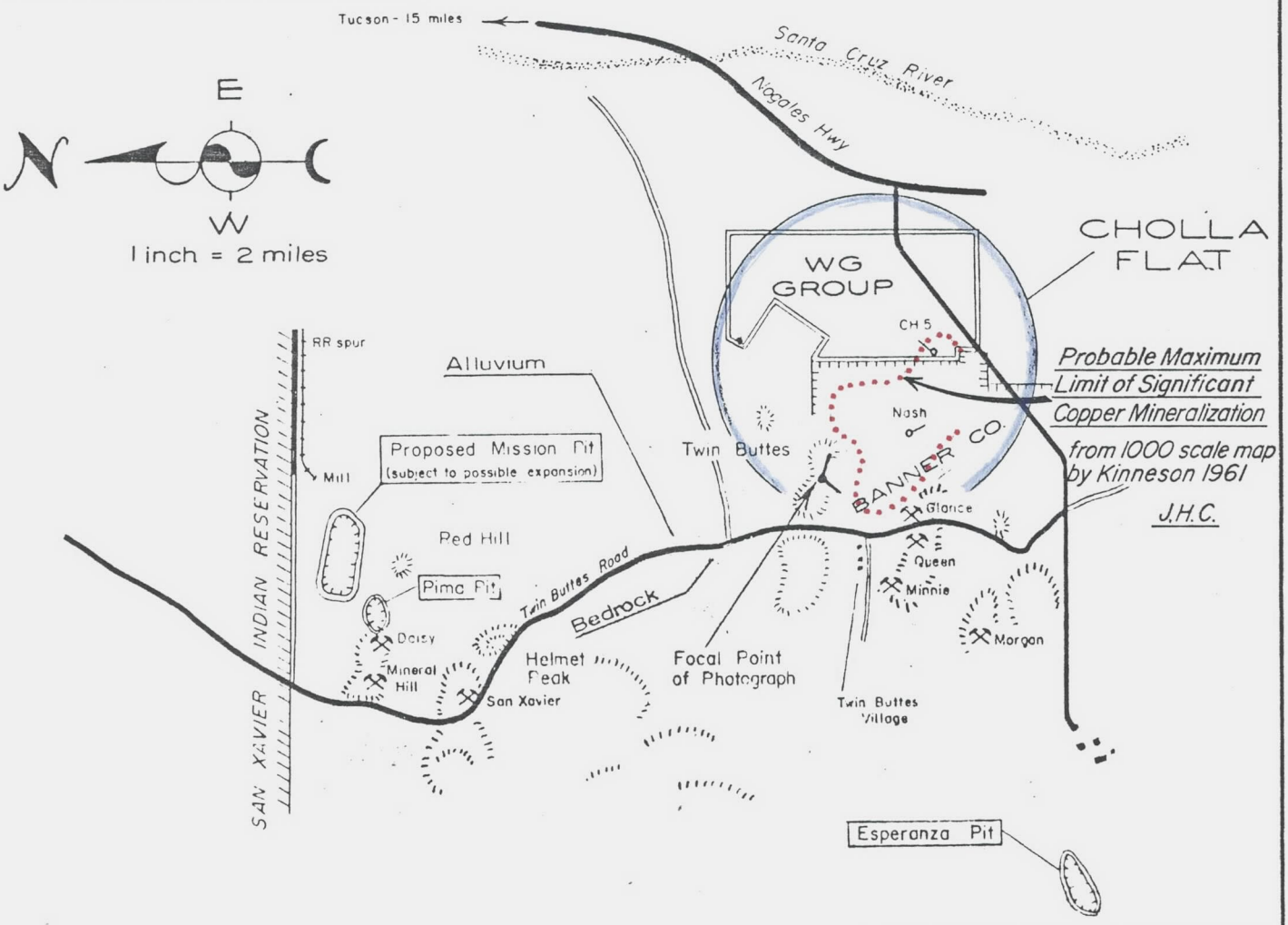
FIGURE 69

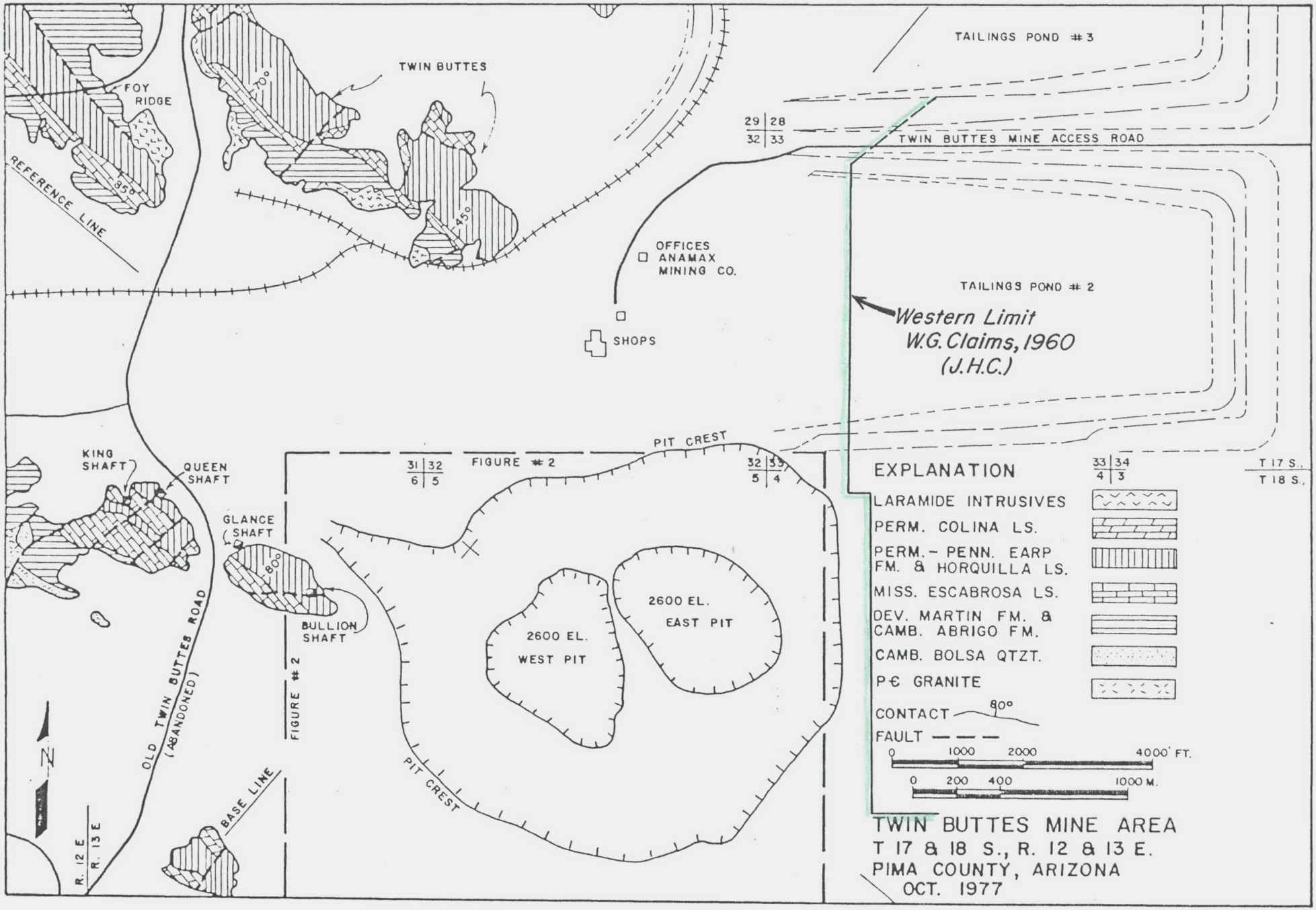
MVK 5493

INDEX MAP — CHOLLA FLAT



View to the Southeast, overlooking alluvial plain at Cholla Flat.
Depth of bedrock deepens toward Santa Cruz River.

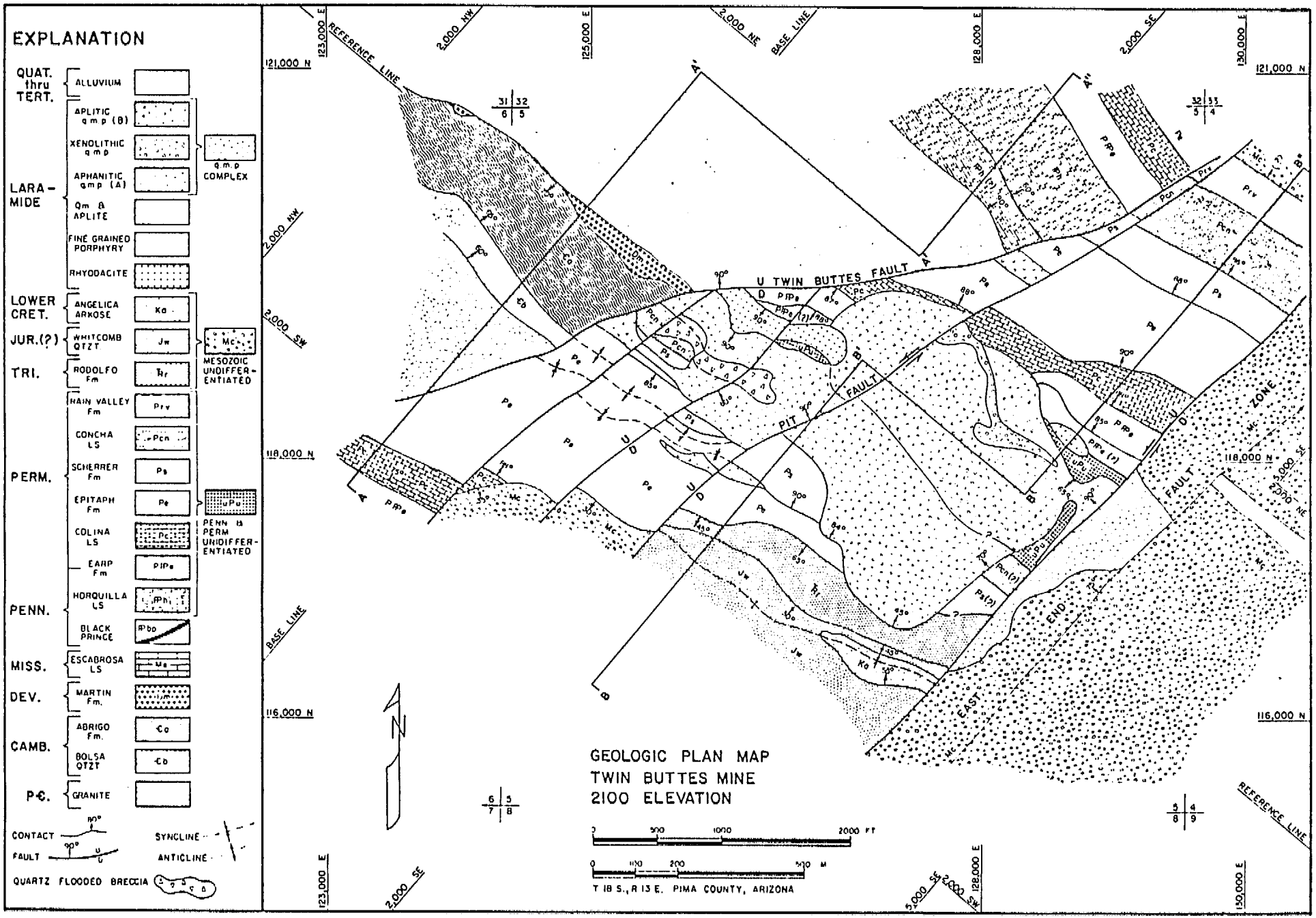




C.F. Barter & J.L. Kelly

Figure 20.1. Outcrop geology and surface features in the Twin Buttes mine area

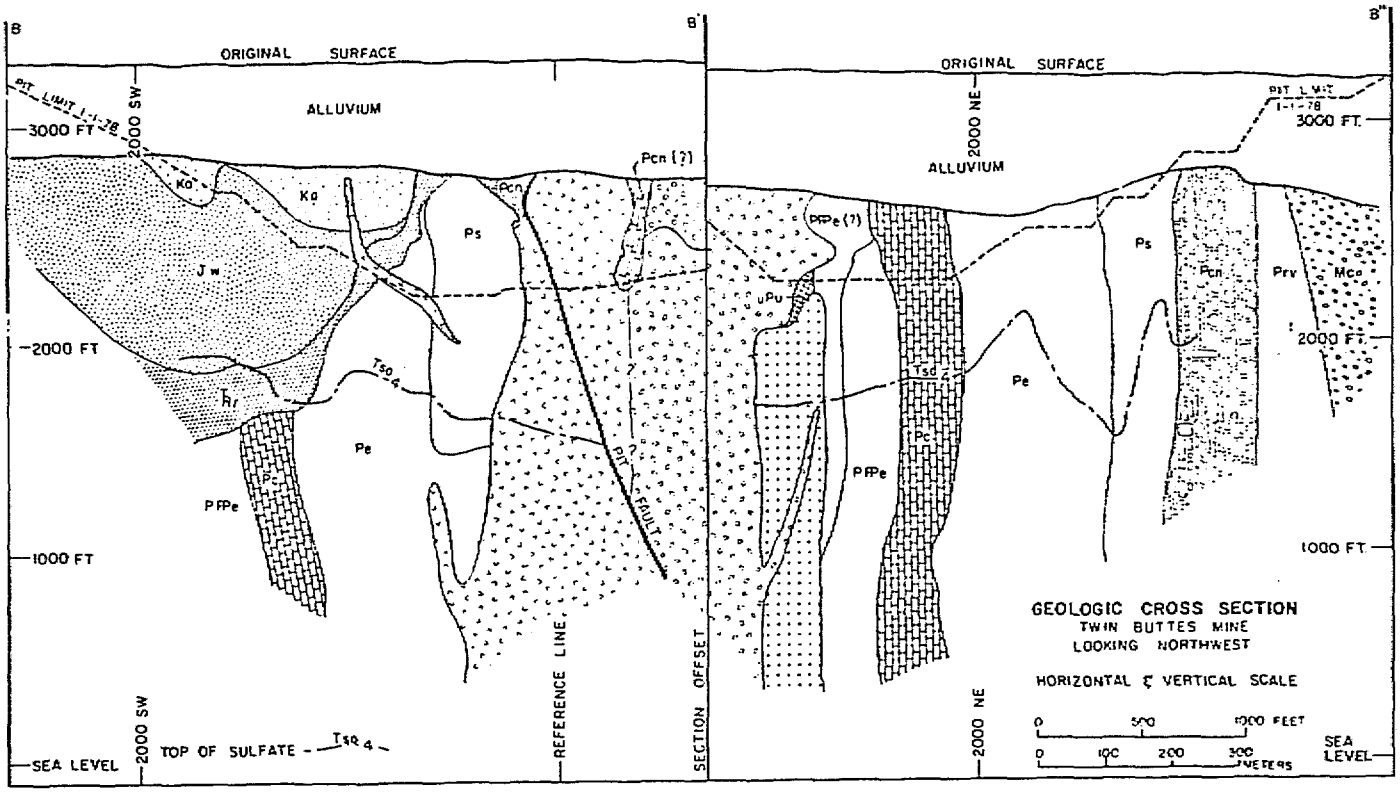
FIGURE 71



C.F. Barter & J.L. Kelly

Figure 20.3. Geologic plan map of the Twin Buttes mine, 2,100-ft. elevation

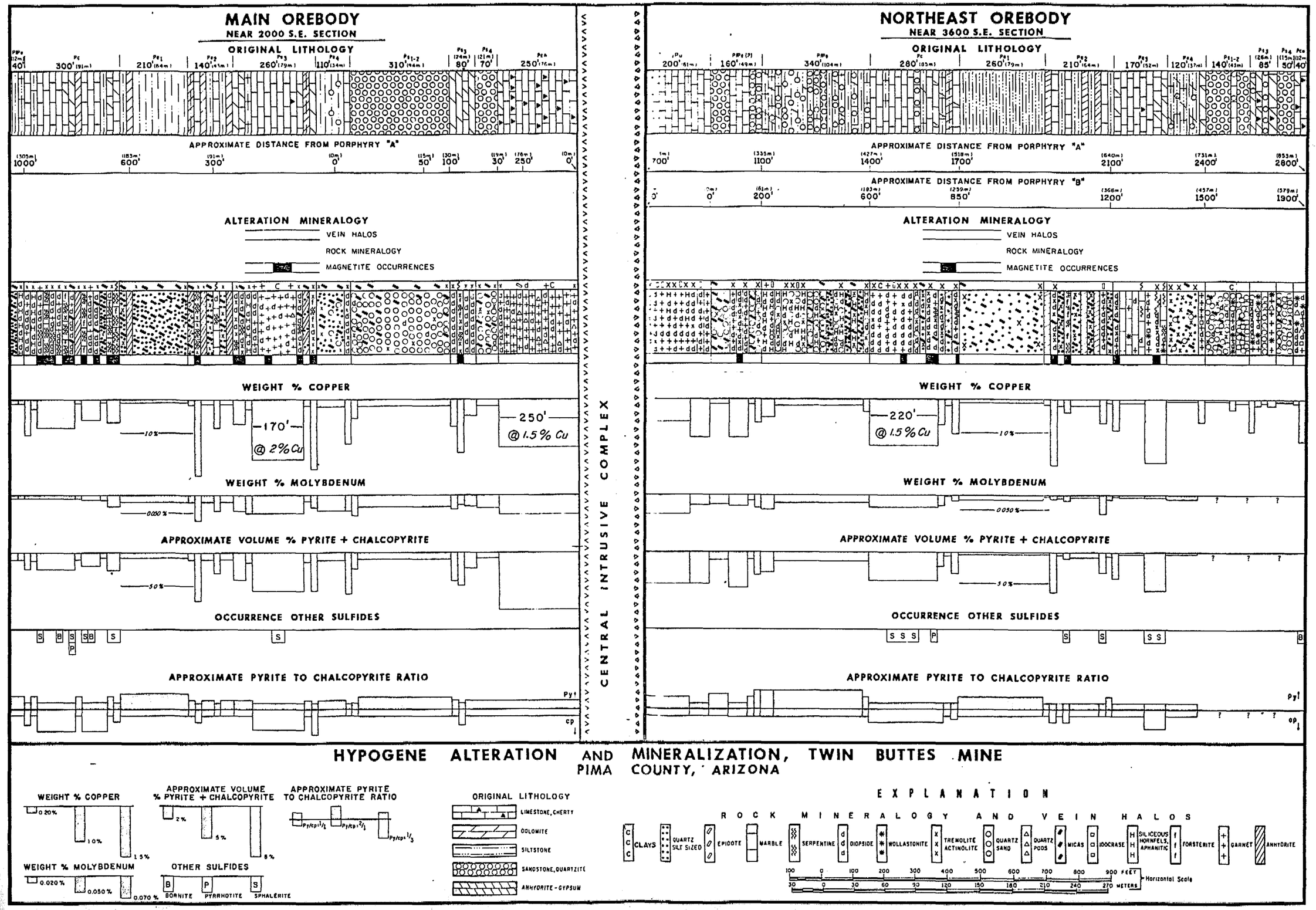
FIGURE 72



Abbreviations:

Jw = Jurassic (?) Whitcomb Quartzite
Ka = Lower Cretaceous Angelica Arkose
Mc = Mesozoic undifferentiated
Pc = Permian Colina Limestone
Pcn = Permian Concha Limestone
Pe = Permian Epitaph Formation
Prv = Permian Rain Valley Formation
Ps = Permian Scherrer Formation
PPe = Permian and Pennsylvanian Earp Formation
Tir = Triassic Rodolfo Formation
Tso₄ = top of sulfate zone
uPu = Permian and Pennsylvanian undifferentiated

Figure 20.4. Geologic cross section through the Main Orebody *(B-B')* along 2,000 SE and the Northeast Orebody *(B'-B")* along 3,600 SE. Line of section is shown in Figures 20.2 and 20.3.



HYPOGENE ALTERATION AND MINERALIZATION, TWIN BUTTES MINE
PIMA COUNTY, ARIZONA

C.F. Barter & J.L. Kelly

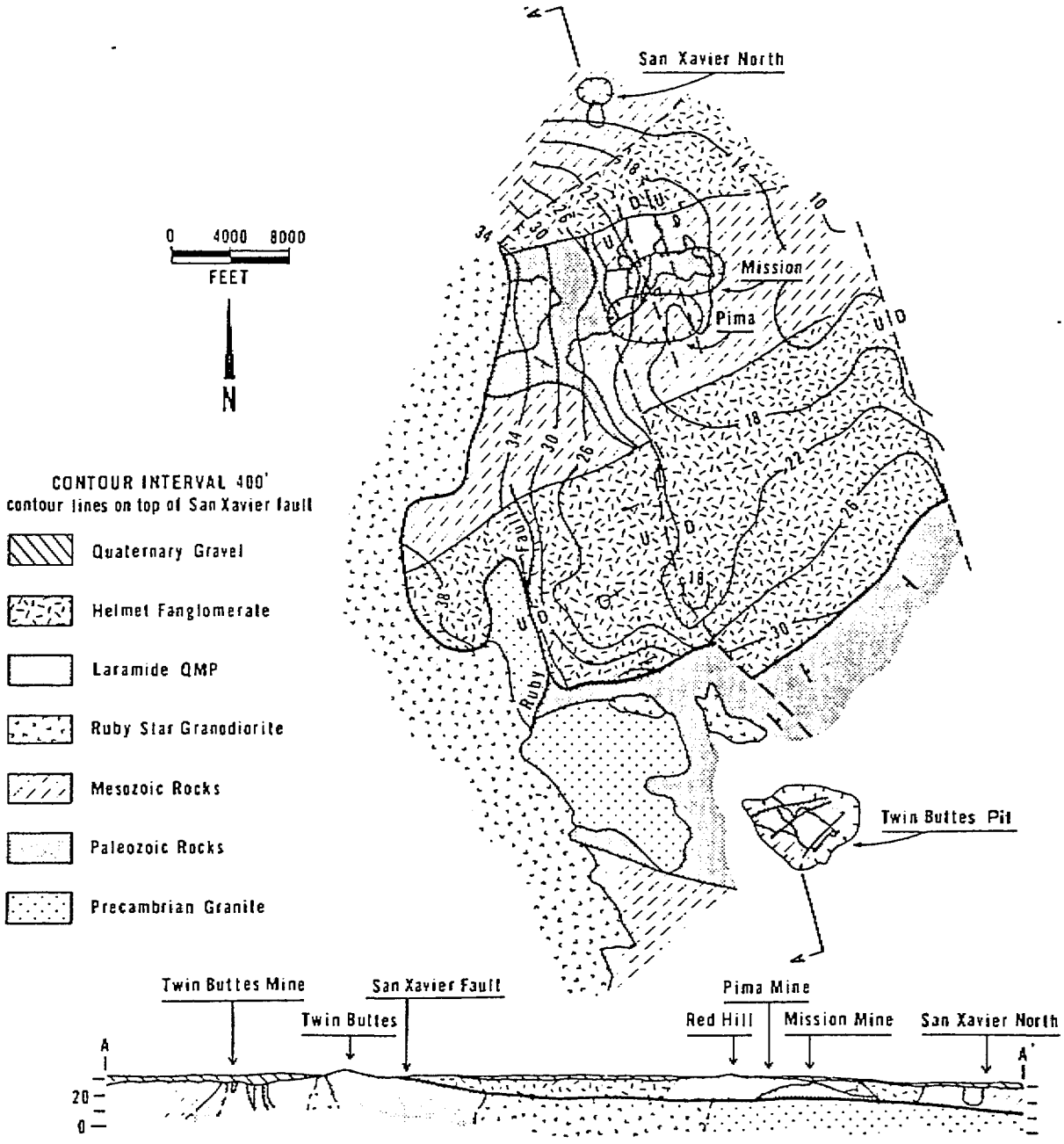
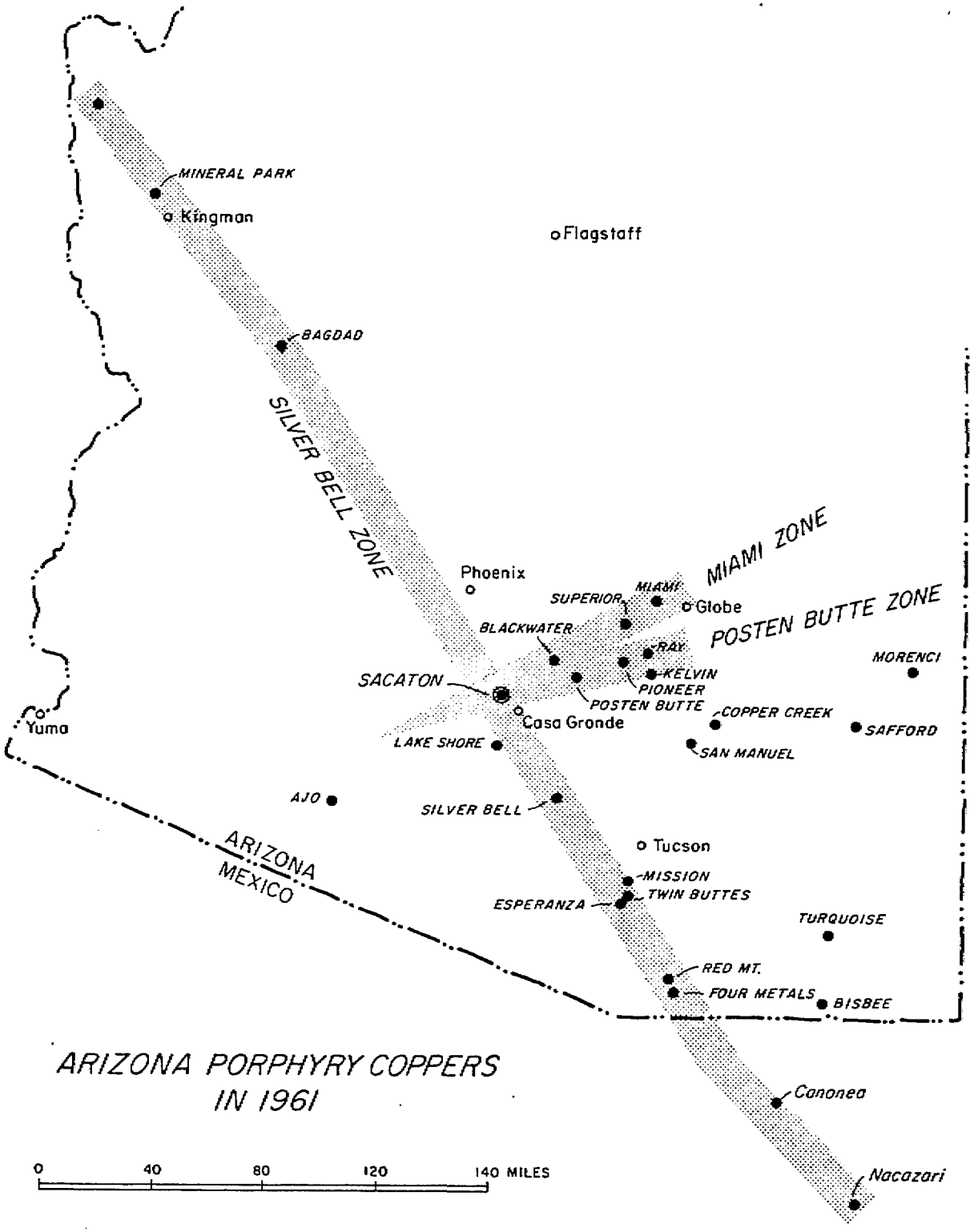


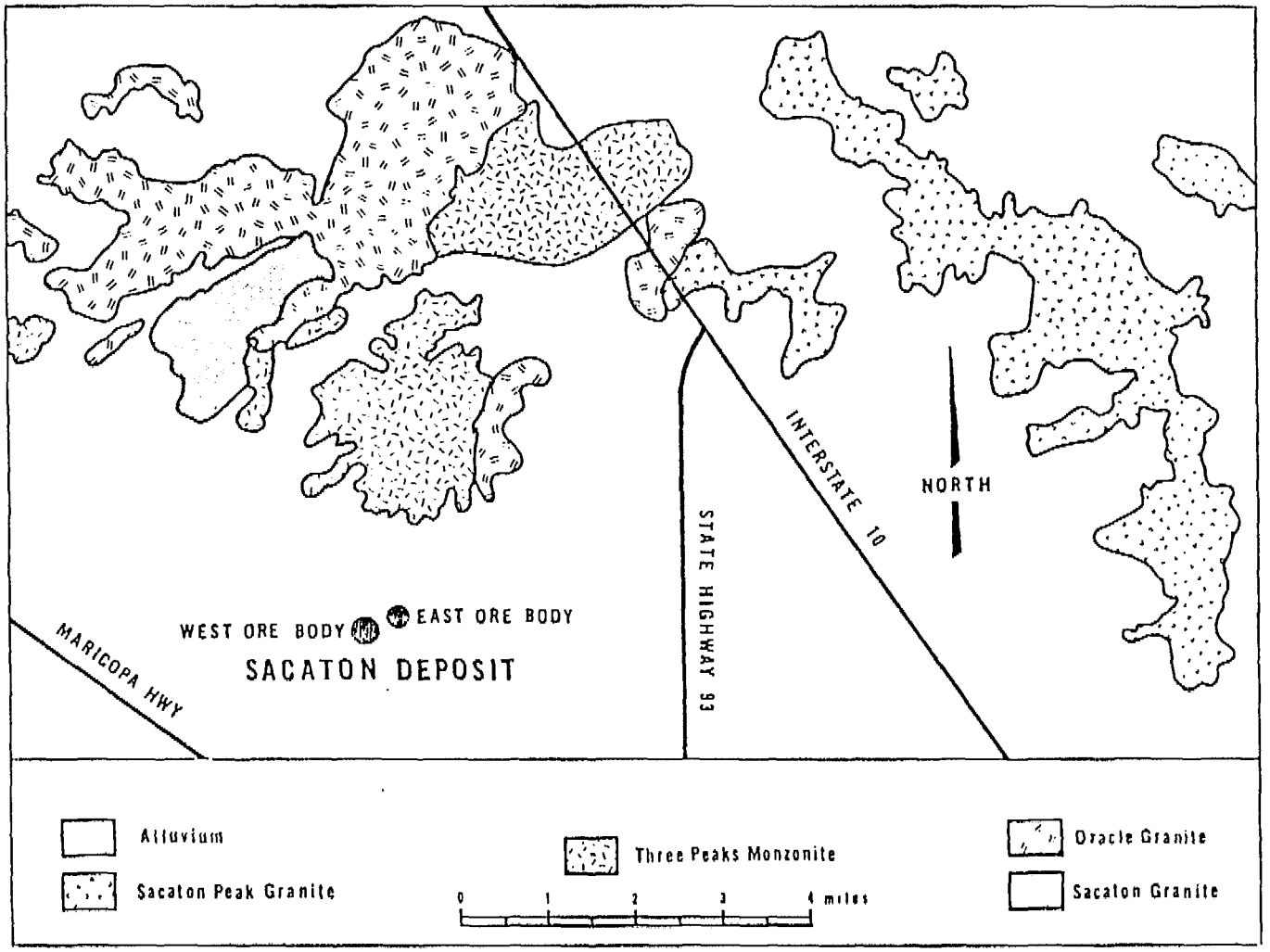
Figure 22.1. General geology of the Pima mining district. Contour lines represent elevation of the San Xavier fault, as interpreted from diamond drill hole samples and scattered surface exposures

Louis J. Jonson

FIGURE 76



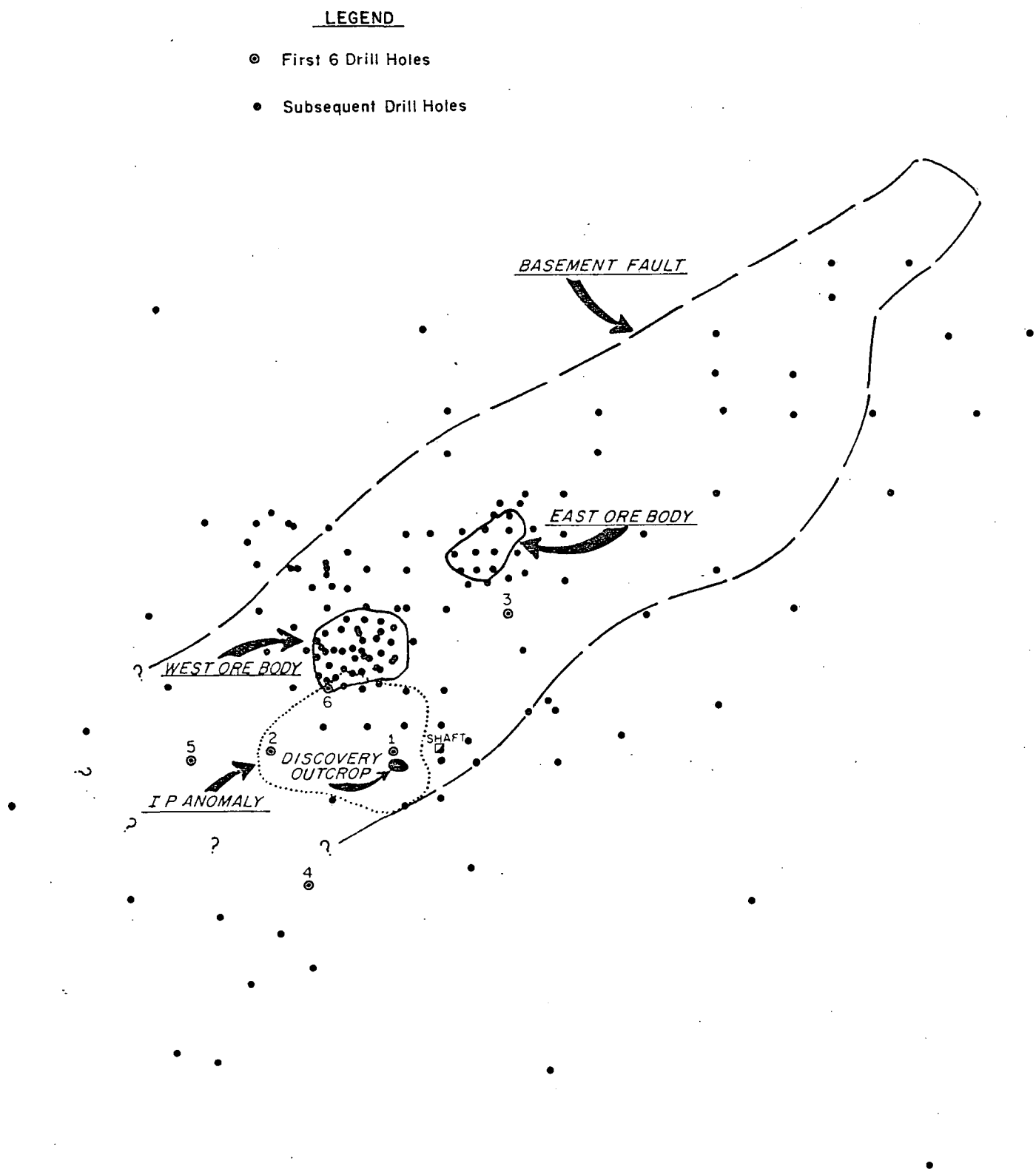
ARIZONA PORPHYRY COPPERS IN 1961



Generalized geologic map of the Sacaton Mountains. Modified after Balla (1972).

FIGURE 76 A

FIGURE 77

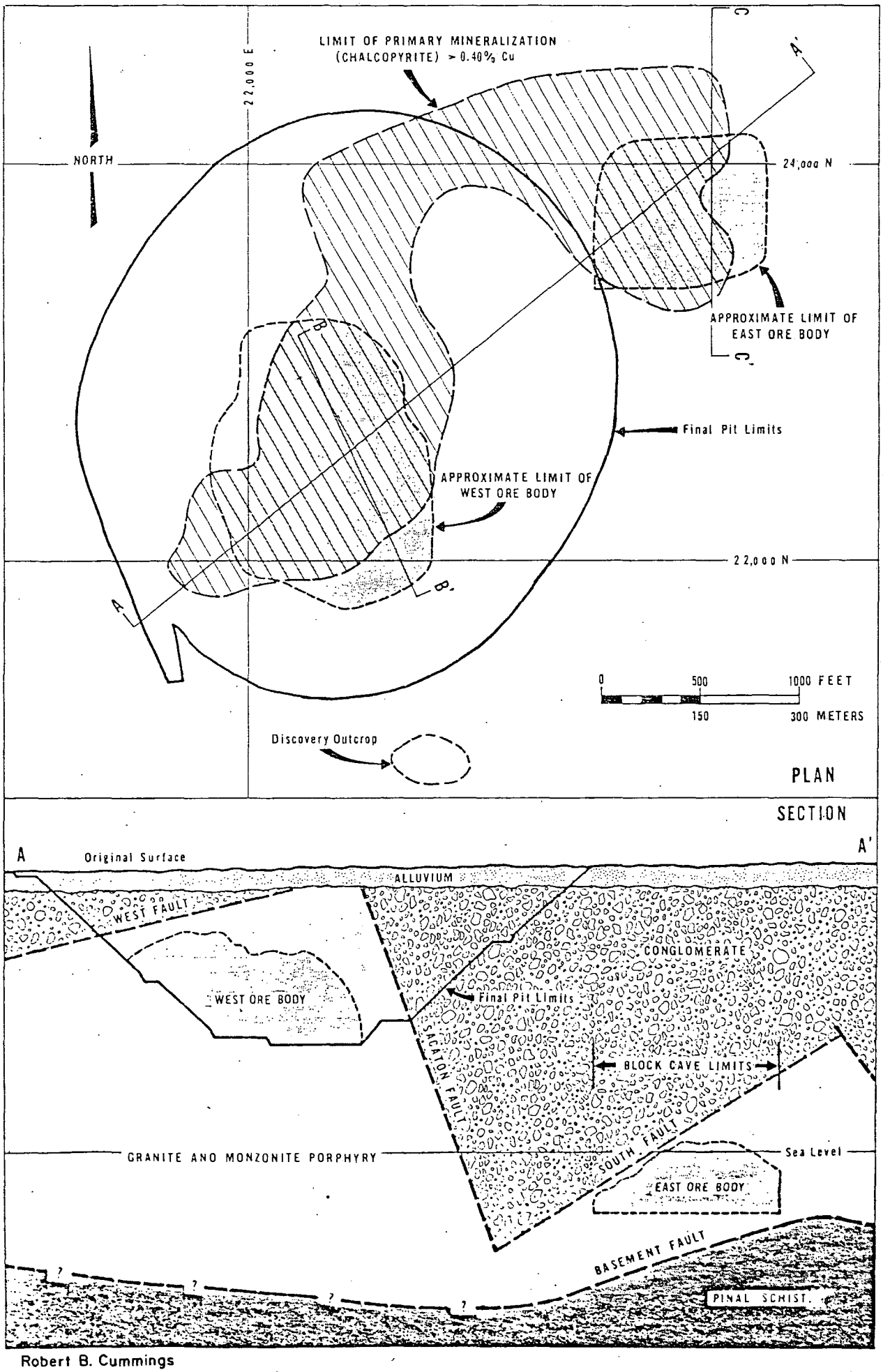


ASARCO SACATON PROJECT

Pinal County, Arizona

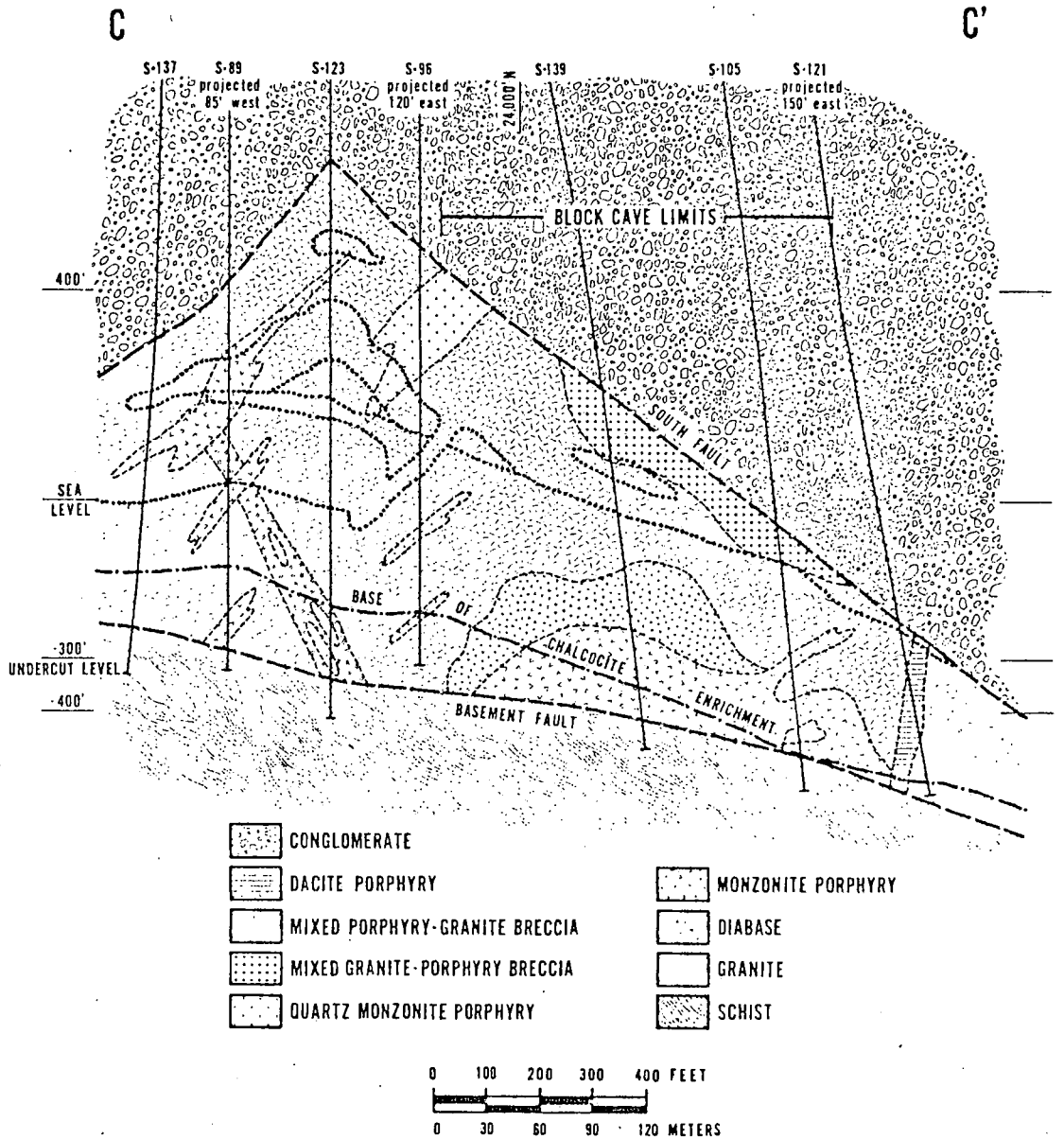
0 1000 2000 3000 4000 5000 FEET

JANUARY, 1973



Robert B. Cummings

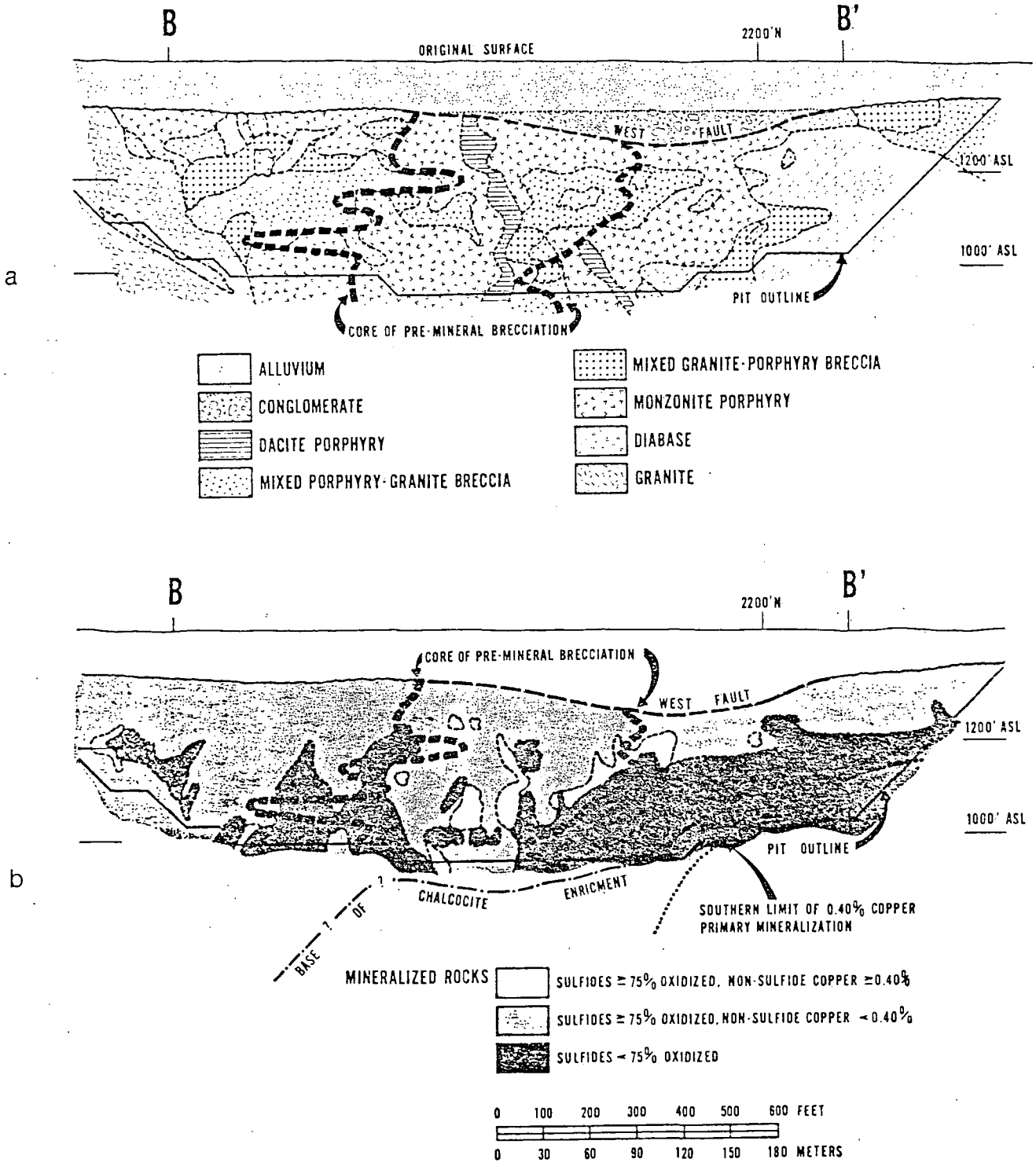
Generalized plan and section, showing the limits of the East and West orebodies, Sacaton



Cross section *C-C'* through the East orebody shows (*a*) rock types and (*b*) distribution of sulfides.

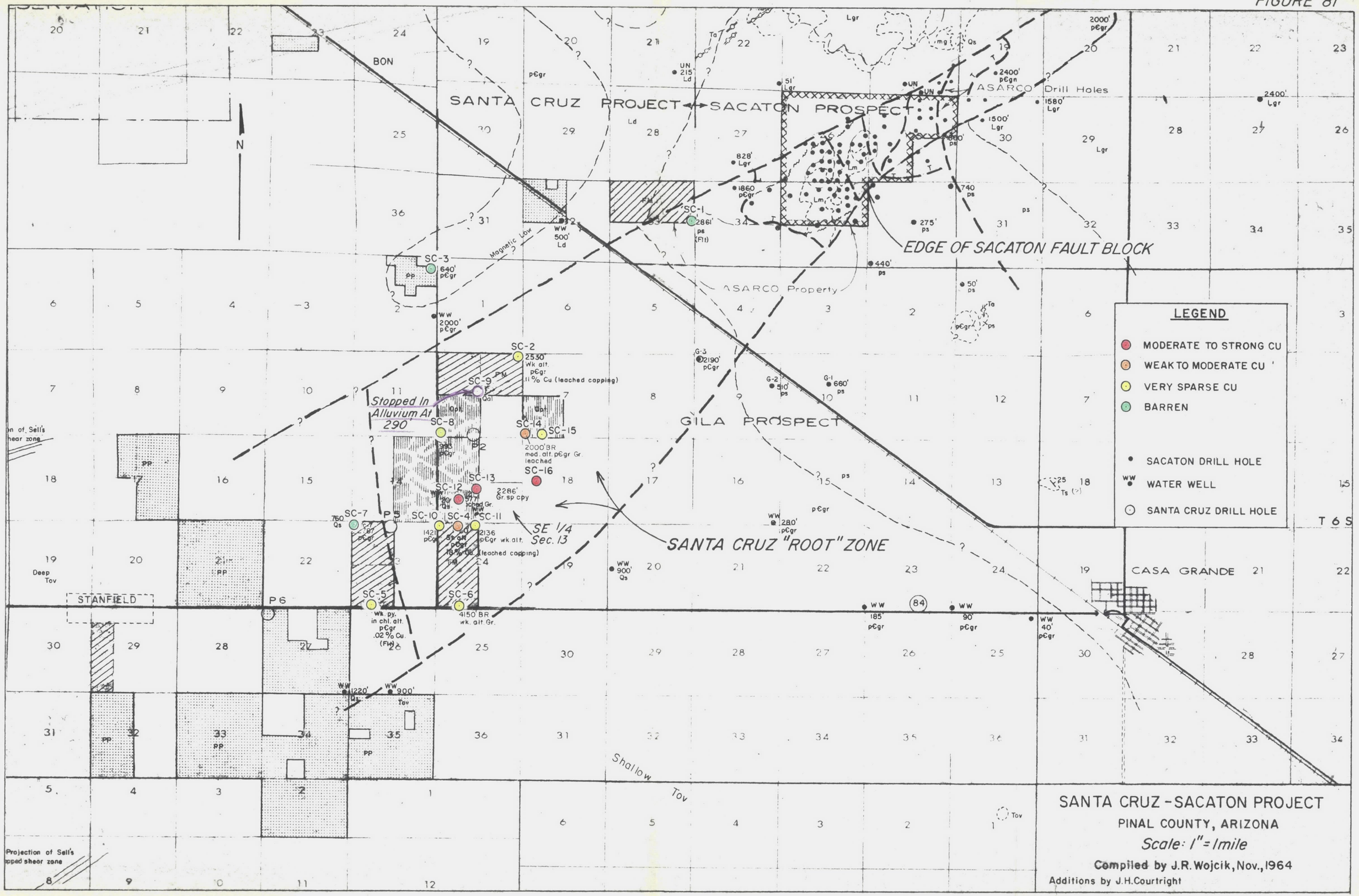
Robert B. Cummings

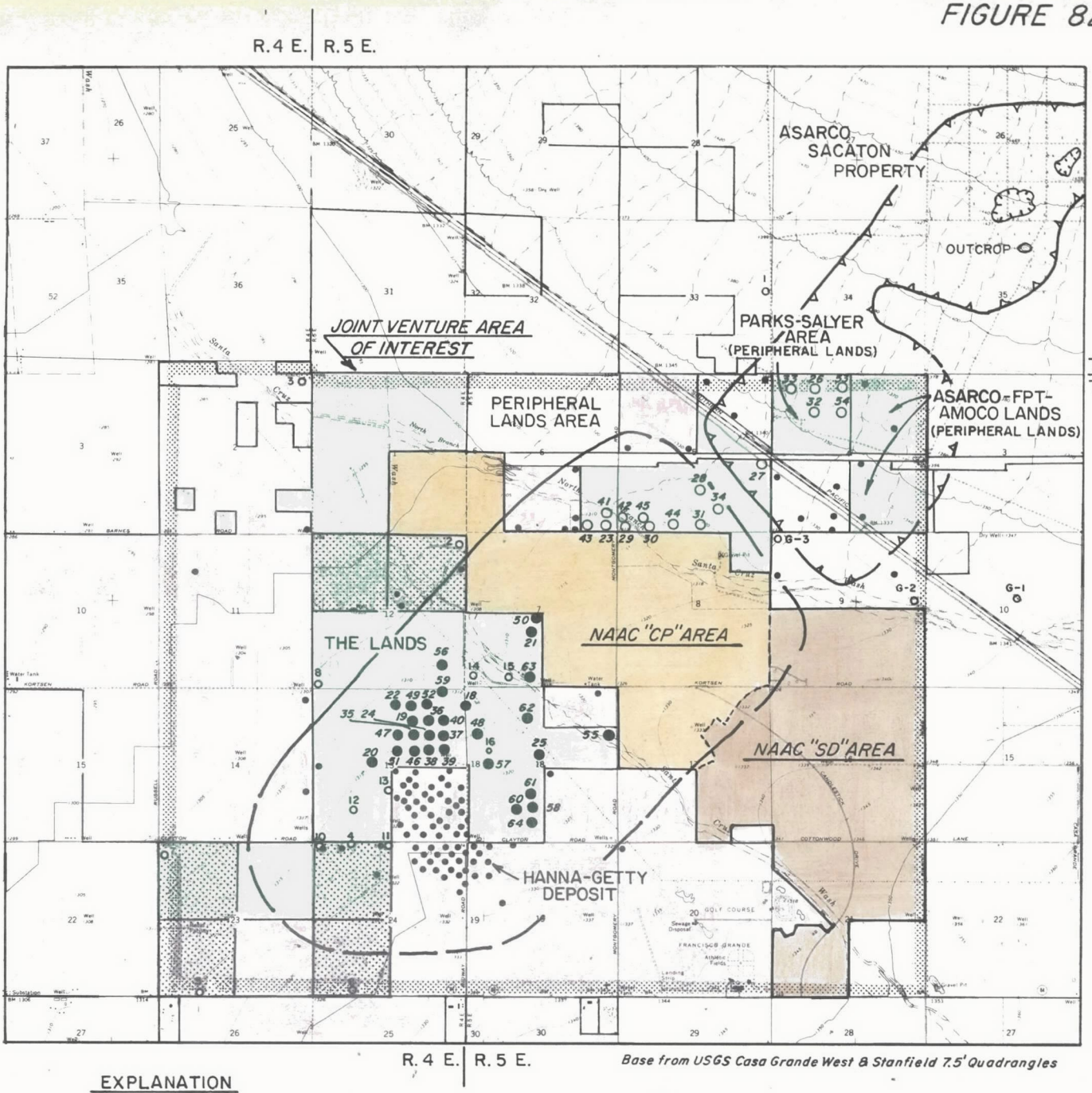
FIGURE 79



Cross section *B-B'* through the West orebody shows (*a*) rock types and (*b*) distribution of sulfides.

FIGURE 81


SANTA CRUZ PROJECT
SACATON PROSPECT
ASARCO Drill Holes
EDGE OF SACATON FAULT BLOCK
ASARCO Property
GILA PROSPECT
SANTA CRUZ "ROOT" ZONE
SE 1/4 Sec. 13
Stopped In Alluvium At 290'
Magnetic Low
Projection of Sell's shear zone
STANFIELD
CASA GRANDE
Shallow Tov
T 6 S
LEGEND
MODERATE TO STRONG CU
WEAK TO MODERATE CU
VERY SPARSE CU
BARREN
SACATON DRILL HOLE
WATER WELL
SANTA CRUZ DRILL HOLE
SANTA CRUZ - SACATON PROJECT
PINAL COUNTY, ARIZONA
Scale: 1" = 1 mile
Compiled by J.R. Wojcik, Nov., 1964
Additions by J.H. Courtright



Base from USGS Casa Grande West & Stanfield 7.5' Quadrangles

EXPLANATION

- ASARCO-FREEPORT HANNA-GETTY FEDERAL LODE CLAIMS
- HANNA-GETTY HANNA-GETTY FEDERAL LODE CLAIMS
- NAAC "CP" (SUBDIVIDED)
- NAAC "SD" (SUBDIVIDED)
- OUTLINE OF SUBSTANTIAL ALTERATION & MINERALIZATION "IN PLACE"
- OUTLINE OF DISPLACED ALTERATION & MINERALIZATION RESTING ON THE SACATON BASEMENT FAULT

N

- PREVIOUS ASARCO DRILL HOLES
- ASARCO-FREEPORT DRILL HOLES OF THIS REPORT
- ASARCO-FREEPORT DRILL HOLES

} "SC" PREFIX NOT SHOWN

- DRILL HOLES OF OTHER COMPANIES

FIGURE 1

SANTA CRUZ PROJECT

PINAL COUNTY, ARIZONA

SANTA CRUZ PROJECT AREA

SCALE 1" = 1 mile

H.G.K. ASARCO INC. Dec., 1981

FIGURE -83

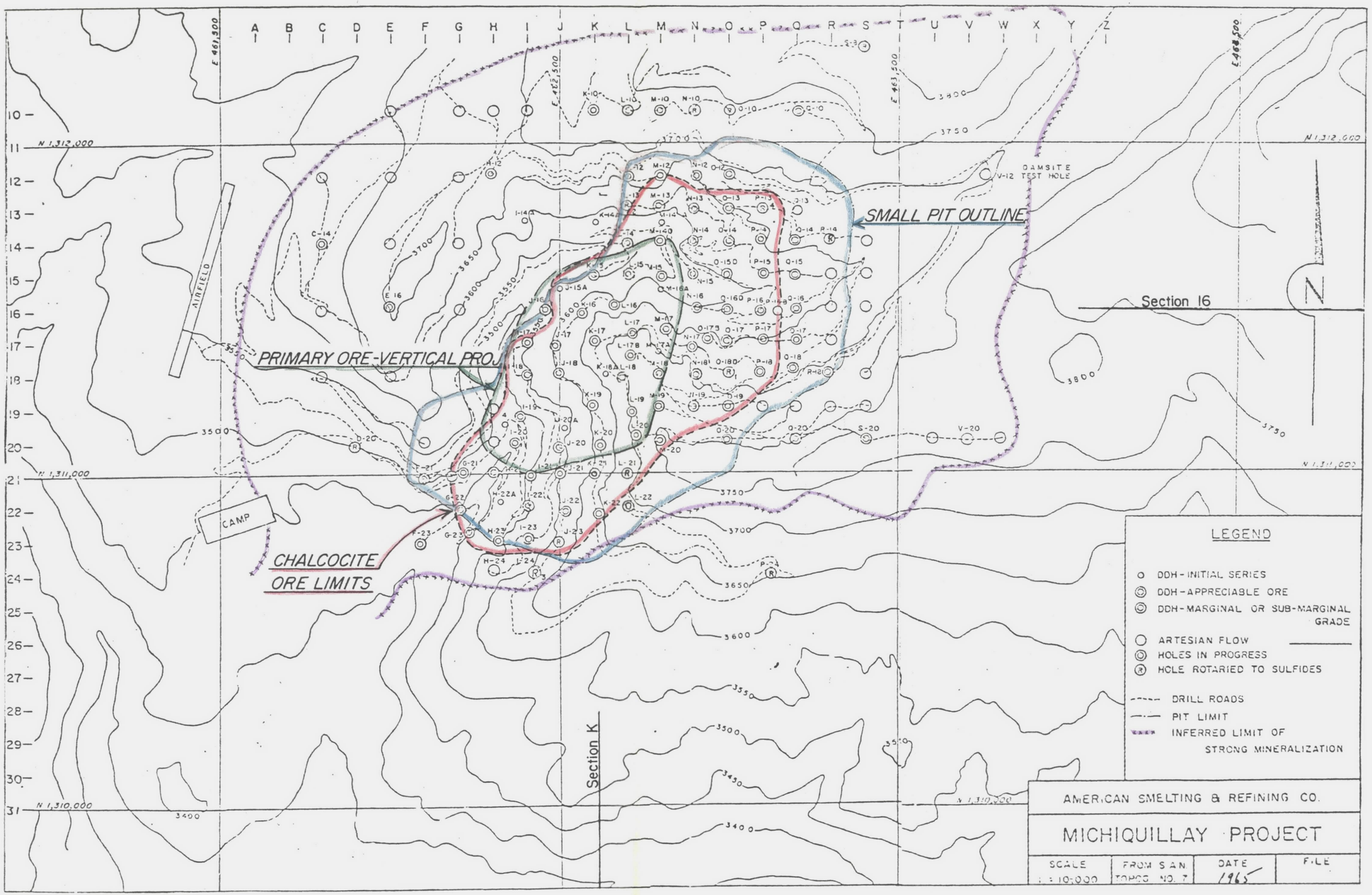

SMALL PIT OUTLINE
PRIMARY ORE-VERTICAL PROJ.
CHALCOCITE ORE LIMITS
DAMSITE TEST HOLE
V-12
AIRFIELD
CAMP
Section 16
Section K
N 1,312,000
N 1,311,000
N 1,310,000
E 461,300
E 462,500
E 463,500
E 464,500
LEGEND
DDH - INITIAL SERIES
DDH - APPRECIABLE ORE
DDH - MARGINAL OR SUB-MARGINAL GRADE
ARTESIAN FLOW
HOLES IN PROGRESS
HOLE ROTARIED TO SULFIDES
DRILL ROADS
PIT LIMIT
INFERRED LIMIT OF STRONG MINERALIZATION
AMERICAN SMELTING & REFINING CO.
MICHIQUILLAY PROJECT
SCALE 1" = 1000'
FROM S.A.R. TOPOG. NO. 7
DATE 1965
FILE

FIGURE-83 A

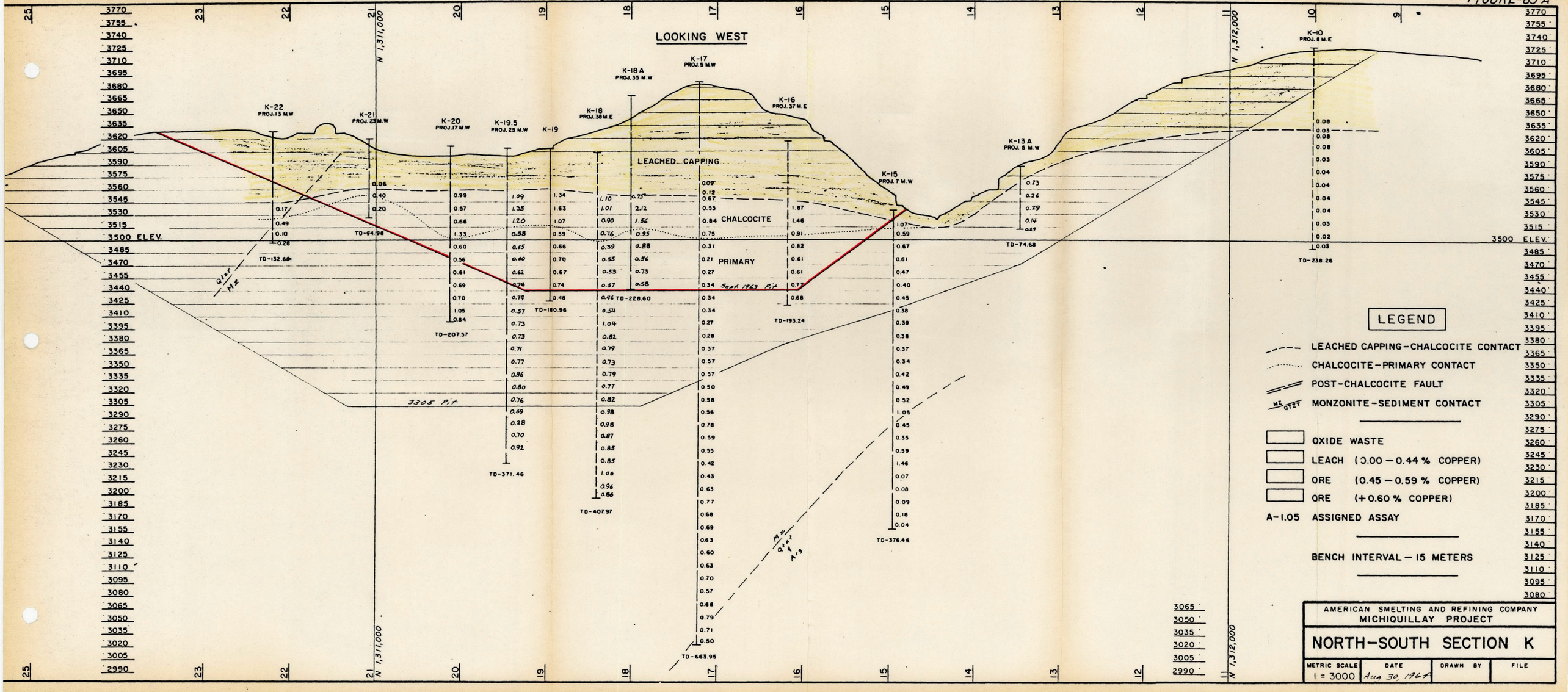

LOOKING WEST
K-22 PROJ.13 M.W
K-21 PROJ. 23 M.W
K-20 PROJ.17 M.W
K-19.5 PROJ.25 M.W
K-19
K-18 PROJ.38 M.E
K-18 A PROJ.35 M.W
K-17 PROJ.5 M.W
K-16 PROJ.37 M.E
K-15 PROJ.7 M.W
K-13 A PROJ. 5 M.W
K-10 PROJ. 8 M.E
LEACHED CAPPING
CHALCOCITE
PRIMARY
Sept. 1963 Pit
3305 Pit
Qtzt
MZ
TD-94.98
TD-132.68
TD-207.57
TD-180.96
TD-228.60
TD-371.46
TD-407.97
TD-193.24
TD-663.95
TD-376.46
TD-74.68
TD-238.26
3500 ELEV.
N 1,311,000
N 1,312,000
LEGEND
LEACHED CAPPING-CHALCOCITE CONTACT
CHALCOCITE-PRIMARY CONTACT
POST-CHALCOCITE FAULT
MZ QTZT MONZONITE-SEDIMENT CONTACT
OXIDE WASTE
LEACH (0.00 – 0.44 % COPPER)
ORE (0.45 – 0.59 % COPPER)
ORE (+0.60 % COPPER)
A-1.05 ASSIGNED ASSAY
BENCH INTERVAL – 15 METERS
AMERICAN SMELTING AND REFINING COMPANY
MICHIQUILLAY PROJECT
NORTH-SOUTH SECTION K
METRIC SCALE 1 = 3000
DATE Aug 30, 1964
DRAWN BY
FILE

FIGURE-83 B

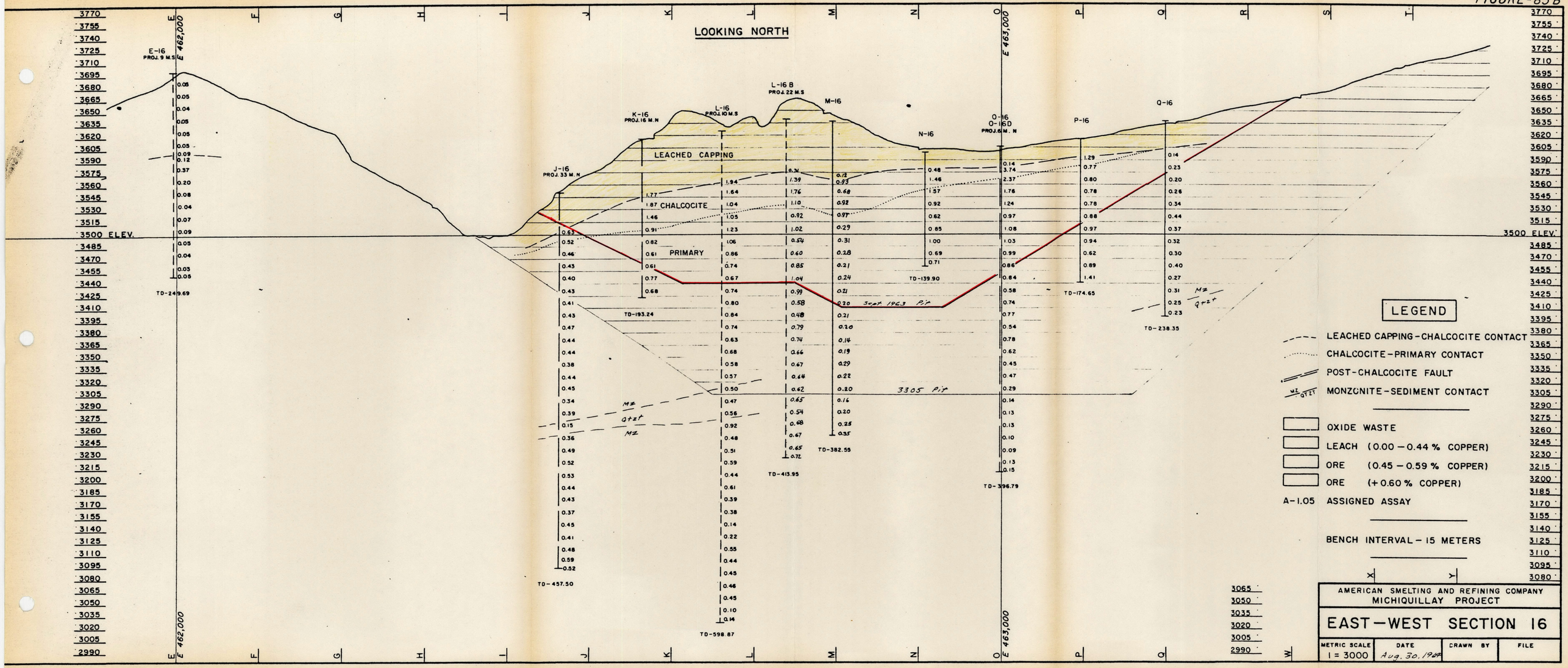
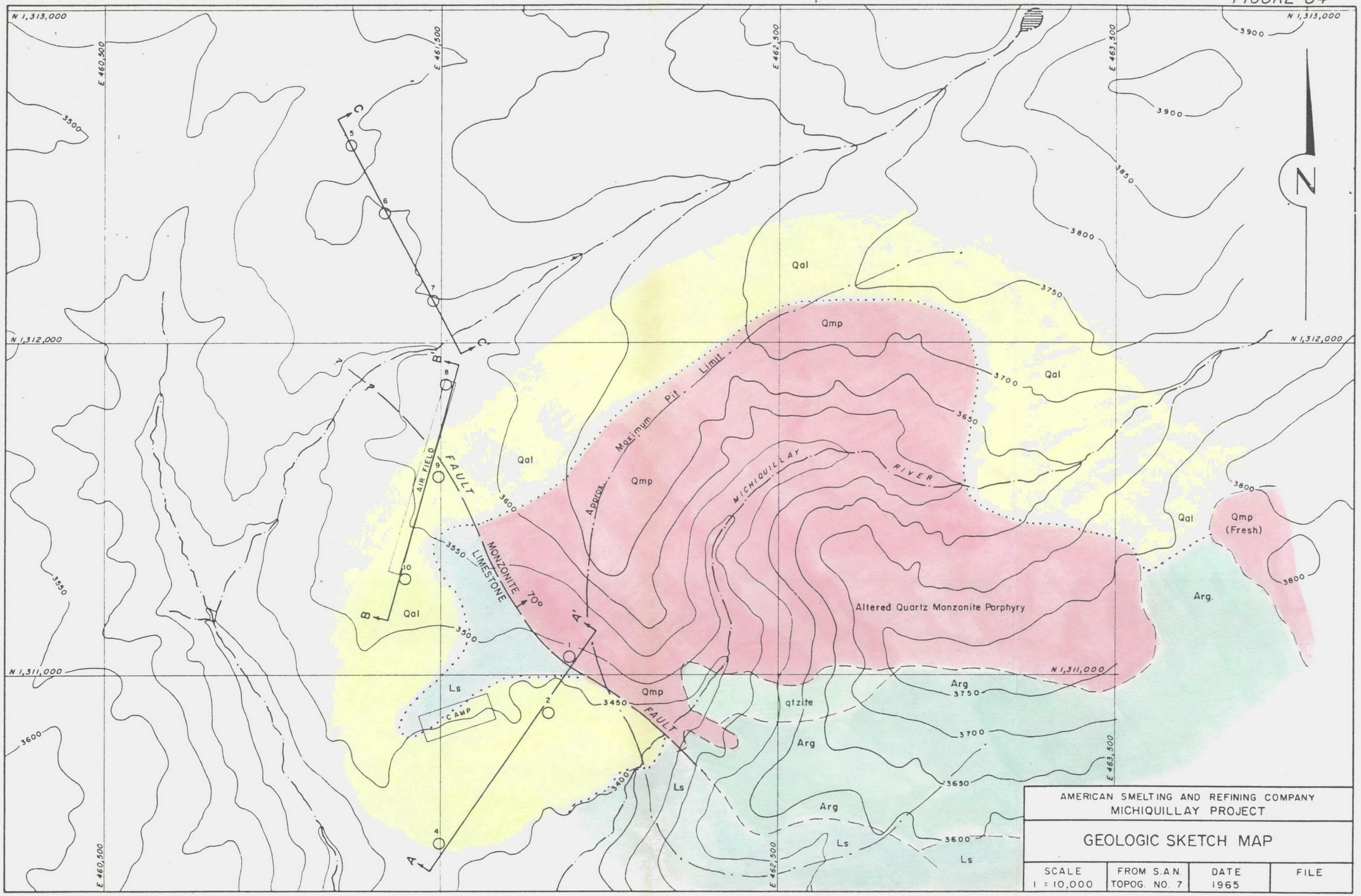

LOOKING NORTH
E 462,000
E 463,000
3500 ELEV.
E-16
PROJ. 9 M.S
TD-249.69
J-16
PROJ. 33 M.N
TD-457.50
K-16
PROJ. 16 M.N
TD-193.24
L-16
PROJ. 10 M.S
TD-598.87
L-16 B
PROJ. 22 M.S
TD-413.95
M-16
TD-382.55
N-16
TD-139.90
O-16
O-16D
PROJ. 6 M.N
TD-396.79
P-16
TD-174.65
Q-16
TD-238.35
LEACHED CAPPING
CHALCOCITE
PRIMARY
Sept 1963 Pit
3305 Pit
Mz
Qtzt
LEGEND
LEACHED CAPPING-CHALCOCITE CONTACT
CHALCOCITE-PRIMARY CONTACT
POST-CHALCOCITE FAULT
MONZONITE-SEDIMENT CONTACT
OXIDE WASTE
LEACH (0.00 – 0.44 % COPPER)
ORE (0.45 – 0.59 % COPPER)
ORE (+0.60 % COPPER)
A-1.05 ASSIGNED ASSAY
BENCH INTERVAL – 15 METERS
AMERICAN SMELTING AND REFINING COMPANY
MICHIQUILLAY PROJECT
EAST–WEST SECTION 16
METRIC SCALE 1 = 3000
DATE Aug. 30, 1964
CRAWN BY
FILE

FIGURE 84



Mi - 2 - D1

FIGURE-85 A

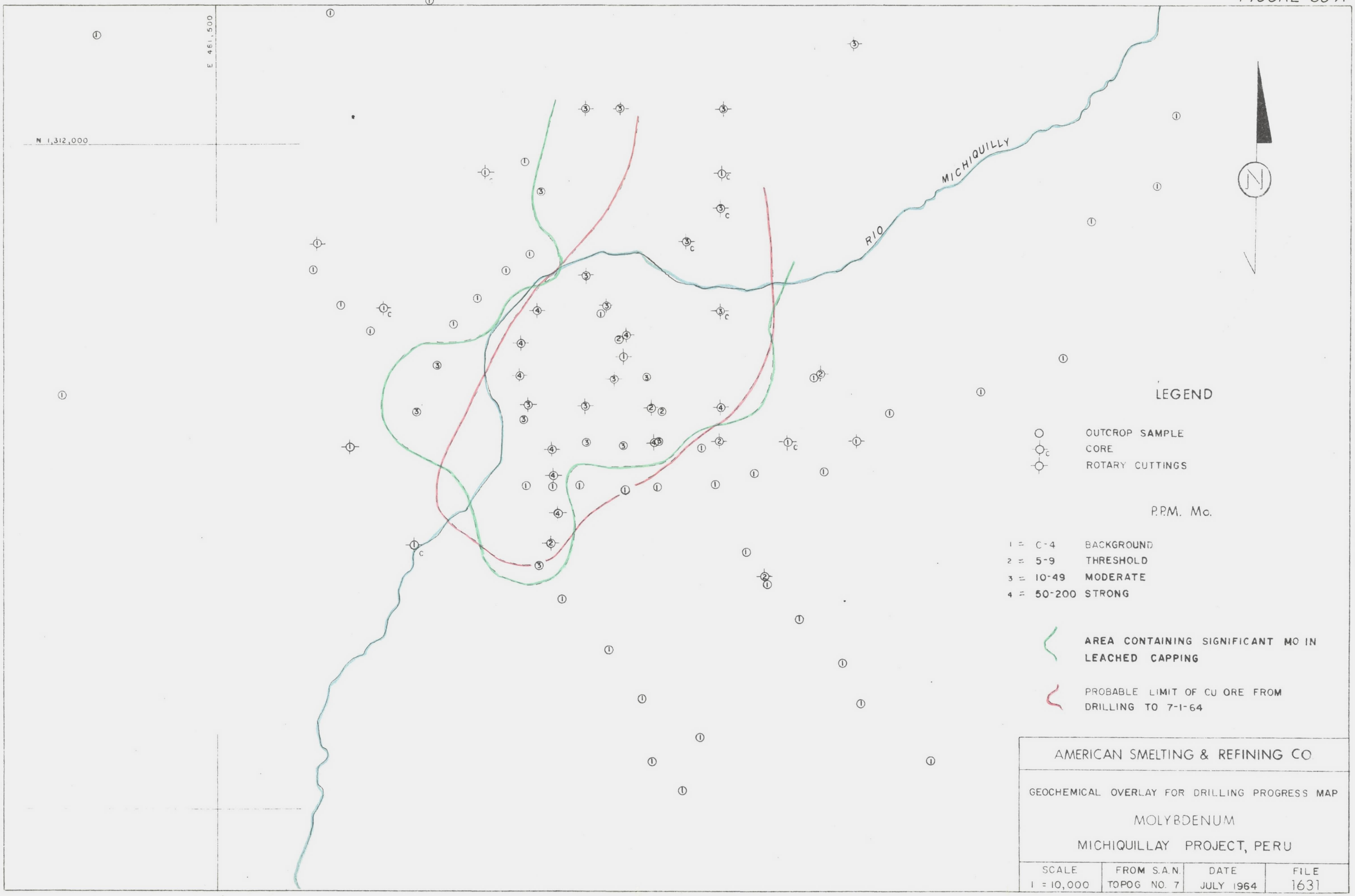
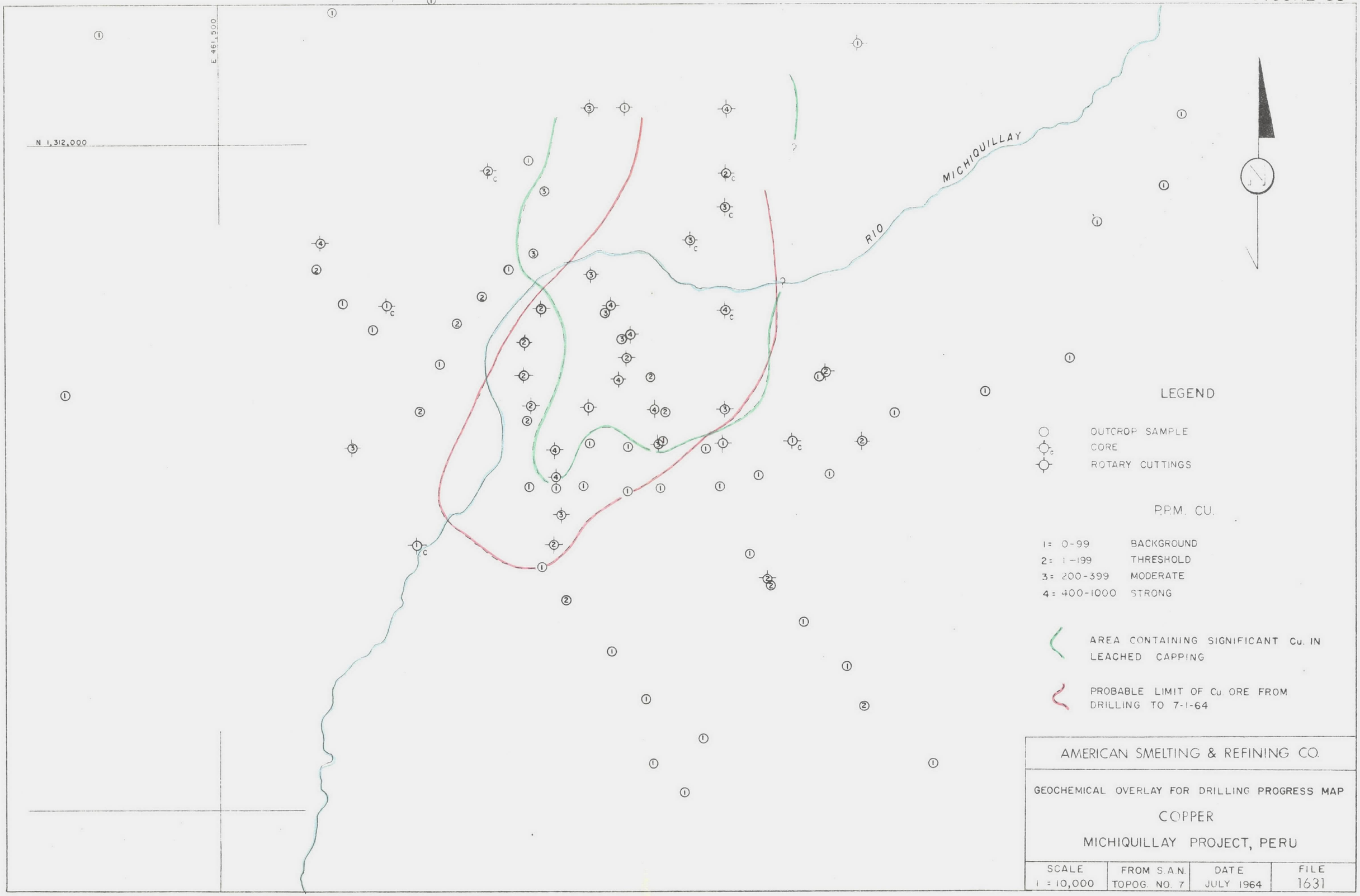
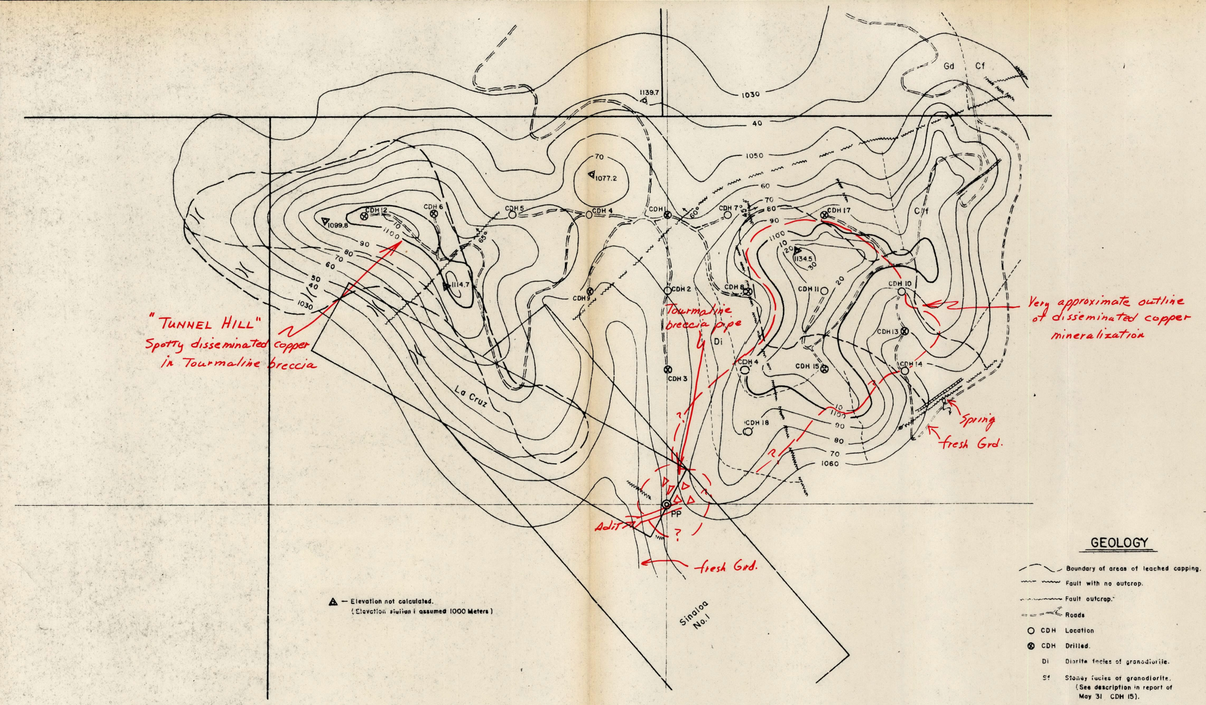

E 461,500
N 1,312,000
RIO MICHIQUILLY
N
LEGEND
OUTCROP SAMPLE
CORE
ROTARY CUTTINGS
P.P.M. Mo.
1 = 0-4 BACKGROUND
2 = 5-9 THRESHOLD
3 = 10-49 MODERATE
4 = 50-200 STRONG
AREA CONTAINING SIGNIFICANT MO IN LEACHED CAPPING
PROBABLE LIMIT OF CU ORE FROM DRILLING TO 7-1-64
AMERICAN SMELTING & REFINING CO
GEOCHEMICAL OVERLAY FOR DRILLING PROGRESS MAP
MOLYBDENUM
MICHIQUILLAY PROJECT, PERU
SCALE 1 = 10,000
FROM S.A.N. TOPOG NO. 7
DATE JULY 1964
FILE 1631

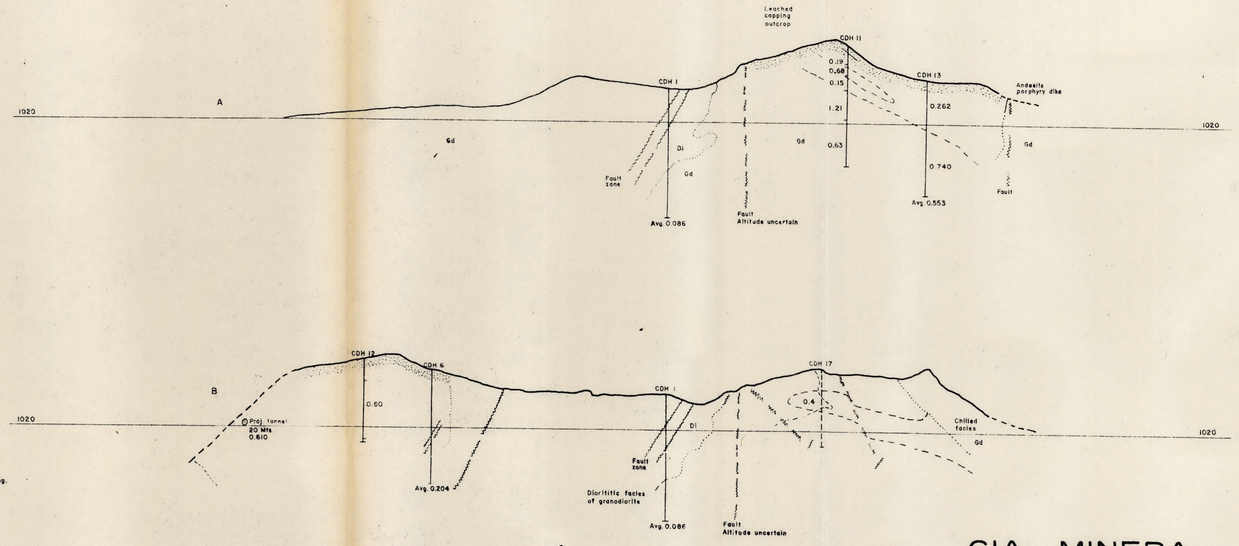
FIGURE 85


E 461,500
N 1,312,000
RIO MICHIQUILLAY
LEGEND
OUTCROP SAMPLE
CORE
ROTARY CUTTINGS
P.P.M. CU.
1 = 0-99 BACKGROUND
2 = 1-199 THRESHOLD
3 = 200-399 MODERATE
4 = 400-1000 STRONG
AREA CONTAINING SIGNIFICANT Cu. IN LEACHED CAPPING
PROBABLE LIMIT OF Cu. ORE FROM DRILLING TO 7-1-64
AMERICAN SMELTING & REFINING CO.
GEOCHEMICAL OVERLAY FOR DRILLING PROGRESS MAP
COPPER
MICHIQUILLAY PROJECT, PERU
SCALE 1 = 10,000
FROM S.A.N. TOPOG. NO. 7
DATE JULY 1964
FILE 1631



GEOLOGY

- Boundary of areas of leached capping.
- Fault with no outcrop.
- Fault outcrop.
- Roads
- CDH Location
- CDH Drilled.
- Di Diorite facies of granodiorite.
- Sf Stoping facies of granodiorite. (See description in report of May 31 CDH 15).
- Andesite - porphyry dike.
- Contact outcrop fairly definite.
- Contact outcrop obscure.
- Cf Chilled facies of granodiorite.
- Mc Gneissic Metamorphic rocks.
- Gd Granodiorite.
- Spring.
- Bulldozer cut.



CIA MINERA DE CONCORDIA

MC'PO DE CONCORDIA
SINALOA, MEXICO

Contour interval: 10 meters Scale: 1 cm = 40 meters

GEOLOGY BY: Webber
1956

MAP NO. 1364

FIGURE-87

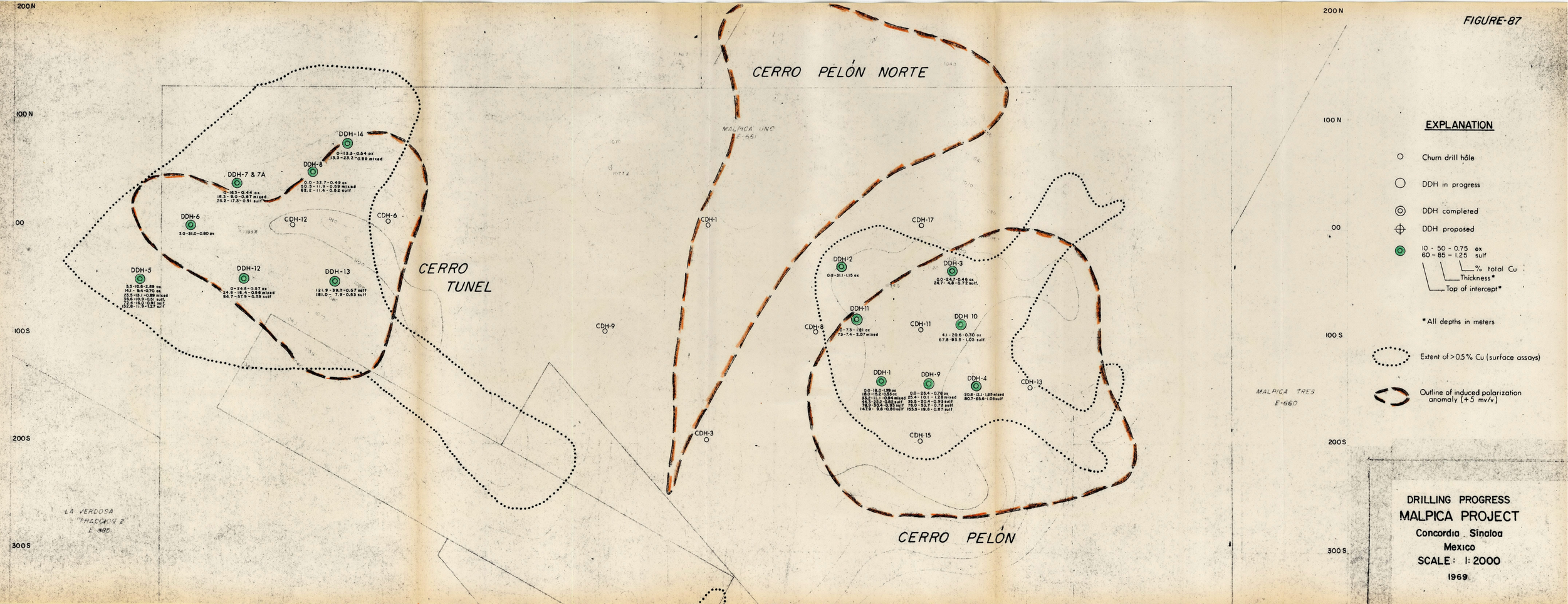
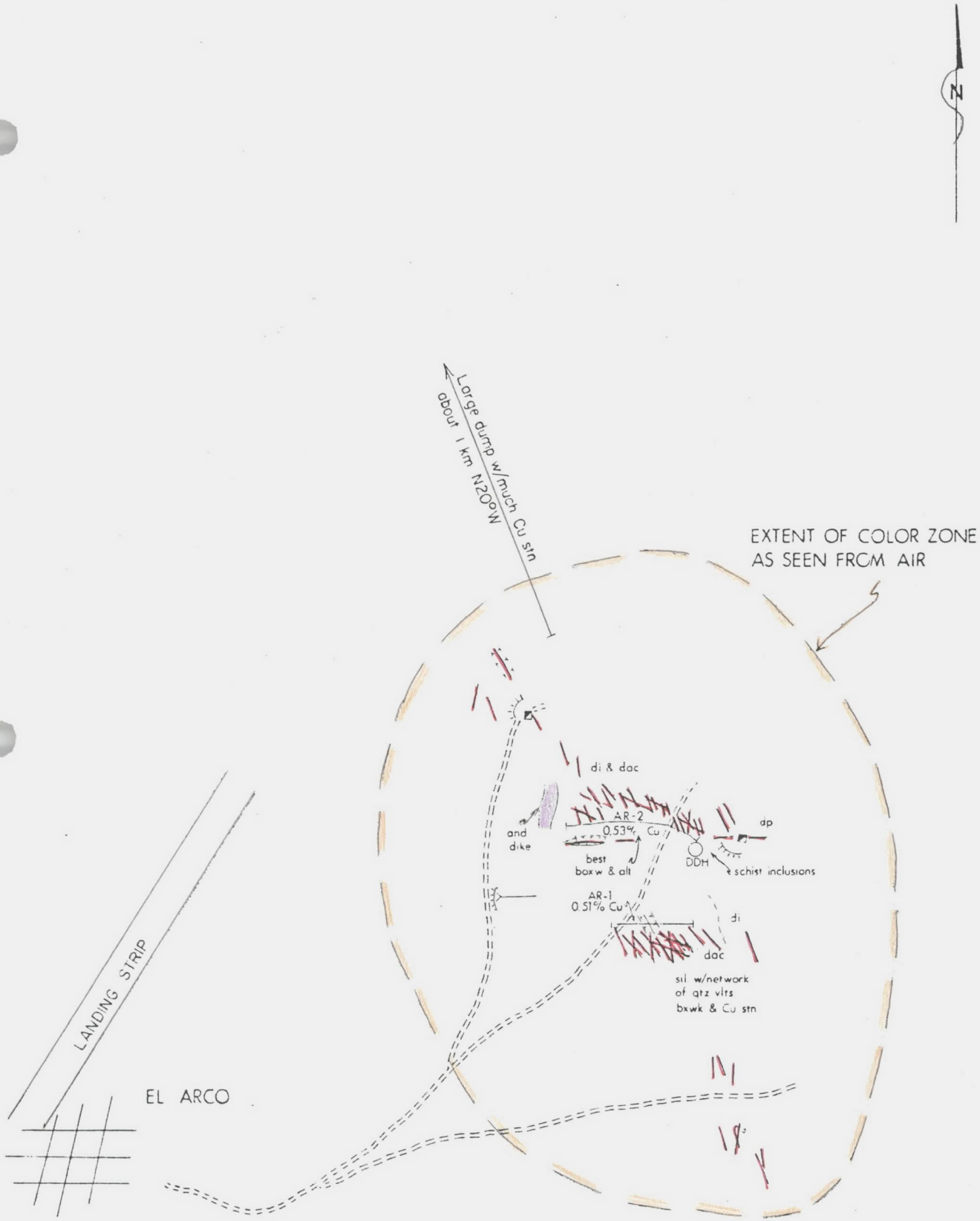

200 N
100 N
00
100 S
200 S
300 S
CERRO PELÓN NORTE
CERRO TUNEL
CERRO PELÓN
MALPICA TRES
E-660
LA VERDOSA
"FRACCION 2"
E-486
DDH-14
0-13.3-0.54 ox
13.3-23.2-0.89 mixed
DDH-8
0.0-32.7-0.49 ox
50.3-11.9-0.69 mixed
62.2-11.4-0.82 sulf
DDH-7 & 7A
0-16.3-0.44 ox
16.3-9.0-0.67 mixed
25.2-17.3-0.91 sulf
DDH-6
3.0-31.0-0.80 ox
CDH-12
CDH-6
DDH-5
3.5-10.6-2.89 ox
14.1-9.4-0.70 ox
23.5-12.1-0.89 mixed
36.6-10.9-0.51 sulf
47.5-10.2-0.91 sulf
57.6-11.9-1.27 sulf
DDH-12
0-24.8-0.57 ox
24.8-16.4-0.56 mixed
41.7-57.9-0.59 sulf
DDH-13
121.9-39.7-0.57 sulf
181.0-7.9-0.53 sulf
CDH-1
CDH-9
CDH-3
CDH-17
DDH-2
0.0-31.1-1.15 ox
DDH-3
0.0-24.7-0.46 ox
24.7-4.8-0.72 sulf.
DDH-11
0-7.3-1.21 ox
7.3-7.4-2.07 mixed
CDH-8
CDH-11
DDH 10
4.1-20.6-0.70 ox
67.8-93.5-1.03 sulf.
DDH-1
0.0-18.0-1.99 ox
18.0-15.2-0.53 ox
33.2-11.1-0.94 mixed
44.3-22.2-0.82 sulf
76.9-30.4-0.93 sulf
147.9-9.8-0.80 sulf
DDH-9
0.0-25.4-0.78 ox
25.4-10.1-1.28 mixed
35.5-20.4-0.93 sulf
76.0-53.7-0.73 sulf
153.5-19.8-0.87 sulf
DDH-4
20.4-21.1-1.85 mixed
80.7-65.6-1.08 sulf
CDH-13
CDH-15
EXPLANATION
Churn drill hole
DDH in progress
DDH completed
DDH proposed
10 - 50 - 0.75 ox
60 - 85 - 1.25 sulf
% total Cu
Thickness*
Top of intercept*
*All depths in meters
Extent of >0.5% Cu (surface assays)
Outline of induced polarization anomaly (+5 mv/v)
DRILLING PROGRESS
MALPICA PROJECT
Concordia . Sinaloa
Mexico
SCALE: 1:2000
1969

FIGURE 88



CROQUIS
del
PROSPECTO EL ARCO
Baja Calif.
Scale: 1" = 1000'

W.E.S. Feb. 1968

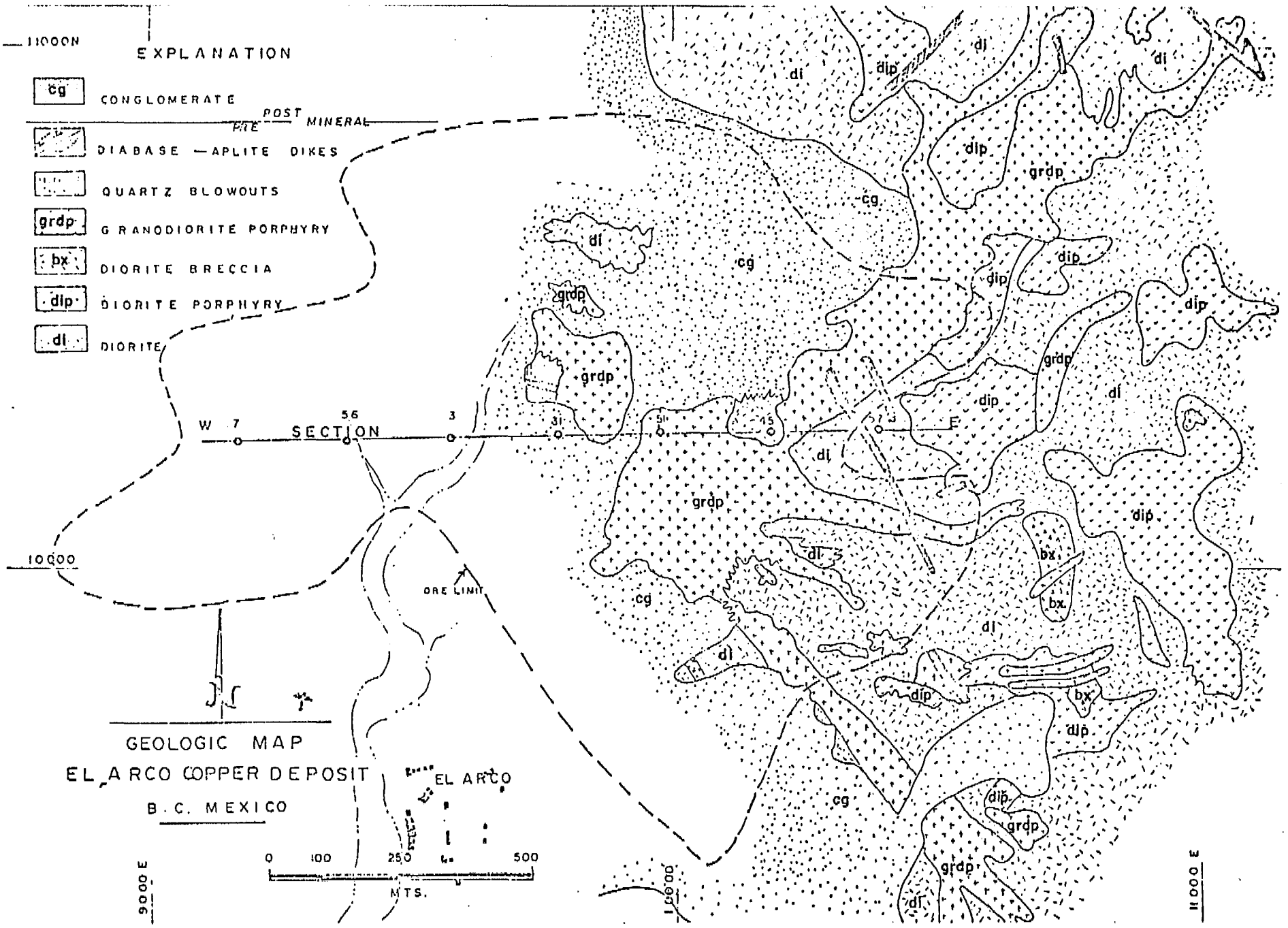


FIGURE-89

By Amador Osaria H. et al

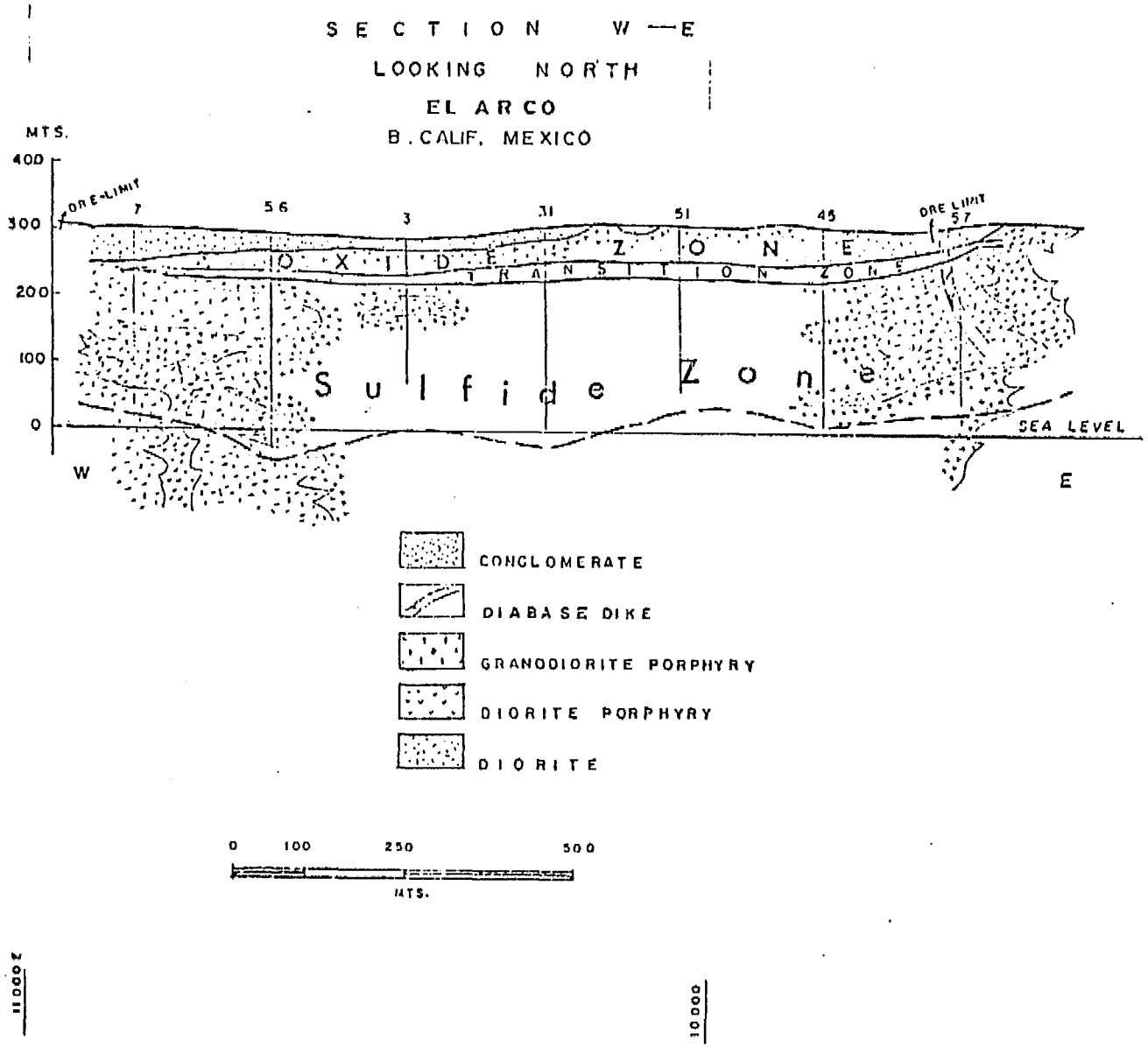
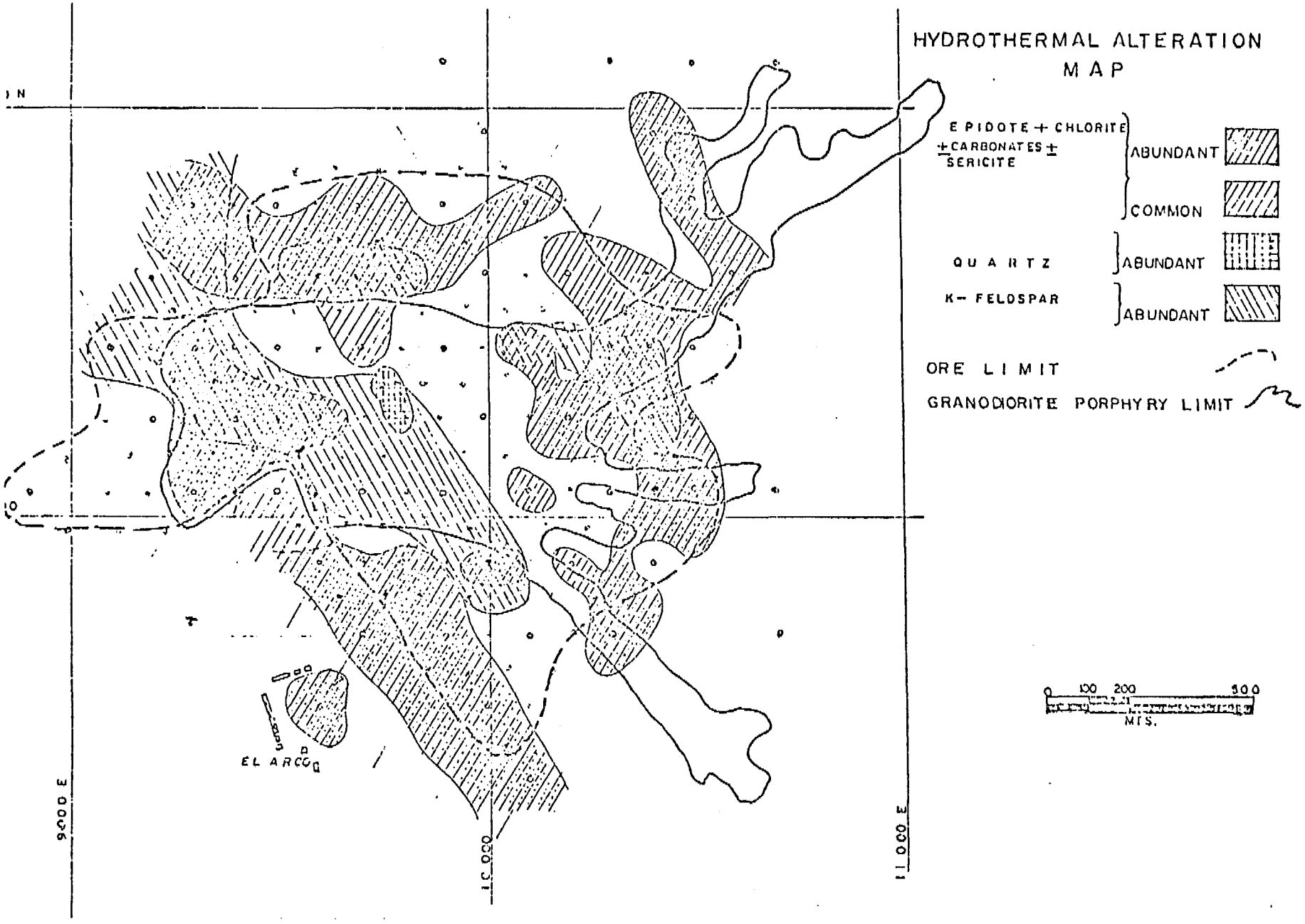


FIGURE-90

By Amador Osaria H. et al



By Amador Osorle H. et al

FIGURE-91

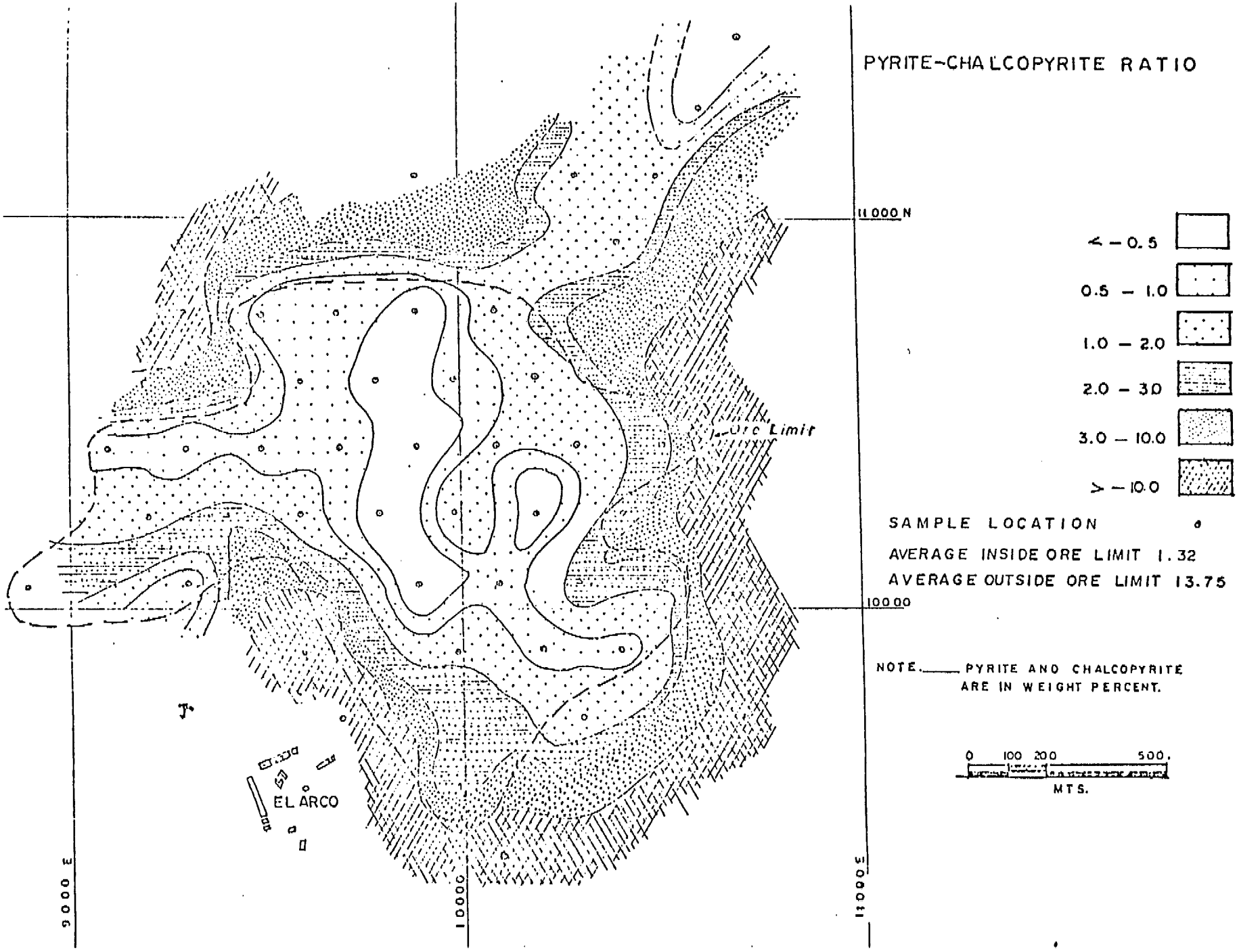
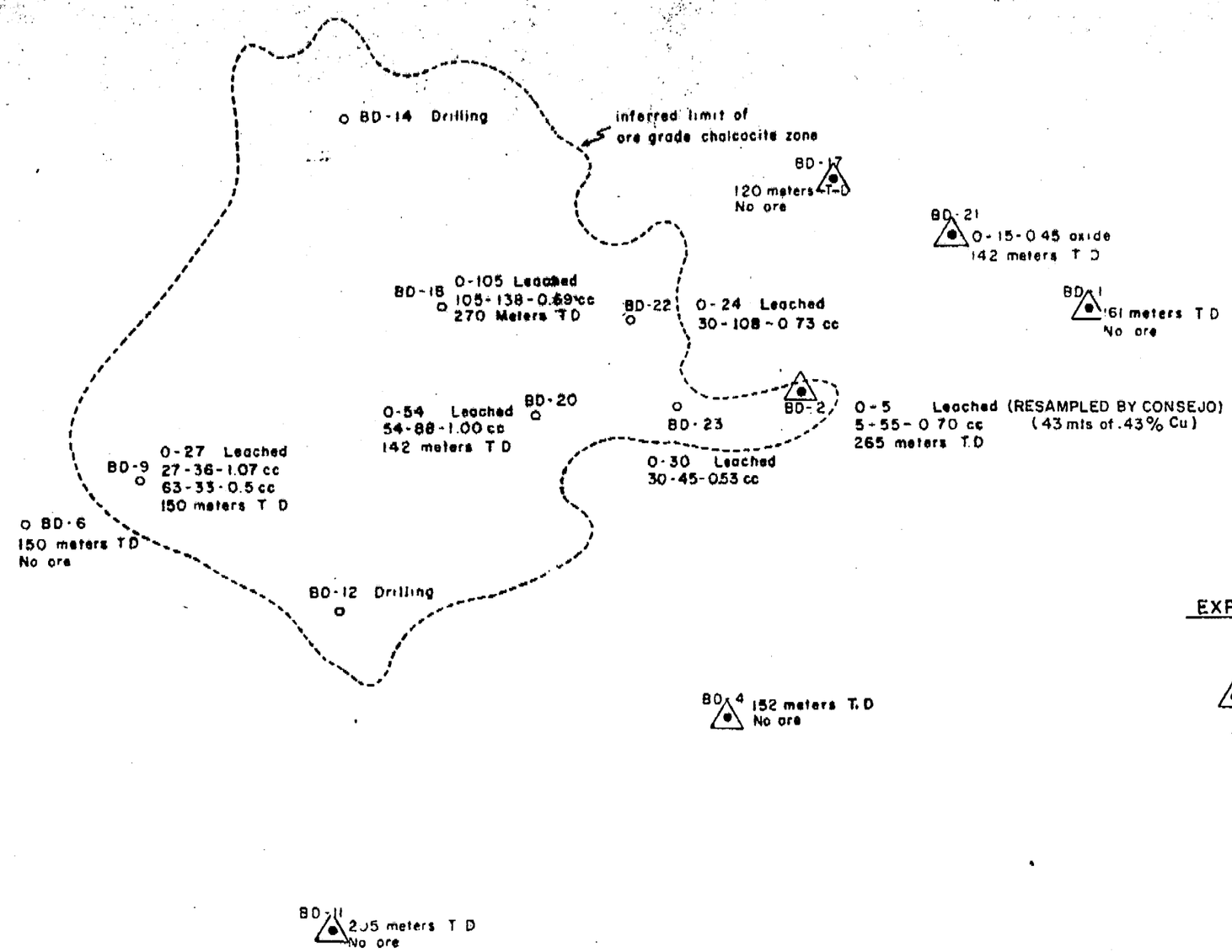


FIGURE-92

By Amador Osorio H. et al



EXPLANATION OF DRILL HOLE DATA

55-88-1.00 cc
From-Intervol-% Cu-Min.

UNITED NATIONS DRILL HOLES

CONSEJO DRILL HOLES

LA CARIDAD PROSPECT

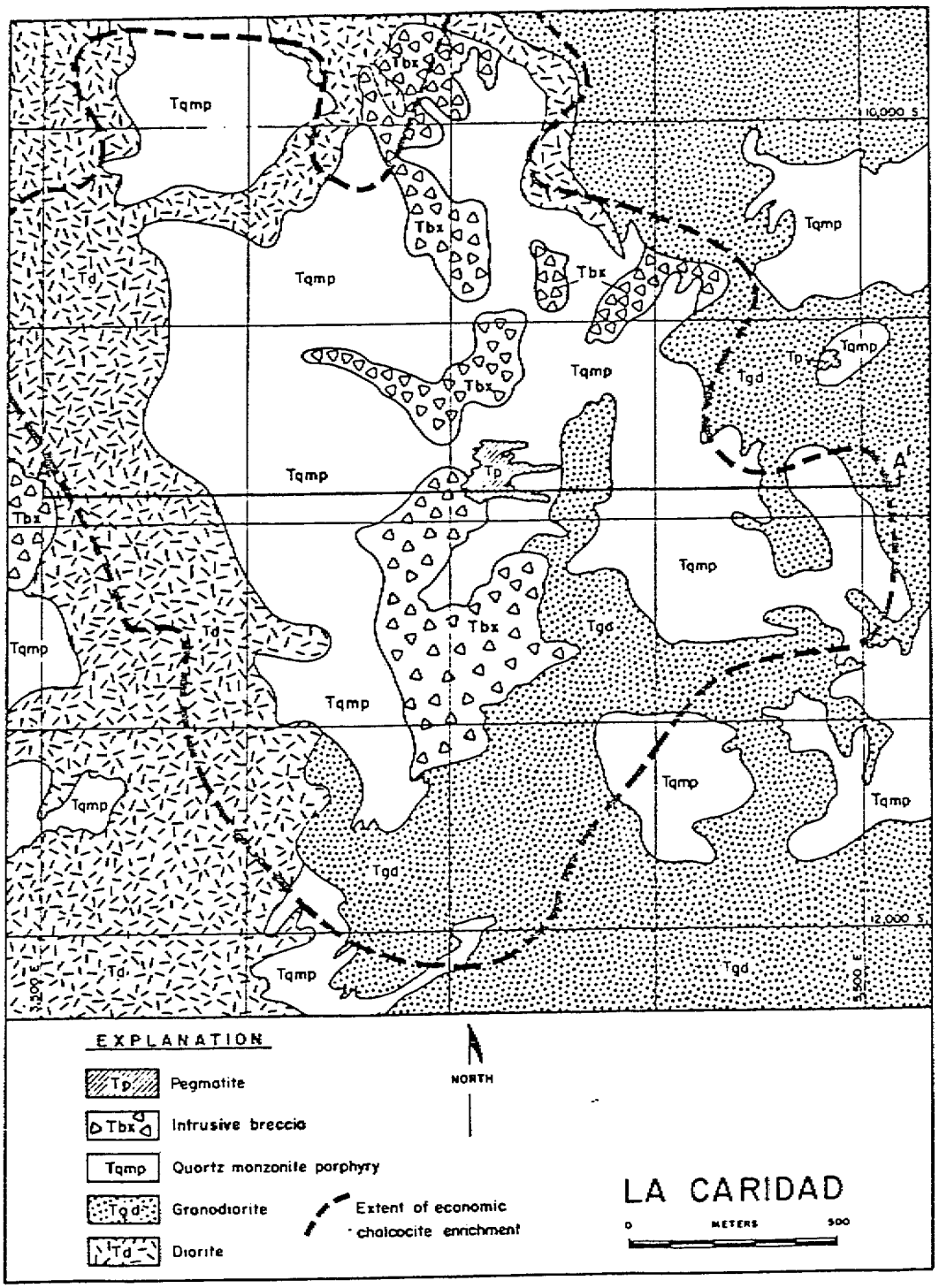
Nacozari, Sonora

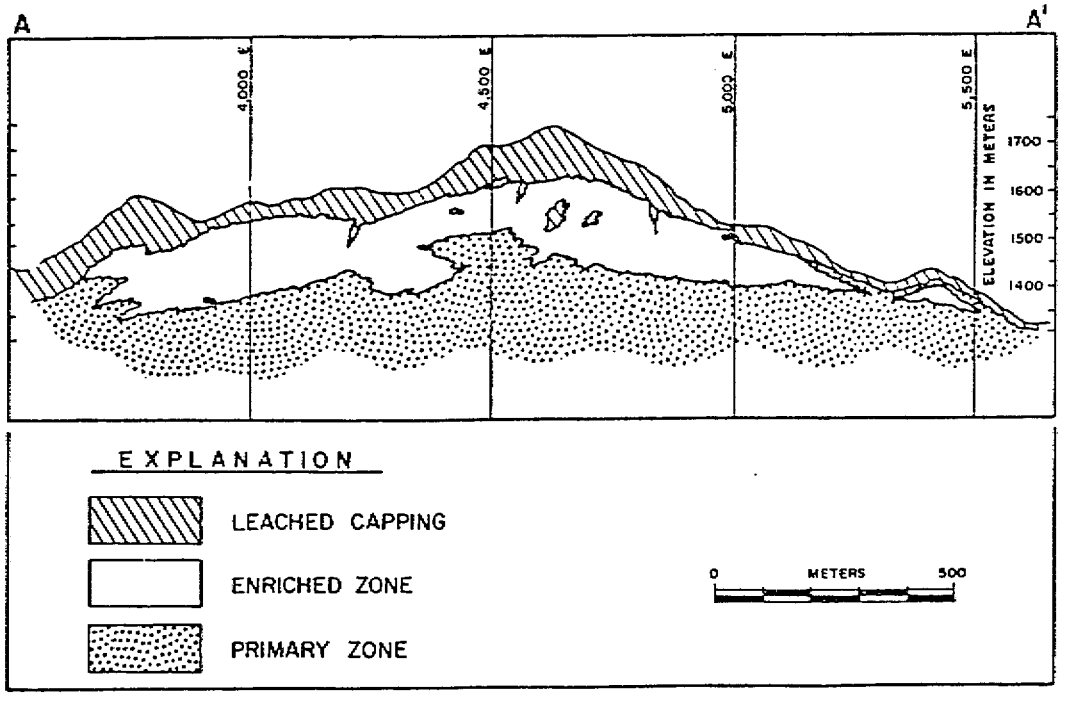
DRILLING PROGRESS AND INFERRED EXTENT OF ORE

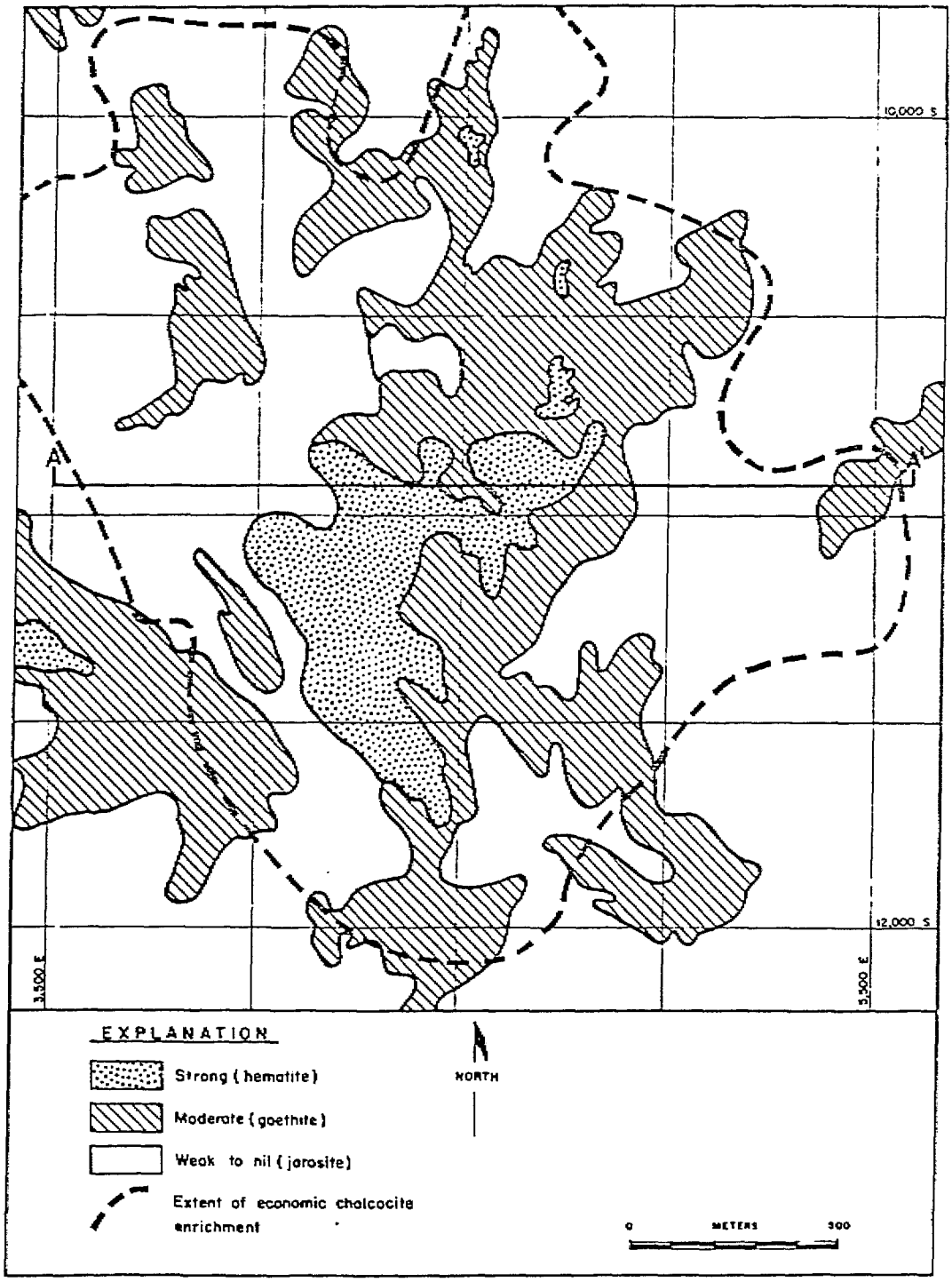
Scale 1:10,000

May 1968

W. E. Saegart


Tqmp
Tbx
Td
Tp
Tgd
A
A'
10,000 S
12,000 S
5,500 E
EXPLANATION
Pegmatite
Intrusive breccia
Quartz monzonite porphyry
Granodiorite
Diorite
Extent of economic chalcocite enrichment
NORTH
LA CARIDAD
0
METERS
500


A
A'
4,000 E
4,500 E
5,000 E
5,500 E
ELEVATION IN METERS
1700
1600
1500
1400
EXPLANATION
LEACHED CAPPING
ENRICHED ZONE
PRIMARY ZONE
0
METERS
500


10,000 S
12,000 S
3,500 E
5,500 E
A
A'
EXPLANATION
Strong (hematite)
Moderate (goethite)
Weak to nil (jarosite)
Extent of economic chalcocite enrichment
NORTH
0
METERS
300