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ASARCO

Southwestern Exploration Division

December 8, 1982

MEMO FOR R. L. BROWN

Some Porphyry Copper History

PART I

As you observed, the history of discovery and development of Asarco's porphyry coppers seems to have fallen largely through cracks in the files. Perhaps "buried" is a more accurate term; anyway, this is the first of a series of memos that you requested, covering both winners and losers, including those prospects which were passed over and later became mines.

1. THE ELY DISTRICT

My first porphyry experience started in 1941 with mapping undercuts in Consolidated's block-cave operation at Kimberly, Nevada, under the direction of Kenyon Richard. The mine, adjoining Kennecott's Liberty Pit, produced 10,000 tpd of 1.0% primary copper ore. Heavy, swelling ground required frequent retimbering. To reach an undercut it was sometimes necessary to crawl under one or more partially crushed 14" caps. But the operation was profitable at 12 cent copper.

This was one of the first porphyry coppers to be mined by large scale open pit methods. Production from 1908 through 1974 (including underground ores) amounted to around 350 million tons averaging just under 1.0% Cu. Skarn type ore accounted for 20-25% of the total. The mines are now inactive, the last to shut down being the Ruth Pit in 1978.

The District encompasses six more-or-less separate concentrations of copper strung out along an E-W trending zone of alteration 7 miles in length (Fig.1B). The pattern resembles that in some other districts, such as Silver Bell where a deep-seated zone of structural weakness apparently

focused alteration-mineralization along a narrow belt bordered by unaltered rocks, including monzonite porphyry.

By 1941 essentially all chalcocite-enriched ores (Kimbley, Ruth) had long been mined out along with the capping. Then existing outcrops over the unenriched deposits (Emma, Morris-Brooks, Veteran) consisted largely of jasperoid ---- supergene silica mingled with the oxidation products of mineralized skarn. Although Blanchard [1] investigated capping over chalcocite at Ruth, his brief comment does not include any reference to the limonites. He concluded that, "...secondary enrichment was of less importance than previously supposed; and that a number of the ore bodies were primary ore shoots whose tops had scarcely been reached by oxidation."

The old mine produced 2-3% Cu on cc.

Exploration (churn drill) was guided by structural projections based on underground and surface mapping and by features in outcrop, such as remnants of oxidized skarn with copper silicates. The Morris-Brooks, which later became the Tripp Pit, consisted of skarn with 1.25-1.50% Cu cut by porphyry dikes carrying .20-.30% Cu. Having successfully caved the Emma, Consolidated management attempted to mine the Morris-Brooks likewise ---- with disastrous results. The tough skarn ore "hung up" above drawpoints in huge blocks while the low grade porphyry ran down through the chutes like dry sand. Long hole drilling and blasting of the skarn boulders was tried without success; however, the miners kept the mine alive for a time by circumventing draw control. That is, when the grade from a draw point dropped below the cut-off, a string of cars would still be loaded, but not quite full. The train would then be routed under a chute running ore grade and each car topped off providing "salt" in the grab sample which would be taken from the top of each car at the dumping station. The source of the resulting large discrepancy between mine and millhead grade was eventually uncovered and the shift bosses responsible went "down" with the mine. Shortly thereafter, Kennecott acquired Consolidated's ground and began open pit mining of the Morris-Brooks (Tripp) and Veteran areas. As you have noted in "Bridging The Gap,"* during those

* Copper Club, supplement to American Metal Market, Feb. 5, 1980, p. 18A.

years truck haulage being more flexible than rail was adapted to open pit mining, making possible the exploitation of relatively small porphyry deposits.

Back in the '40s and earlier, hydrothermal alteration was recognized as a characteristic of "disseminated" copper occurrences in porphyry, but the existence of multiple zones, each with specific mineral assemblages, was still undiscovered. The porphyry model had yet to evolve.

In a rather recent paper by Westra on the Ely District (2) potassic alteration with plus .40% primary copper is portrayed as a tabular zone, overlain by erosional remnants of phyllic alteration (Figs. 2 and 3).

2. SILVER BELL

Late in 1947, the Company decided on a limited program of check drilling in the Oxide deposit at Silver Bell. Having been assigned direction of this project, I found that gathering information on drilling and sampling practices was a plausible reason for visiting many of the S.W. porphyry mines. This brief survey led to the somewhat pessimistic first impression that "The Old-timers had found them all" ---- since essentially all were in mountain ranges, well exposed by erosion. However, it was evident that porphyry coppers offered easier-to-hit targets, due simply to their large size; also, that pervasive alteration-mineralization, although sometimes difficult to recognize on weathered rock surfaces, was a characteristic feature which could, if identified, provide potentially valuable leads.

As with most porphyry copper districts discovered prior to 1940, mining of outcropping oxidized ores led eventually to the secondarily enriched, disseminated sulphides. Around 1909 various companies undertook churn drill mainly Seely Mudd exploration, probing the full length of the alteration zone, but concentrating primarily on the El Tiro and Oxide areas. While several million tons of 1.5% Cu were found in the latter, poor mill test results discouraged development. Asarco acquired control in 1915, including a smelter at Redrock. Sasco Production of direct smelting ores from the El Tiro area continued intermittently until 1930.

The district remained dormant until the spring of '48 when it was invaded by surveyors, churn drillers and geologists. Incidentally, the drilling to test the validity of earlier results was planned by the Western Mining Dept. as a "winter project" with tents to serve as living quarters. However, with the support of the local manager, A.E. Ring, we built and fully equipped a quonset camp sufficient for 18 men for the then considered extravagant outlay of $60,000.00. In camp operation, it was soon discovered that with cooks, dependability varied inversely with ability: good ones were gone with the first paycheck; bad ones would stay till fired.

The results of interspaced holes drilled in the Oxide deposit tended for the most part to support the validity of samples from adjacent earlier holes. A few additional holes were put down in the Oxide and a reserve of 13 million tons at 1.22% Cu with a 1.5 w/o ratio was calculated. This was concluded to be a marginal proposition by Western Management at the then forecast price of 20¢ copper. A subsequent calculation including El Tiro produced a much larger tonnage (32 million) but lower grade (0.89% Cu). Silver Bell might have remained "in limbo" for some time, but the Federal Government came up with a floor price of 24½¢ in 1951, and the mine went into production 3 years later at a rate of 7000 tpd.

In 1941, Harrison Schmitt [3] and assistants undertook an extensive study of Silver Bell ---- producing a large (old USGS style) folio of maps showing principally rock type and structure. These provided a base for outcrop mapping and the check drilling which started in the spring of '48.

Blanchard [4] made a study of Silver Bell outcrops in 1923, stating that "although the seal brown to maroon color is distinctive enough to serve in a broad way for separating possible ore areas from entirely hopeless ones, clear-cut color distinctions for the whole area do not exist." Later he wrote [5] "... although the maroon-colored limonite has proved to be a dependable guide to enriched chalcocite ore in alaskite prophryr (monz. porphyry), in the adjoining coarse-grained but otherwise mineralologically

almost identical alaskite it was found to be the characteristic limonite color over very low grade pyritic areas." While Blanchard's observations were in some respects helpful, some of his conclusions were questionable.

Early in our work we found that the color of a powdered limonite (produced by scratch) was more reliable than that of a weathered surface, as well as a more practical means of identification than texture or boxwork. Somewhat subtle color contrasts in outcrop areas eventually were detected ---- more dark brown to maroon over ore grade, fading to pale brown with yellowish tints over low grade, or waste (indicated by old drill results), demonstrating that the darker color tones reflected a greater abundance of limonite-after-chalcocite.

In the Young America (Oxide area) Blanchard suspected salting of the churn drill samples as his appraisal of the outcrops indicated a lower grade than the 1.50% Cu of the chalcocite blanket.

Results of our outcrop studies (which were to some extent in agreement with Blanchard's) suggested that additional potential in the Oxide was limited to minor extensions of known ore [6], and that at El Tiro, relatively large, untested areas of favorable capping were present [7]. However, a much greater potential (in the Oxide area) was envisioned by Paul Kerr [8], based on alteration studies conducted concurrently with our work. His concept of hydrothermal alteration, developed at Santa Rita [9], rested on four "stages" ---- (1) fresh biotite, (2) chlorite, (3) hydro-mica, and (4) sericite-clay-quartz assemblages ---- (3) and (4) being favorable, regardless of limonite content or mineralogy. Subsequent drilling at Silver Bell not only failed to verify alteration as the principal guide to ore, but provided evidence that at least part of the sericite in outcrop was derived from supergene alteration of biotite.

Later, outcrop mapping was continued to encompass essentially the full length of the zone of alteration-mineralization (Figs. 4 & 5). It was then

evident that both copper* and iron sulphides accompanied all significant alteration and that the entire zone was a mineral occurrence within which the known ore bodies were simply concentrations of copper (coincident with closer spaced veining) ---- of sufficient size and grade to be mineable under a specific minimum copper price.

Additional reserves were found mainly as relatively low grade secondary enrichment in a westerly continuation of the Oxide ---- under an area of sparse limonite-after-chalcocite, and as primary chalcopyrite ore in skarn** adjacent to El Tiro. Existing open pit perimeters and 1950 ore outlines are superimposed on the Mineralization Map (Fig.5). In general the better grade chalcocite ores mined were beneath areas classified as "moderate to strong," and relatively low grade beneath "pyritic" areas. Alteration in both cases was rated as "moderate to intense." Subsequent detailed investigations provided new light on various geologic aspects, including the occurrence of potassic alteration and its relation to hypogene copper mineralization. The most comprehensive study to date was carried out by Graybeal on the El Tiro area [11].

3. TOQUEPALA

Our work on Silver Bell was interrupted in the spring of '49 to undertake an investigation of the Toquepala prospect in Southern Peru under the direction of H.A. Kursell. A legal battle with Cerro de Pasco had shortly before been decided in Asarco's favor. At this time churn drilling was in progress at Quellaveco which Asarco had acquired two years earlier. In reviewing Cerro's files (purchased by Asarco) we found that 31 of their diamond drill holes at

* Hypogene copper content of altered intrusives ranges between .01% and .50%.

** Steven Von Fay's investigation, which included retrieval of old underground assay data buried in dead storage, led to this discovery.

Toquepala indicated around 65 million tons of 1.75% Cu amenable to open pit mining. Surprisingly, this was considered marginal and option payments were discontinued ---- providing the opportunity which Kursell grasped by "rescuing" the unhappy optionors.

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Asarco drilling subsequently established a reserve of 421 million tons of 1.04% Cu at a stripping ratio of 3:1. Plans were completed for production at a rate of 25,000 tpd, contingent on obtaining an EXIM bank loan; however, the loan was turned down (1952). In 1955, three other companies (Cerro, P.D. and Newmont) were brought in along with another property, Cuajone, and a loan was approved. Asarco came out with 57.75% of the stock in the new company, S.P.C.C.

During negotiations, P.D. representatives expressed considerable skepticism as to the accuracy of the drill sample results, particularly the Cerro holes at Toquepala which averaged around 25% core recovery. Even though casing in the Cerro holes has been lowered at 5' intervals through the chalcocite zone, providing acceptably accurate sludge samples in our judgement, a check sampling program was carried out. This involved putting down a churn drill hole along side each of 10 Cerro DD holes and raising on 5 Asarco churn drill holes. Presumably, P.D. expected to improve its bargaining position if the check samples ran relatively low. The results (12), however, came out remarkably close ---- averaging within 0.005%, although hole-to-hole comparisons showed differences of as much as 25%. The raise samples (channel) averaged within 0.015% Cu of the churn drill results. Bulk samples from the raises averaged 5.0% higher than the churn drill samples.

Milling started in 1960 at a rate of 30,000 tpd. Head grade through 1972 averaged 1.28% Cu, slightly higher than forecast.

Our work in 1949 consisted principally of outcrop mapping ---- by the somewhat tedious method of plane table and alidade, using mules for transportation. Of course, the main emphasis was first on correlation of Cerro's

drill results with limonites in the leached outcrops above. It was found that their first 6 holes were collared in two areas of copper-stained outcrops which occurred in less altered rock on either side of the ore zone. The next hole, situated precisely halfway between, hit the heart of the high-grade chalcocite body.

Outcrops over the high grade in general were observed to contain far more goethite-jarosite than hematite ---- a disturbing situation to say the least; however, as mapping progressed, a thick hematite-rich layer in the capping was found on Upper Spur and West Ridge. These erosional remnants of a high-lying horizon in the capping were interpreted as representing the end of the first cycle of enrichment [13], accounting for the predominance of goethite-jarosite in the capping below (Fig. 6). Two cycle enrichment history was likewise evident in the capping at Quellaveco, 15 kms to the north.

Our studies resulted in the conclusion that Cerro had delimited the high-grade, but exploration possibilities for moderate grade ore were good [14]. This assessment proved to be valid; however, some rather large discrepancies turned up between the "favorable ground" pattern and the ore body outline as drilled out (Fig.7). The most prominent of these being the north centrally positioned, large uncolored area. Considerable interior waste rock was drilled there, but over 50% of the area contained substantial intercepts running over 1.0% Cu as chalcocite ---- beneath pervasively altered but very lean-looking leached outcrops. Obviously, capping interpretation can be hazardous.

Going back to '49, a churn drill arrived on the property before we had completed the mapping. To save time in site preparation, it was set up on a gravel bed in the bottom of Toquepala Quebrada ---- a location we hoped would fall within the perimeter of the main breccia pipe, but the drill cut pebble breccia with low-grade primary all the way. Shortly, thereafter a rather

caustic communique was received from Kursell: "With all that high-grade around, just how did you manage to locate our first hole in waste?"

4. SAFFORD

Early in 1950, attention was drawn to the Safford District when Consolidated Coppermines started drilling near Lone Star Peak. Generally weak, but locally moderate porphyry copper type alteration-mineralization was noted in leached outcrops of limited extent at Lone Star and elsewhere along a WNW trending belt 10 miles in length. Reconnaissance mapping (15) determined that these rather small showings in volcanics and intrusives occupied a window in post-mineral rocks (valley fill and volcanics), and thus could represent portions of extensive zones under adjacent cover (Fig.8). However, probable limits were found, except at Lone Star where relatively strong alteration-mineralization was exposed along the base of the lava cover.

Near the westerly end of the window, some copper stain occurred in rather fresh looking andesitic volcanics which were cut by weakly altered porphyry dikes. This somewhat unpromising appearing prospect later (1958) became the site of the Phelps Dodge discovery, the Dos Pobres ore body containing 400 million tons of .72% Cu, occurring principally as chalcopyrite and bornite. However, according to published data (16), the first 50 million tons mined could average over 1.30% Cu. The dikes at surface expand downward into a laccolithic mass, but the majority of the copper occurs in the andesite as fine grained hypogene sulphides.

After the discovery became known, and during a prolonged lull in the drilling, we managed an unauthorized visit to collect samples from the outcropping andesite. It was found that this fresh-appearing, dark green to black rock was, in fact, intensely altered with 0.1% to 0.2% Cu, mostly as very finely divided chrysocolla. Hypogene zoning in the vertical range then seemed the only explanation for the underlying ore-grade mineralization.

But, as portrayed in a published paper [16], the cylindrically shaped ore zone does not reach the surface, but terminates upward against the post-mineral Butte fault (a major structure which we had overlooked) with no decrease in grade (cross-section, Fig. 10). Thus, apparently only low-grade fringe mineralization was exposed in the outcrops, even though a plan map (Fig. 9) shows the deposit to be located north of the fault sub-outcrop. A larger scale geologic plan provides no indication of the ore pipe, or its location, and a section across the fault is not included, presumably to avoid drawing attention to exploration possibilities down dip, beyond P.D. property limits.

Results of a test cave block on the 2500 (elev.) level indicated that the ground is too firm to be caved without blasting. In the past year development work was suspended, due to the weak copper market.

Kennecott acquired the adjacent Lone Star prospect in 1956 and carried out extensive drilling and underground work over several years, resulting in an indicated tonnage of 800 million of mixed oxide-sulphide grading .55% Cu, plus 300(?) million tons of .60% Cu deep primary. The property has been idle since the completion of an in-situ leach test at 3000' depth on the primary mineralization.

5. LAKESHORE

Back in 1950 the Lakeshore prospect, located on Indian land at the foot of the Slate Mountains, was well known as a copper oxide occurrence in skarn. As exposed by small-scale open pit mining in previous years, the steep-dipping ore bed varied from 20 to 70' wide over a length of 900'. On the east the skarn was bounded by quartzite which was in fault contact with unaltered granite on the pit's east side (Fig. 11). Barren appearing andesite overlain by alluvium, formed the west wall of the pit. Lacking evidence of an associated porphyry intrusive, it was concluded that the deposit was granite-contact related ---- with little exploration potential, since possible continuity on strike and at depth had already been drill-tested by the USBM with less-than-favorable results.

Subsequently, a large number of exploratory holes were put down by various groups, the deepest drilling being by Callahan-Shattuck Denn in 1967. This latter program was based mainly on magnetic anomalies south and southeast of the pit. One hole west of the pit cut a few short intercepts of +1.0% Cu as oxide in skarn at around 500'. Two others in the area failed to reach bedrock at 1000'. We examined the property at that time as a possible joint venture, but did not find sufficient reason to recommend action (17).

In 1962 El Paso Natural Gas acquired control and reactivated a salt-roast plant, producing native copper. In search of more skarn ore they drilled relatively deep and eventually discovered a substantial sized, enriched porphyry copper deposit on the west (Fig. 11). Reserves (1970):

Sulphide (excluding skarn)	- 240 mil. tons at	.70% Cu
Skarn	- 23 mil. tons at	1.69% Cu
Oxide	- 200 mil. tons at	.71% Cu
Oxide (1.0% Cu cutoff)	- 28 mil. tons at	1.50% Cu

As noted in "Exploration Lessons from Near-Misses and Failures"*, the porphyry intrusive was completely buried, but the fringe of its zone of alteration-mineralization was exposed in the outcropping volcanics. They appeared, however, essentially barren and this vital clue went unrecognized.

Hecla acquired a 50% interest in exchange for one million shares of their stock and commenced production in 1975, mining around 15,000 tpd, combined oxide (in andesite) and sulphide (in skarn) ores. Considerable difficulties (plus severe dilution) were encountered in cave-mining of the skarns (which were to provide acid for vat-leaching of the oxide). Large operating losses were sustained and by late '77 Hecla, near bankruptcy, closed the mine and forfeited their interest in the lease. Later, Noranda secured an option from the Papagos and commenced producing cement copper from oxide ore late in 1980.

* Exploration Conference, 1975.

Current production is around 6000 tpd of 1.0% acid soluble copper.

6. MINERAL PARK

Turquoise hunting indians were the first to prospect the leached outcrops of this porphyry copper-moly deposit. It lies within the Wallapai Mining District which, through 1946, produced $24 million in gold, silver, lead and zinc. During this period, the Mineral Park area was explored for copper; but only minor amounts of chalcocite and lean primary mineralization were encountered in several adits and shafts. also 4 or 5 old CD holes – no records

An examination of the outcrops and accessible workings was made in 1950. No sizeable concentrations of hematite were observed in the capping in a mile wide area of relatively strong alteration-mineralization. It was concluded that the capping reflected the generally low grade primary cut in the adits (.05% Cu, .03% Mo) and thus exploration possibilities were unattractive [18].

The prospect was again examined late in '55, following rumors that Bear Creek had pulled out after completing 15 drill holes. We spotted 7 of their drill sites in the field (Fig. 12); otherwise nothing was found to alter our previous leached outcrop interpretations and opinions as to potential [19]. Some time thereafter, Duval moved in and started drilling on the slopes of Ithaca Peak. Excerpt from an article in the Mining World, July 1959: "In view of the large size of the stock and the extent of known mineralization, many engineers and geologists felt that Kennecott's work had not eliminated all favorable areas; thus, the Duval program of drilling." It was subsequently learned that at least one geologist (ex-Bear Creek) "felt that way" since he had presented Duval with Bear Creek's drill results. With the exception of 2 holes angled under Ithaca Peak (Fig. 12) containing substantial intercepts (300' and 142') of chalcocite running .6 and 1.0% Cu, respectively, all were submarginal. Presumably the decision makers in

Total prod: 102 M Tons – .30% Cu, .027% Mo

Kennecott considered the potential too small to warrant further work.

By 1961 Duval had drilled out 58 million tons of open pit ore grading 0.55% Cu, 0.04% Mo. The bulk of this was mined out by the end of 1979, at which time there was 50 million tons of 0.20% Cu and 0.05% Mo remaining, according to a publication [20]. As shown in this paper (Figs. ~~14~~ 13 & ~~15~~ 14), the ore is in the form of a crudely shaped donut, enclosing a low grade core. Incidentally, the paper provides essentially no data on supergene enrichment ---- the process which in effect, "created" the ore deposit.

As for our "broken picks," the predominance of goethite-jarosite over hematite in the leached outcrops above chalcocite ore probably was due to a high py:cc ratio [21] in the ore from which the limonites were derived (around 10% pyrite was observed in ore-grade mineralization during a "post-mortem" visit to the Mineral Park pit). Or, the outcrops may represent an erosional surface between two cycles of enrichment (as at Toquepala). The latter explanation is less plausible, as the chalcocite blanket tends to conform with topography and is thus quite likely first cycle.

Finally, it should be noted that the metal market played a large role in the operation's viability. In 1961, at the start of mine development, the ore was near marginal, but by 1970 increased demand for copper and moly had essentially doubled its gross dollar value; by 1980 the copper price had moved up 50% and moly 500%, which more than offset the decline in Cu head grade. The subsequent sharp price trend reversal caused suspension of operations in December 1981.

7. CHRISTMAS MINE

This copper-bearing skarn occurrence, around the periphery of a small diorite stock, had long been known to geologists as a typical contact-metamorphic deposit. The mine, which for many years supplied fluxing ore for Asarco's Hayden smelter, had produced well over one million tons of

2.4% Cu by 1950 (Fig. 15), the year of our visit. This was derived mostly from Pennsylvanian Naco beds. Pervasive alteration-mineralization was noted in the diorite outcrops, as well as in extrusive andesites, but with little indication of enrichment in the leached capping. Drill holes in the diorite showed an average of around .40% Cu as chalcopyrite and, it was concluded that the occurrence was, in fact, a minature porphyry copper [22]. Three deep holes had intercepts of over 60' of 2.50% Cu in the Devonian below, suggesting a possible large tonnage potential; however, heavy wet ground had been encountered in the deeper workings and the chances of a profitable operation at that grade and depth (1500') did not appear worth taking.

Subsequently, Inspiration carried out an extensive drill program and in 1956 announced the finding of 10 million tons of 2.0% (primary) copper in the Devonian Martin formation. Mineralization in O'Carroll bed had proven to be far more extensive and richer than in the overlying Escabrosa and Naco limestones (Fig. 16). After several delays in development, mining (by room and pillar) commenced around 1962, but plagued by rock support problems and heavy water inflows from the underlying Cambrian quartzite, production ceased in 1966 ---- another failure in underground mining of porphyry copper skarns.

With an almost new mill standing idle, open pit mining later was undertaken. This operation, 6000 tpd at .60% Cu; 5:1 waste:ore, closed December, 1981.

Incidentally, Eastlick [23] reports hydrothermal alteration-mineralization in the diorite and volcanics, including secondary K-spar and biotite, but does not recognize the deposit as a porphyry copper occurrence.

8. FOUR METALS

In 1950, the file on this prospect, a mineralized breccia pipe which had been explored on three adit levels, contained both favorable and unfavorable reports, but essentially no sample data and little geology. To better assess the deposit's potential, mapping and sampling were undertaken. Only minor

amounts of limonite-after-chalcocite were observed in leached outcrops of the breccia which occupied an arcuate-shaped area about 700' across (Fig. 17). Underground sampling partially delimited a zone of around 0.7% primary copper, bordered by 0.2-0.3% primary (Fig. 18). Little more than traces of chalcocite occurred in sulphides just below the base of oxidation (exposed in raise from No. 2 to No. 1 adit level), leading to the conclusion that the apparent lack of enrichment was probably due to rapid fluctuations of the water table during oxidation, resulting in dispersion of the copper in solution [24]. Also, the volume of better primary was obviously too small.

Later (in 1954) Duval moved in, drilled several plus or minus 1500' holes and moved out. At that time it appeared that exploration had been carried to the saturation point; however, in 1963, Phil Jenney (Noranda-Iso) found an untested portion of the better grade primary (Fig. 17) which (surprisingly) contained some chalcocite enrichment. As I recall, the grade was about 1.0% Cu, but the size, around 5 million tons, too small to be exploitable.

9. RED MOUNTAIN

Several areas of pervasive alteration-mineralization were observed in the northern Patagonia during reconnaissance mapping around the Flux lead-zinc mine early in 1951. The most spectacular of these occurrences was Red Mountain, composed largely of extrusive volcanics. A few small porphyry intrusives and breccia pipes with sparse limonite-after-chalcocite were found, but the leached outcrops in general displayed the orange-red tones characteristic of those derived from pyrite. This conclusion was lent some support by exposures in the old Aztec 1500' adit, driven in from the NW, well down on the mountain slope, which cut disseminated pyrite with thin chalcocite coatings averaging around .06% Cu.

Some 16 years later, several holes drilled by Kerr-McGee from locations near the mountain top, encountered a thin, low-grade blanket of enrichment underlain by 0.15 to 0.2% primary copper extending to around 3000', the

maximum depth drilled. Some time after they invited participation to share the risk of deeper drilling, we negotiated a deal whereby Asarco could acquire 60% with an expenditure of $450,000 over a 3 year period [25], but our authorization request ($125,000 for the first year) was turned down. Our objective was, however, relatively high-grade skarn mineralization which theoretically could exist if the Paleozoic limestones were present beneath the volcanics, as in the Hardshell area on the south where pyroclastics of assumed Laramide age rested unconformably on limestones. This age assumption was later proved incorrect (USGS designation: Jurassic or Triassic).

Eventually, Kerr McGee proceeded with deeper drilling, cutting sharply increased primary grades coincident with stronger potassic alteration, from around 3500' to well below 5000' depth (Fig. 19). The breccias carried better values (plus 1.0% Cu) than either the porphyry or volcanics and, although still not fully explored, the deposit reportedly contains over 350 million tons of .58% Cu, including 15 million tons of breccia ore at 2.0% (Fig. 20).

Some of the deeper holes (around 6000') bottomed in volcanics of probable Jurassic or Triassic age; thus the depth to possible skarn ores in Paleozoic limestones is likely prohibitive. The project is presently inactive.

10. SUNNYSIDE (BX)

Well altered breccia boulder float containing abundant "live limonite," found in the bottom of upper Flux Canyon, led to the source, a monzonite breccia pipe 500' by 800' in surface extent. Leached outcrop evidence indicated that exploration possibilities were confined to the pipe, which was too small, unless an uncommonly rich supergene zone had been formed. However, drilling was proposed [26] and 3 holes completed late in '51. Our faith in breccia pipe was somewhat shaken by the results ---- deep leaching (over 400') but only minor enrichment of spotty low grade primary (mainly enargite). An isometric projection (Fig. 21) shows the pipe narrowing with depth. Average grade: 0.48% Cu, .16 oz Ag.

The absence of appreciable enrichment was considered due to an unstable water table history, as with the Four Metals deposit located 5 miles to the south.

* * * * * * * * * * *

June '51 seems an appropriate time to end Part I of this narrative, as the following 18 months were taken up with other work ---- principally drilling projects in Nigeria and Mexico.

J. H. Courtright

JHC:mek

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FIGURES

1A.	Location Map	
1B.	Ely District (Robinson Mining District)	1978
2.	" " Alteration	1978
3.	" " Copper distribution	1978
4.	Silver Bell, Geologic Plan	1954
5.	" " , Mineralization map	1949
6.	Toquepala, Geologic Plan & Section	1958
7.	" , Plan - Exploration Poss.	1949
8.	Lone Star District, Mineralization map	1950
9.	" " " , Geologic Plan	1972
10.	" " " , Dos Pobres Section	1972
11.	Lakeshore Mine, Geologic Section	1969
12.	Mineral Park, Geologic Plan	1950
13.	" " , " "	1982
14.	" " , Geologic Section	1982
15.	Christmas, Geologic Plan	1957
16.	" " Section	1957
17.	Four Metals, " Plan	1951
18.	" " , " Section	1951
19.	Red Mountain, Geologic Plan	1980
20.	" " , " Section	1980
21.	Sunnyside, Isometric Sketch	1951

PC History copy: & place in individual files w/ maps.

I. pages 3, 6, 9, 10, 12 → 16,
4 copies p. 18
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5 copies p. 31
3 copies p. 32
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[illegible] copies p. 34
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12 copies Fig III-A 46

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SOME PORPHYRY COPPER HISTORY - PART I

By J.H.Courtright

Date 12/8/82

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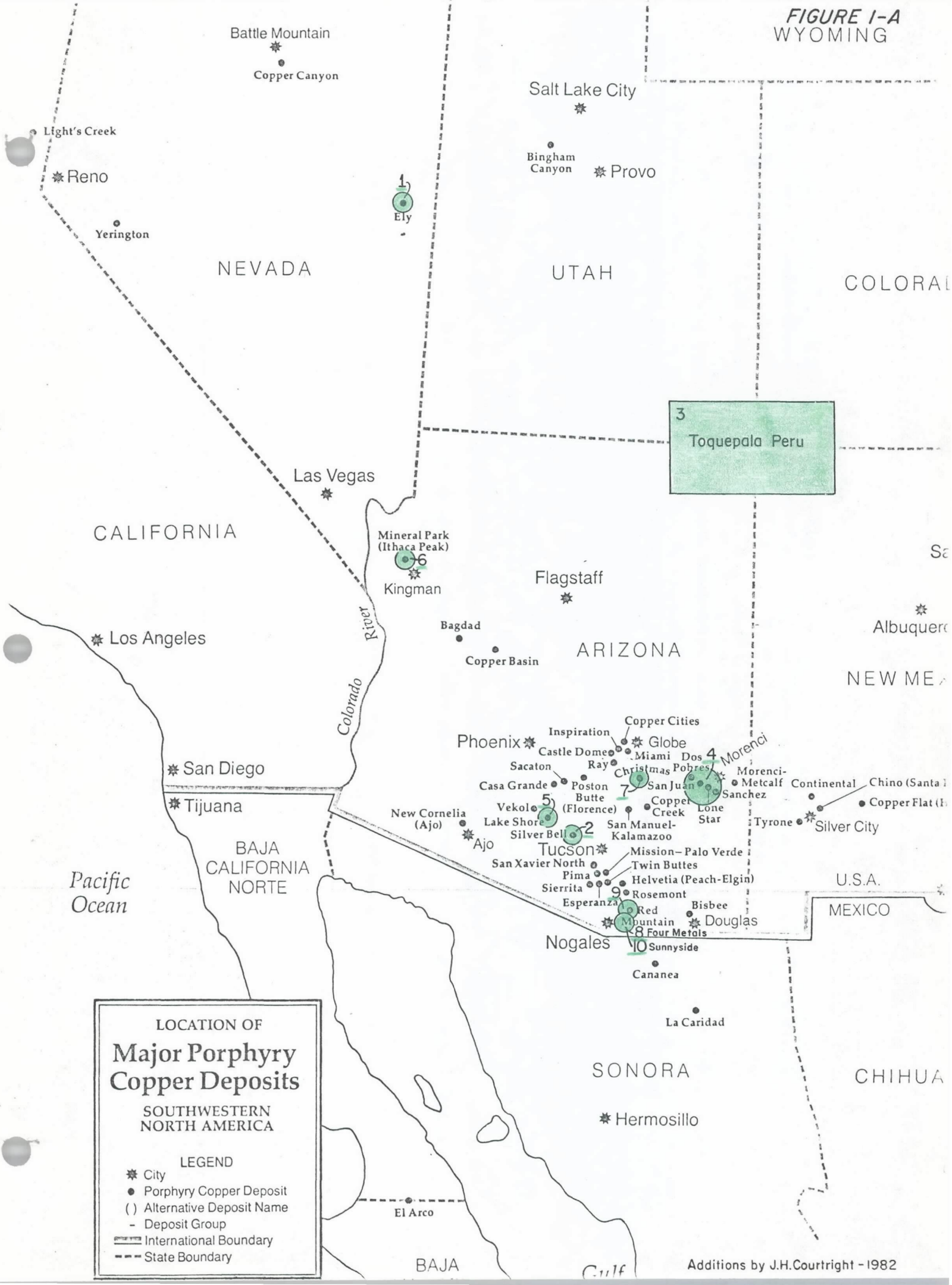
FIGURE 1-A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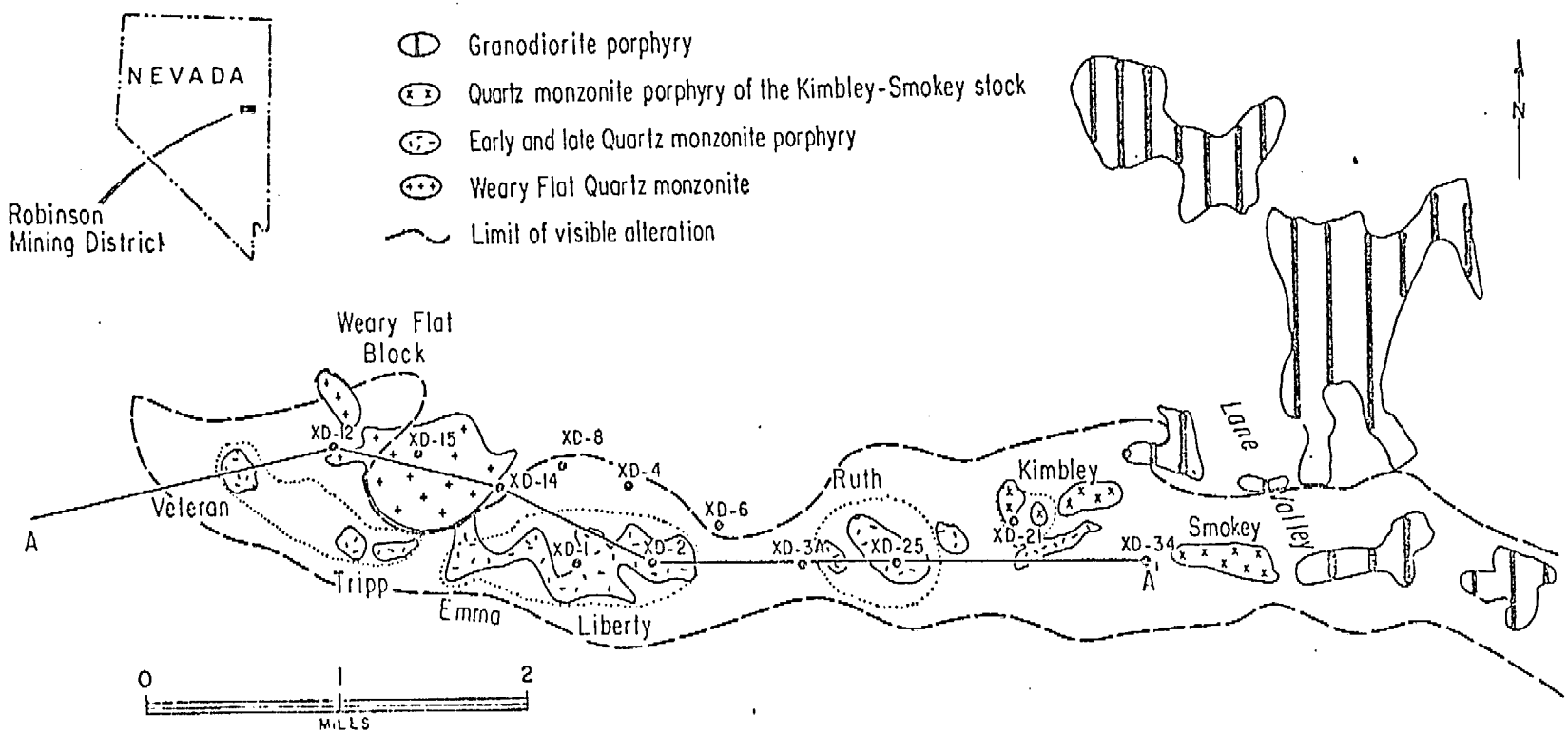
COLORAD
Toquepala Peru
Las Vegas
CALIFORNIA
Mineral Park (Ithaca Peak)
Kingman
Flagstaff
Albuquerc
Los Angeles
Bagdad
Copper Basin
ARIZONA
NEW ME
Colorado River
Copper Cities
Inspiration
Phoenix
Globe
Castle Dome
Miami
Dos Pobres
Morenci
Ray
Sacaton
Christmas
Morenci-Metcalf
Continental
Chino (Santa
San Diego
Casa Grande
Poston Butte (Florence)
San Juan
Sanchez
Copper Flat
Tijuana
Vekol
Copper Creek
Lone Star
New Cornelia (Ajo)
Lake Shore
San Manuel-Kalamazoo
Tyrone
Silver City
Silver Bell
Ajo
Tucson
Mission-Palo Verde
BAJA CALIFORNIA NORTE
San Xavier North
Twin Buttes
Pima
Helvetia (Peach-Elgin)
Pacific Ocean
Sierrita
Rosemont
U.S.A.
Esperanza
Red Mountain
Bisbee
Douglas
MEXICO
Four Metals
Nogales
Sunnyside
Cananea
La Caridad
SONORA
CHIHUA
Hermosillo
El Arco
BAJA
Gulf
LOCATION OF
Major Porphyry Copper Deposits
SOUTHWESTERN NORTH AMERICA
LEGEND
City
Porphyry Copper Deposit
( ) Alternative Deposit Name
- Deposit Group
International Boundary
State Boundary
Additions by J.H.Courtright - 1982



BY GERHARD WESTRA, 1978

FIGURE 1-B

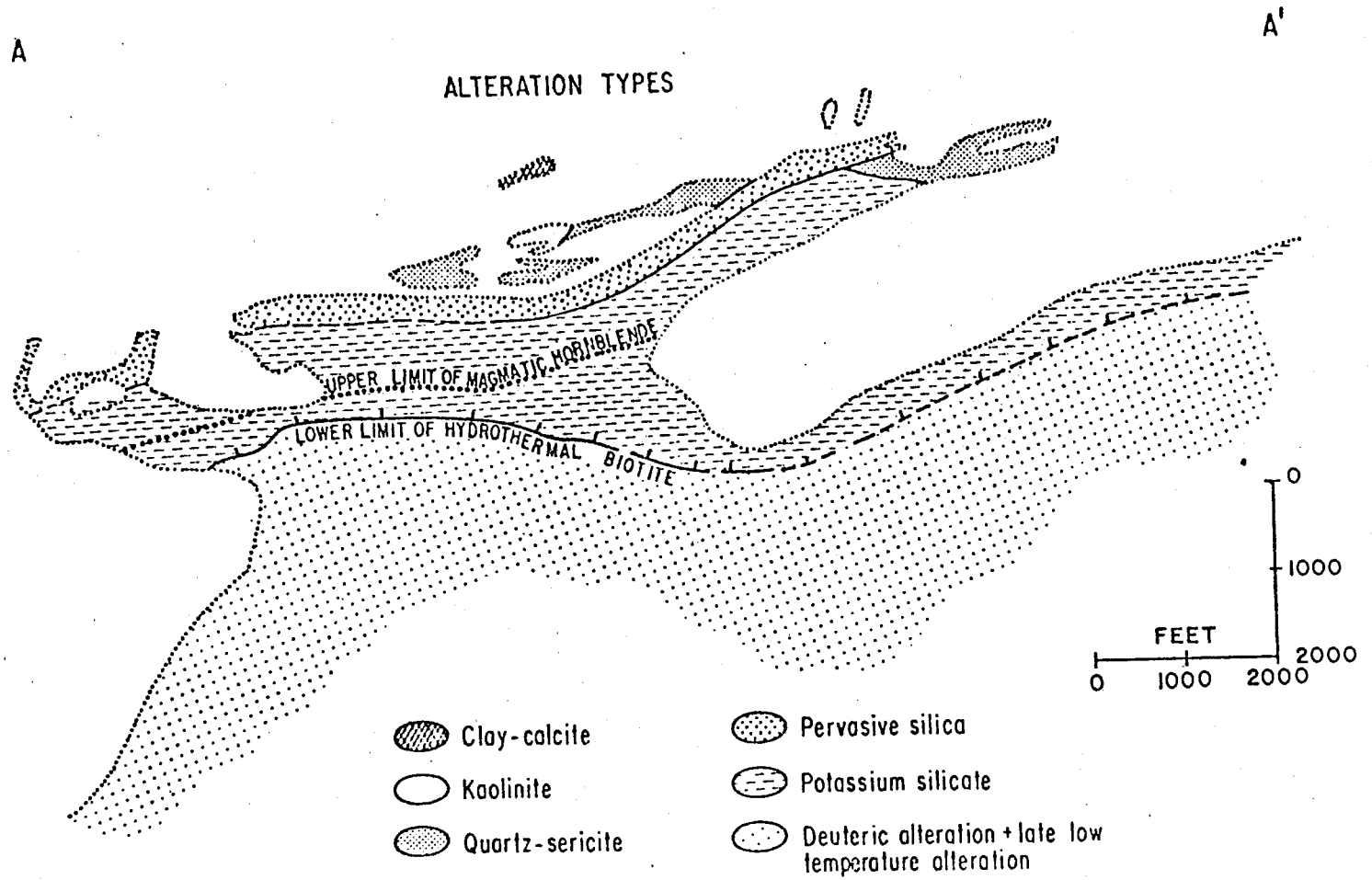


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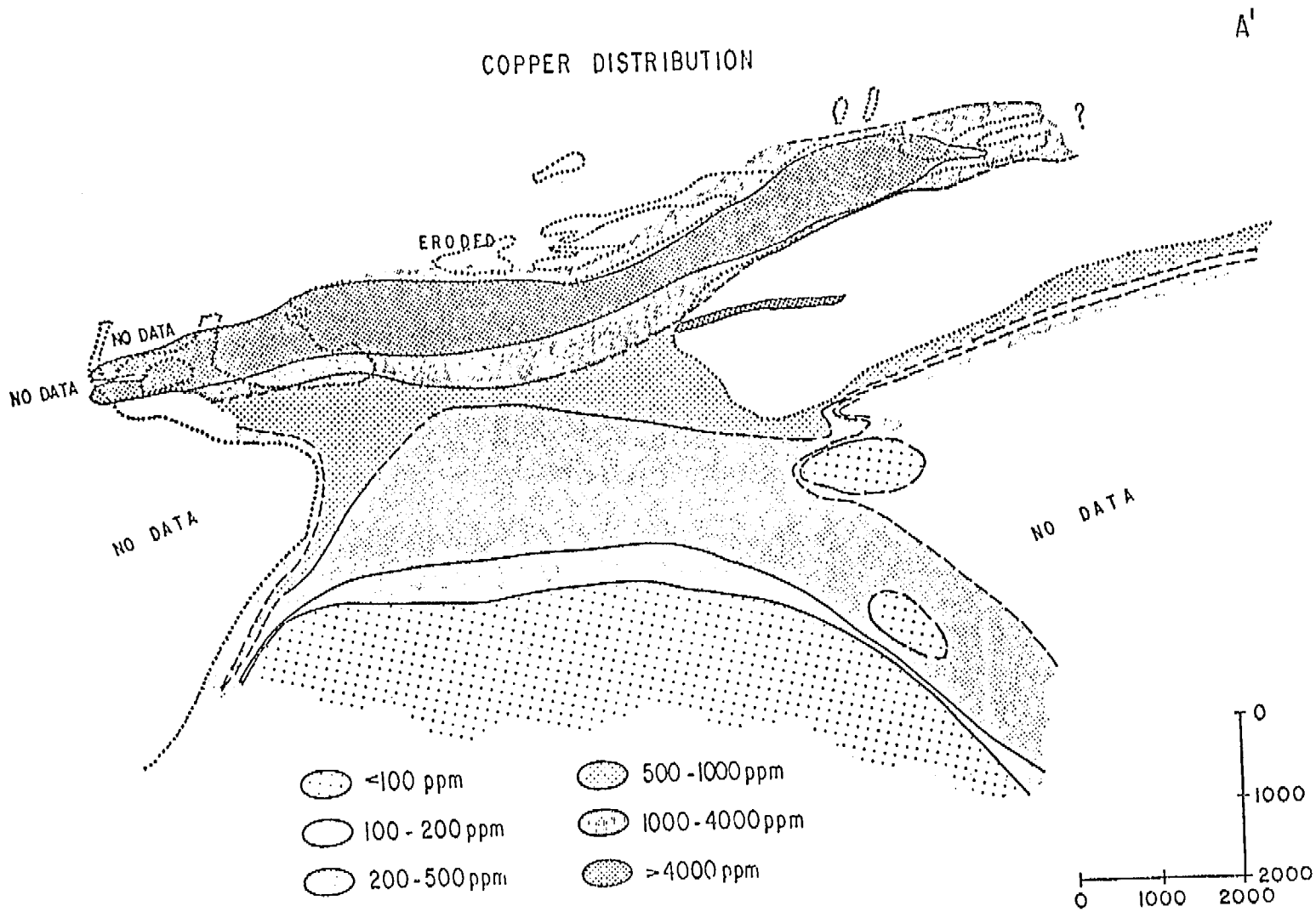
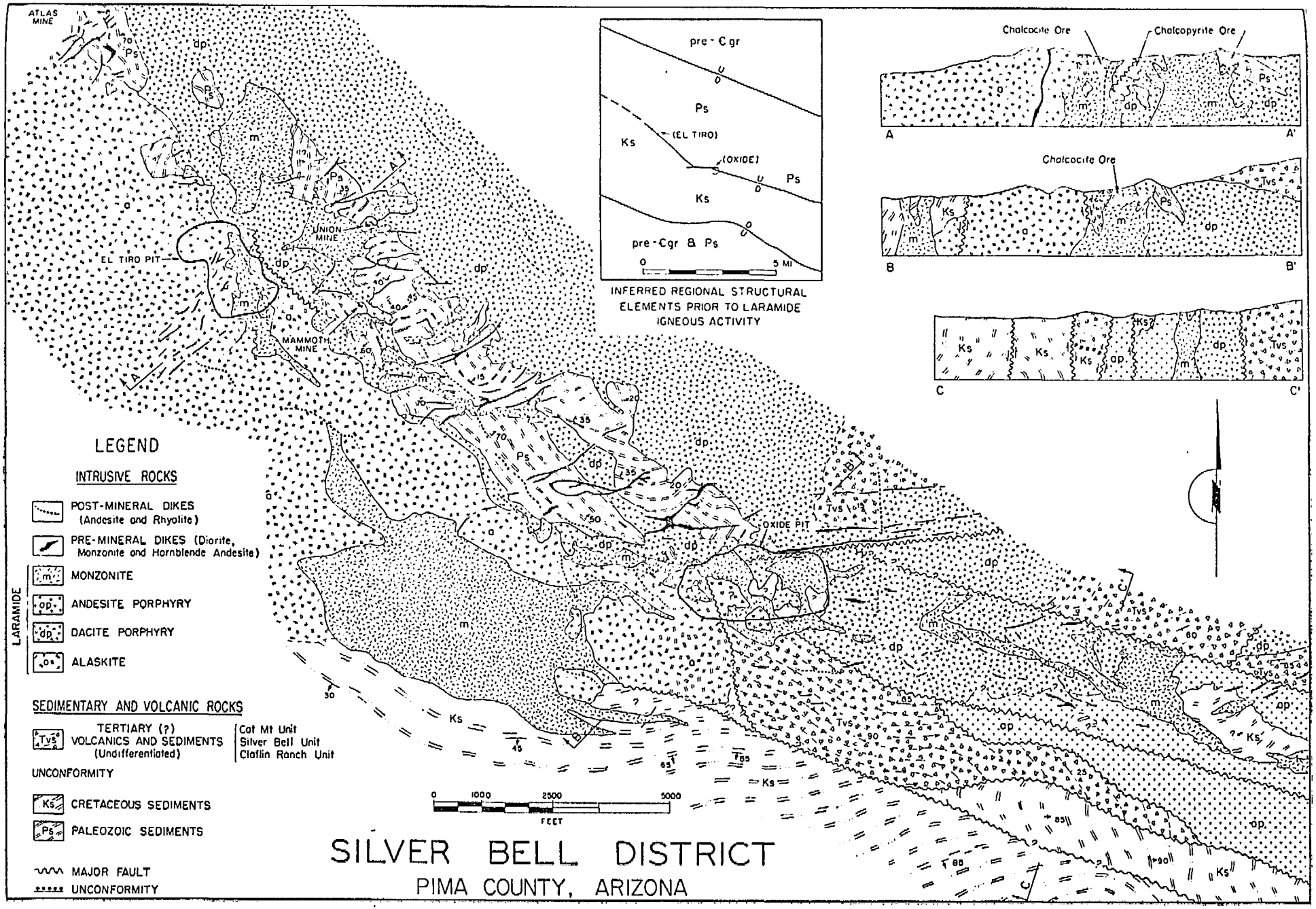
FIGURE 2



BY GERHARD WESTRA, 1978

FIGURE 3

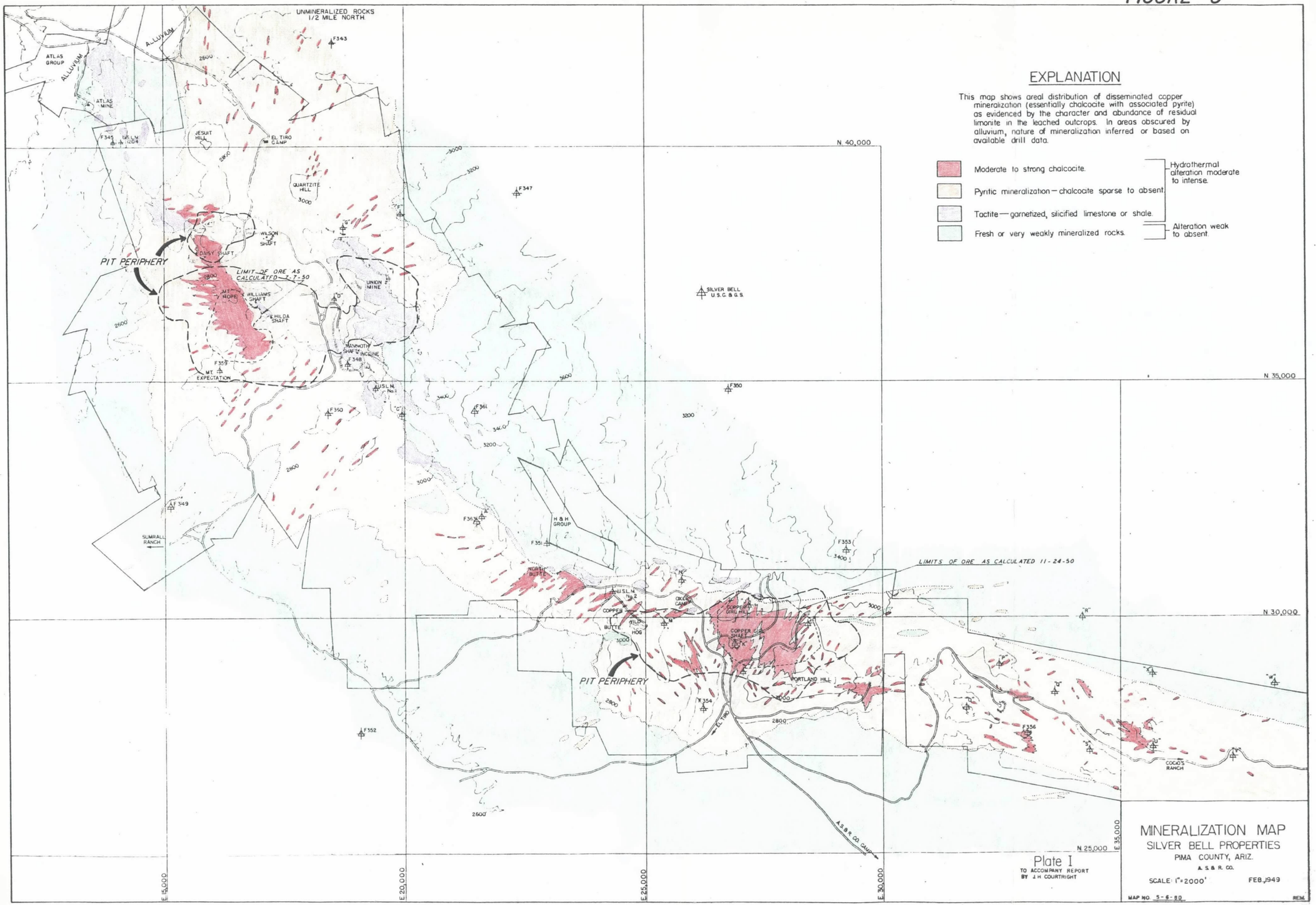


SILVER BELL DISTRICT

PIMA COUNTY, ARIZONA

FIGURE 4

FIGURE 5



EXPLANATION

This map shows areal distribution of disseminated copper mineralization (essentially chalcocite with associated pyrite) as evidenced by the character and abundance of residual limonite in the leached outcrops. In areas obscured by alluvium, nature of mineralization inferred or based on available drill data.

- Moderate to strong chalcocite.
- Pyritic mineralization — chalcocite sparse to absent.
- Tactite — garnetized, silicified limestone or shale.

} Hydrothermal alteration moderate to intense.

- Fresh or very weakly mineralized rocks.

} Alteration weak to absent.

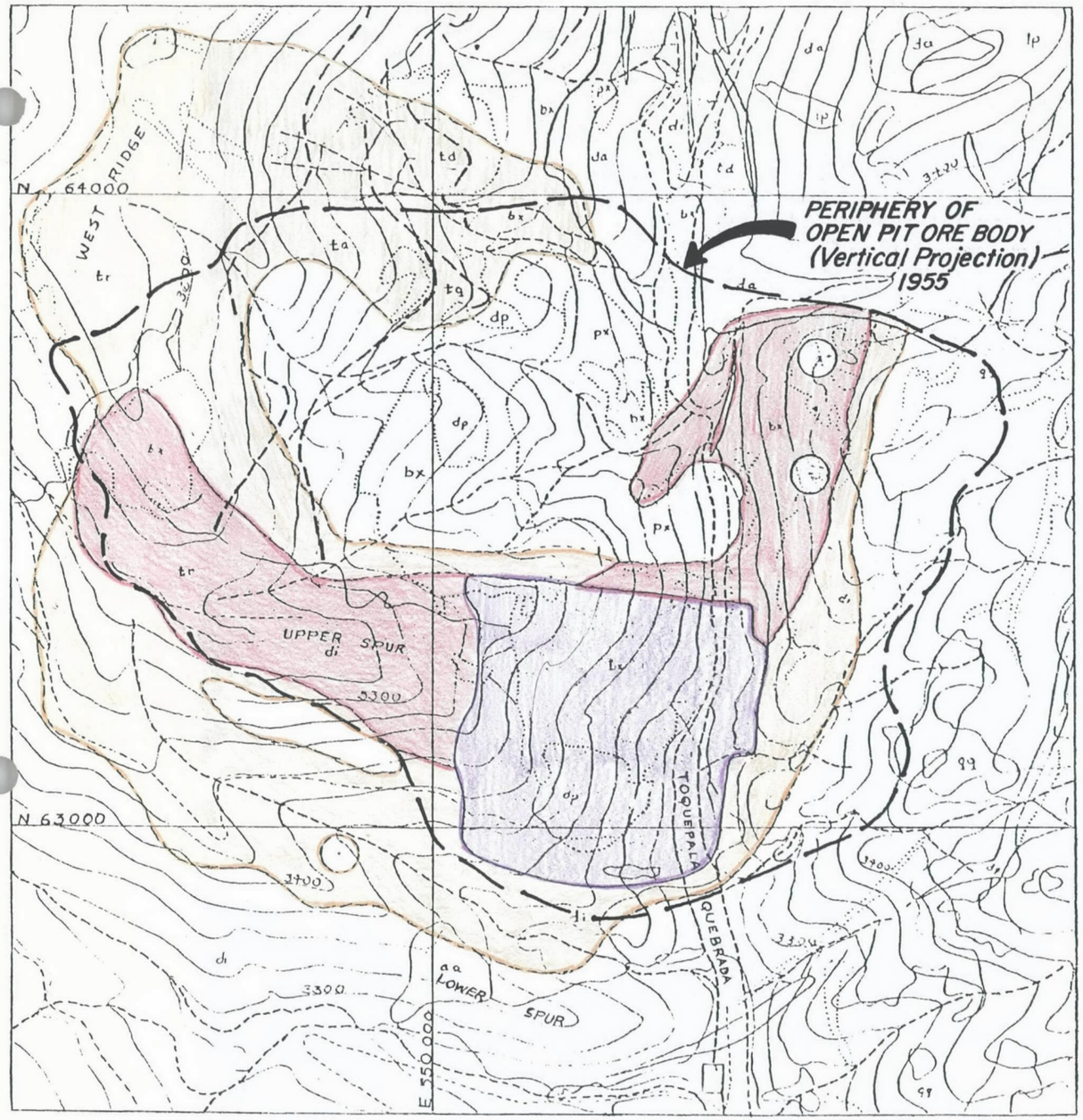
Plate I
TO ACCOMPANY REPORT BY J.H. COURTRIGHT

MINERALIZATION MAP
SILVER BELL PROPERTIES
PIMA COUNTY, ARIZ.
A. S. & R. CO.

SCALE: 1" = 2000' FEB. 1949

MAP NO. 5-6-80 REM.

Additions by J.H. Courtright - 1982



EXPLANATION

As determined by leached outcrop mapping, areal extent of copper mineralization in relation to known ore is shown. This map summarizes the information presented by the 1:2000 scale Outcrop Map No. 8.

Area of ore drilled by C.de P.

AREAS CONSIDERED FAVORABLE FOR EXPLORATION:

1st. ORDER — Moderate to strong mineralization

2nd. ORDER — Moderate to weak mineralization

N

TOQUEPALA N.P.M. & S. Co.

SUMMARY OF EXPLORATION POSSIBILITIES

0 50 100 200 500 M

Scale 1:10000 contour interval 25 meters

TO ACCOMPANY REPORT BY:

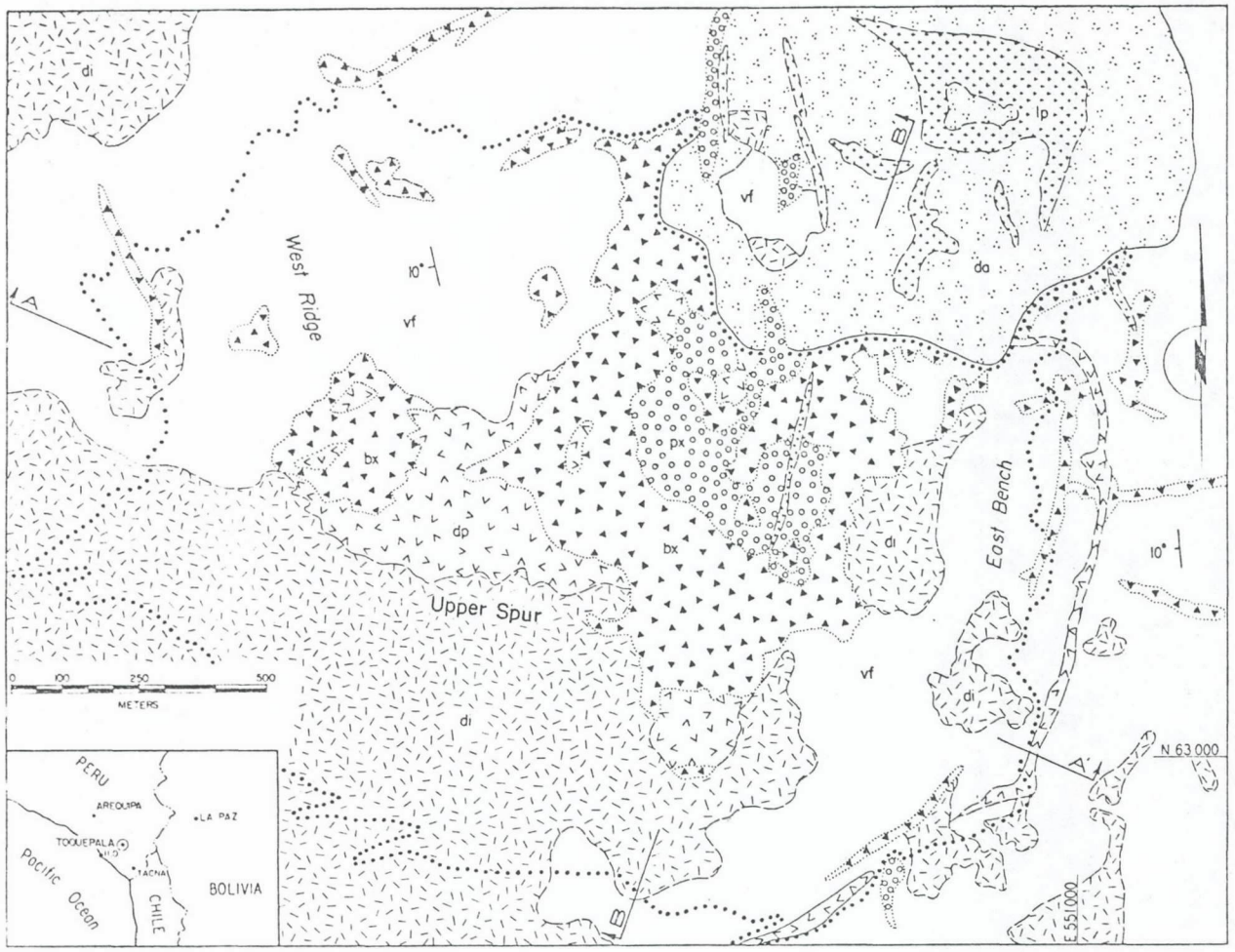
KENYON RICHARD
J.H. COURTRIGHT
SEPTEMBER, 1949

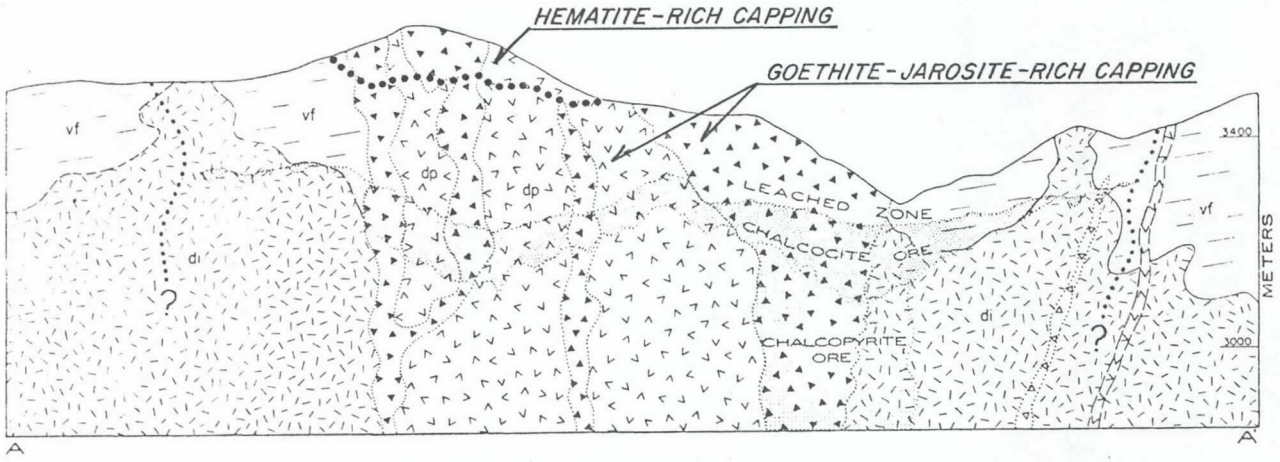
3

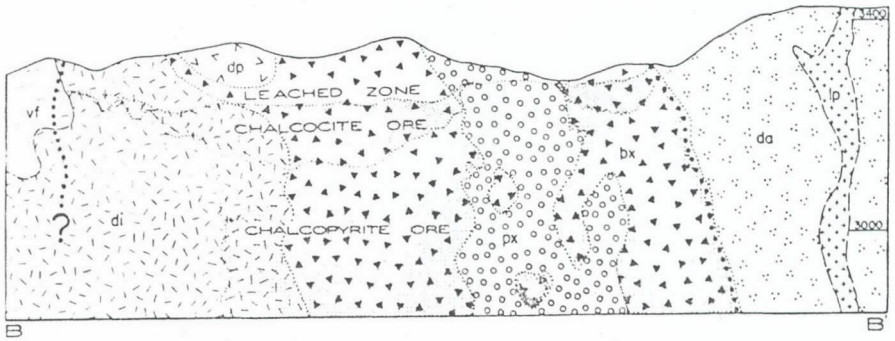
FIGURE 7

Additions by J.H.C.–1982

FIGURE 6







LEGEND

- LATITE PORPHYRY
- PEBBLE BRECCIA
- DACITE AGGLOMERATE
- ORE BRECCIA
- DACITE PORPHYRY
- DIORITE
- VOLCANIC FLOWS
- OUTLINE OF HYDROTHERMAL ALTERATION ZONE

TOQUEPALA GEOLOGIC MAP AND SECTIONS

Additions by J. H. Courtright-1982

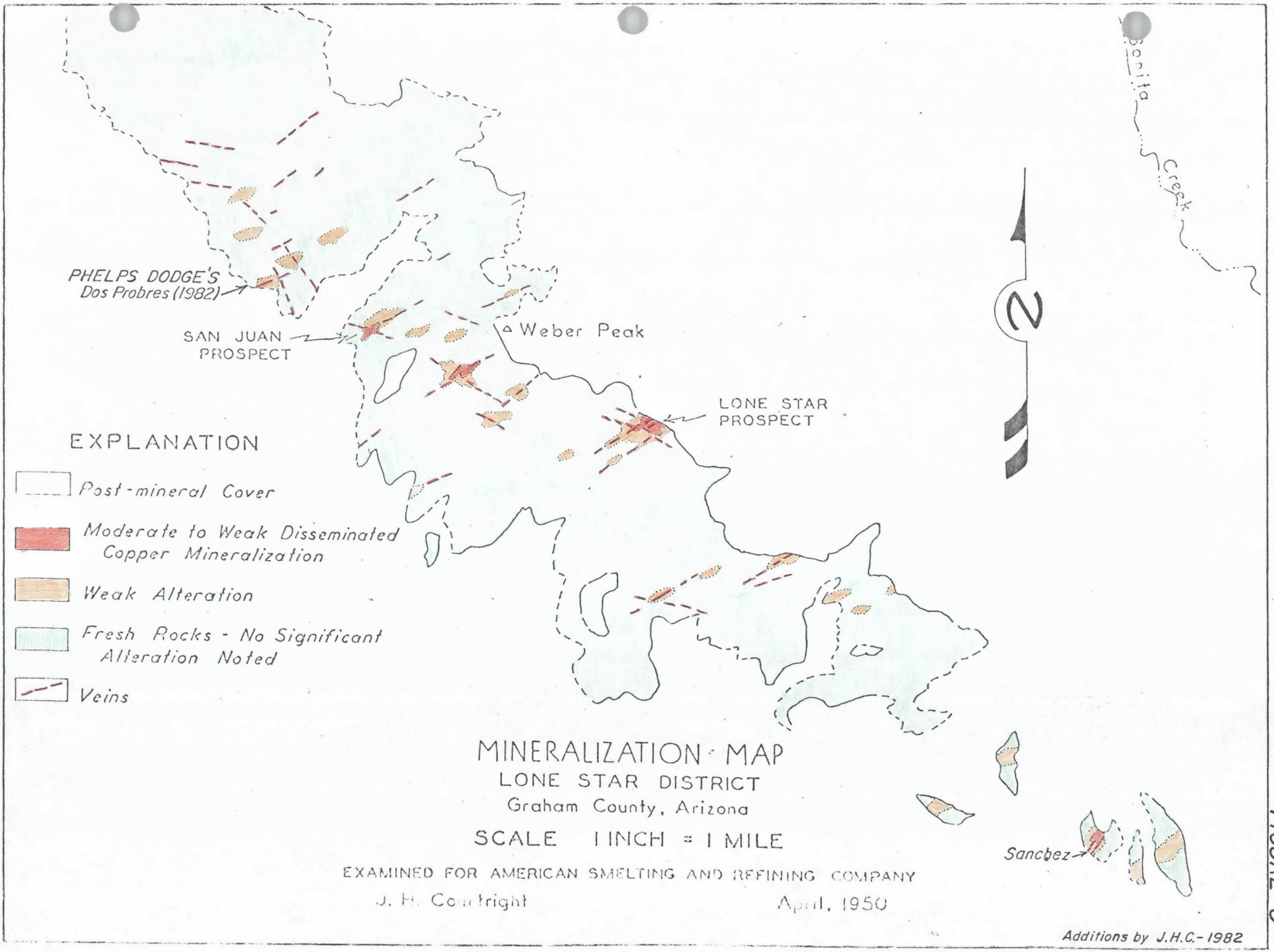

Bonita Creek
PHELPS DODGE'S
Dos Probres (1982)
SAN JUAN
PROSPECT
Weber Peak
LONE STAR
PROSPECT
N
EXPLANATION
Post-mineral Cover
Moderate to Weak Disseminated Copper Mineralization
Weak Alteration
Fresh Rocks - No Significant Alteration Noted
Veins
Sanchez
MINERALIZATION MAP
LONE STAR DISTRICT
Graham County, Arizona
SCALE 1 INCH = 1 MILE
EXAMINED FOR AMERICAN SMELTING AND REFINING COMPANY
J. H. Courtright
April, 1950
Additions by J.H.C.- 1982

FIGURE 8

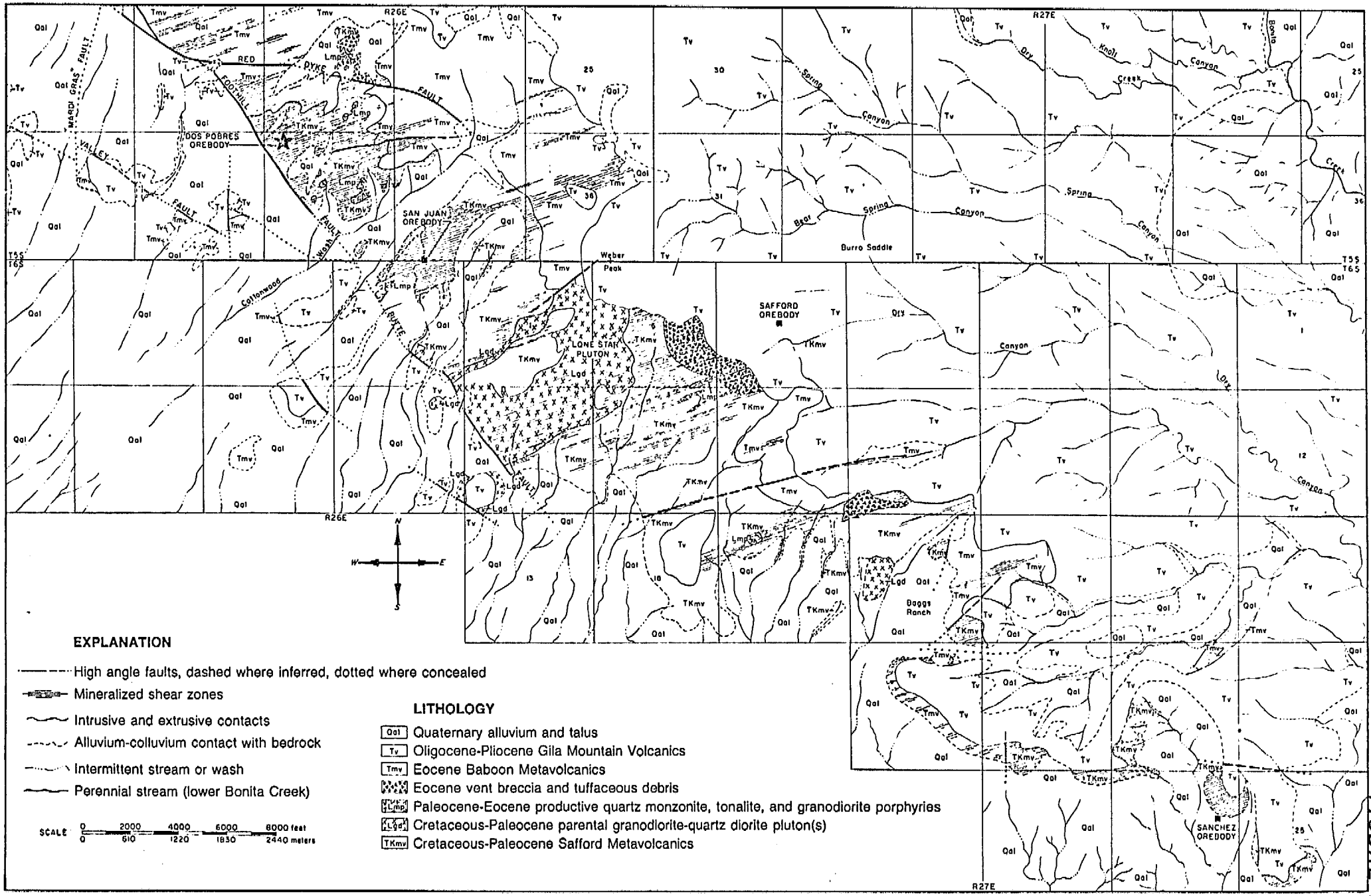


Figure 16.2. Geologic map of the Lone Star mining district.
Mapped and collated by R. Geer and others, Phelps Dodge Corp., 1972.

FIGURE 9

FIGURE 9

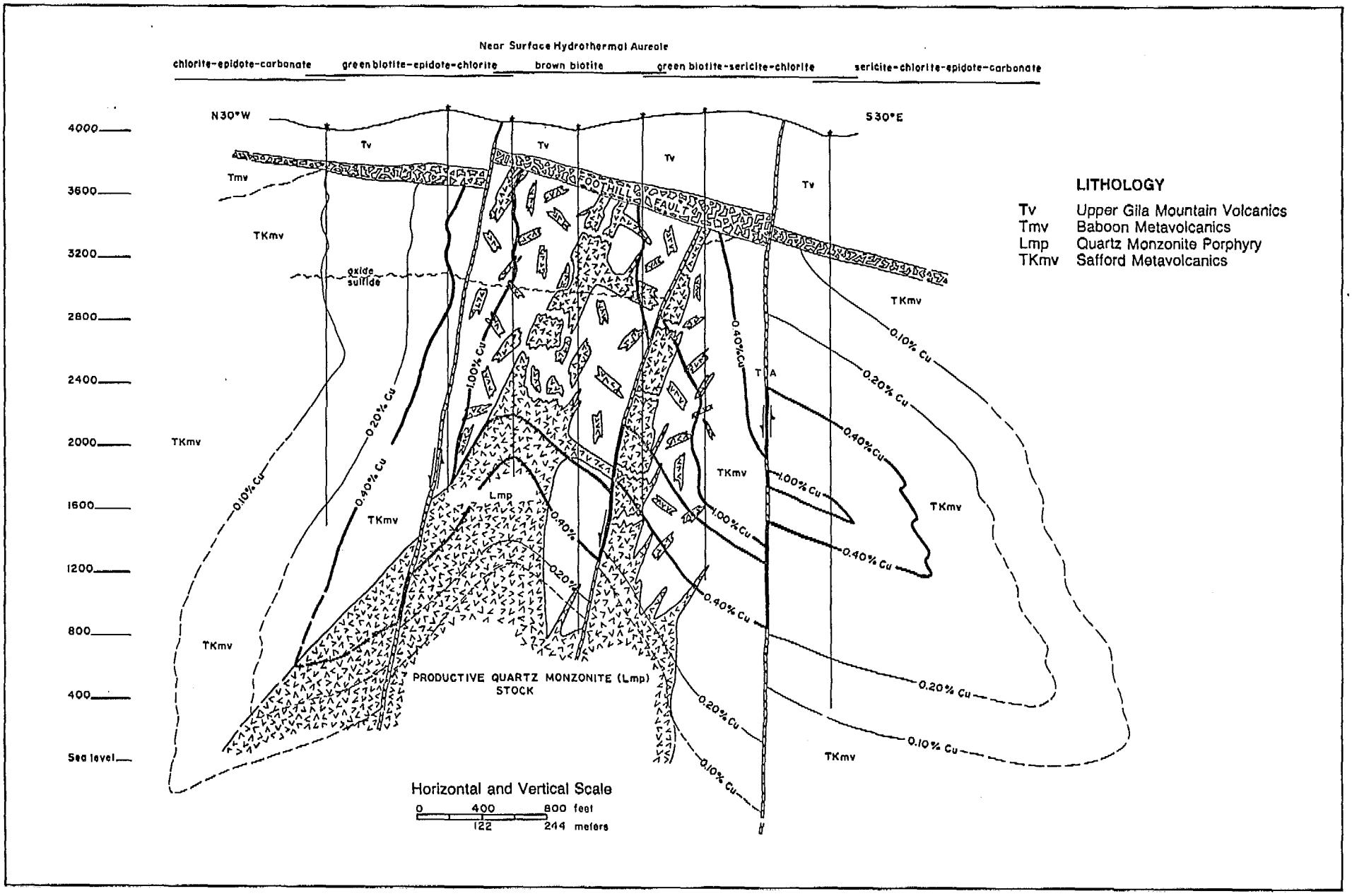
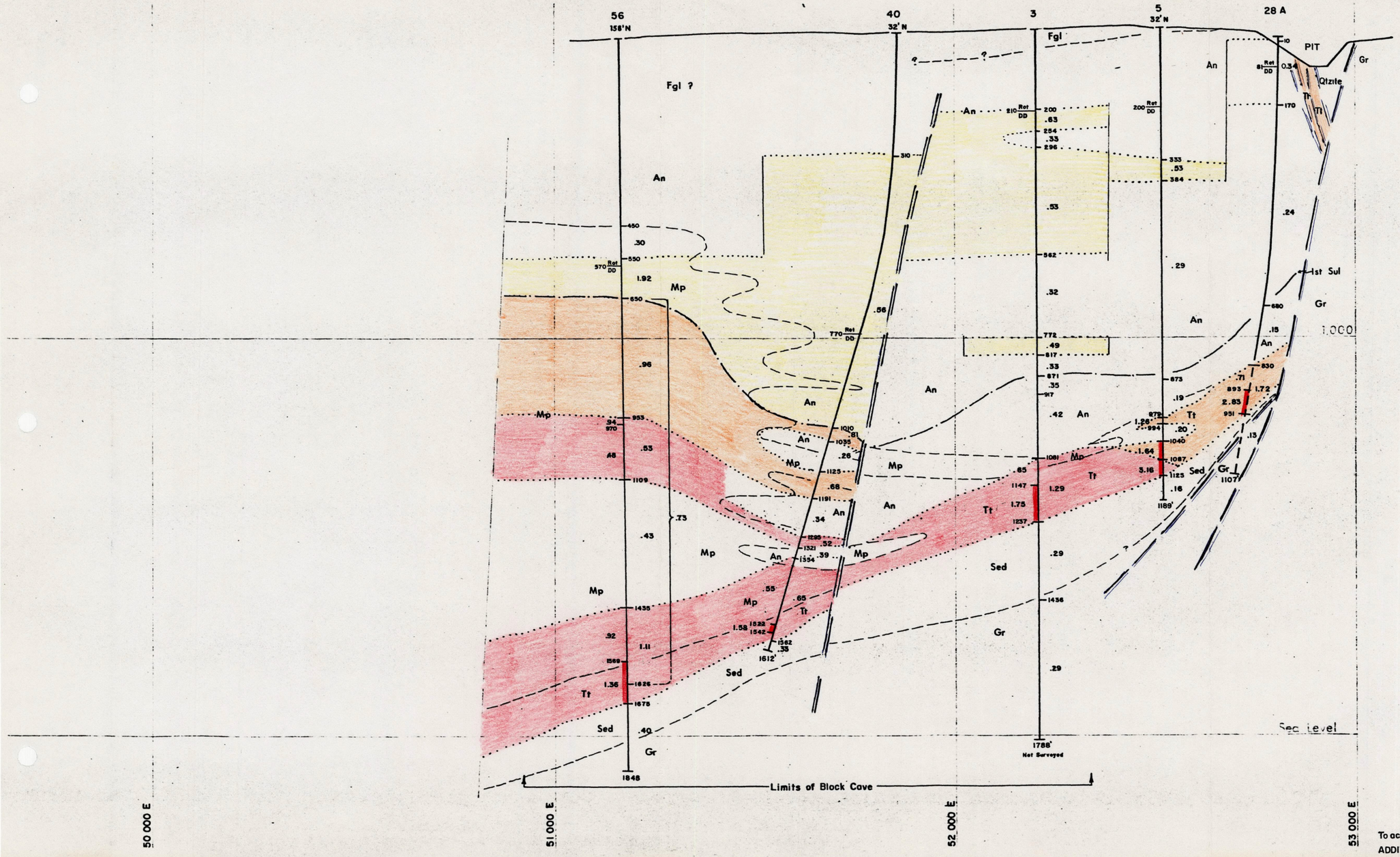


Figure 16.5. Cross section of the Dos Pobres orebody, looking N60°E. Vertical lines descending from the surface mark locations of drill holes.

FIGURE 10



EXPLANATION

FIGURE 11

— SEDIMENTS & VOLCANIC ROCKS —

- Tgl — Alluvium & fanglomerates
- An — Andesite, andesite breccias, andesitic sediments
- Tt — Tactite (skarn)
- Sed — Sediments (undifferentiated)

— IGNEOUS ROCKS —

- Mp — Monzonite porphyry
- Gr — Granite
- Int — Intrusive (undifferentiated)

— MINERALIZATION —

- Oxidized + 0.40 % Cu
- Mixed zone + 0.50 % Cu (variable amounts of chalcocite, chalcopyrite & oxidized copper)
- Sulfide zone + 0.50 % Cu

950

.80 Drill hole intercept, 150' of 0.80 % Cu

1030'

Tactite zone intercept @ 1.1 % Cu — 1.1 — (Color bar indicates plus 1.0% Cu)

1100'

Rot DD — 480' End of Rotary; Start of Coring

SECTION 50 275 NORTH

looking north

LAKESHORE DEPOSIT

Pinal County, Arizona

SCALE 1" = 200'

To accompany report, J.H.C. to J.J.C., 1-2-69

ADDITIONS BY J.H. COURTRIGHT. DEC. 1982

2137

FIGURE 12

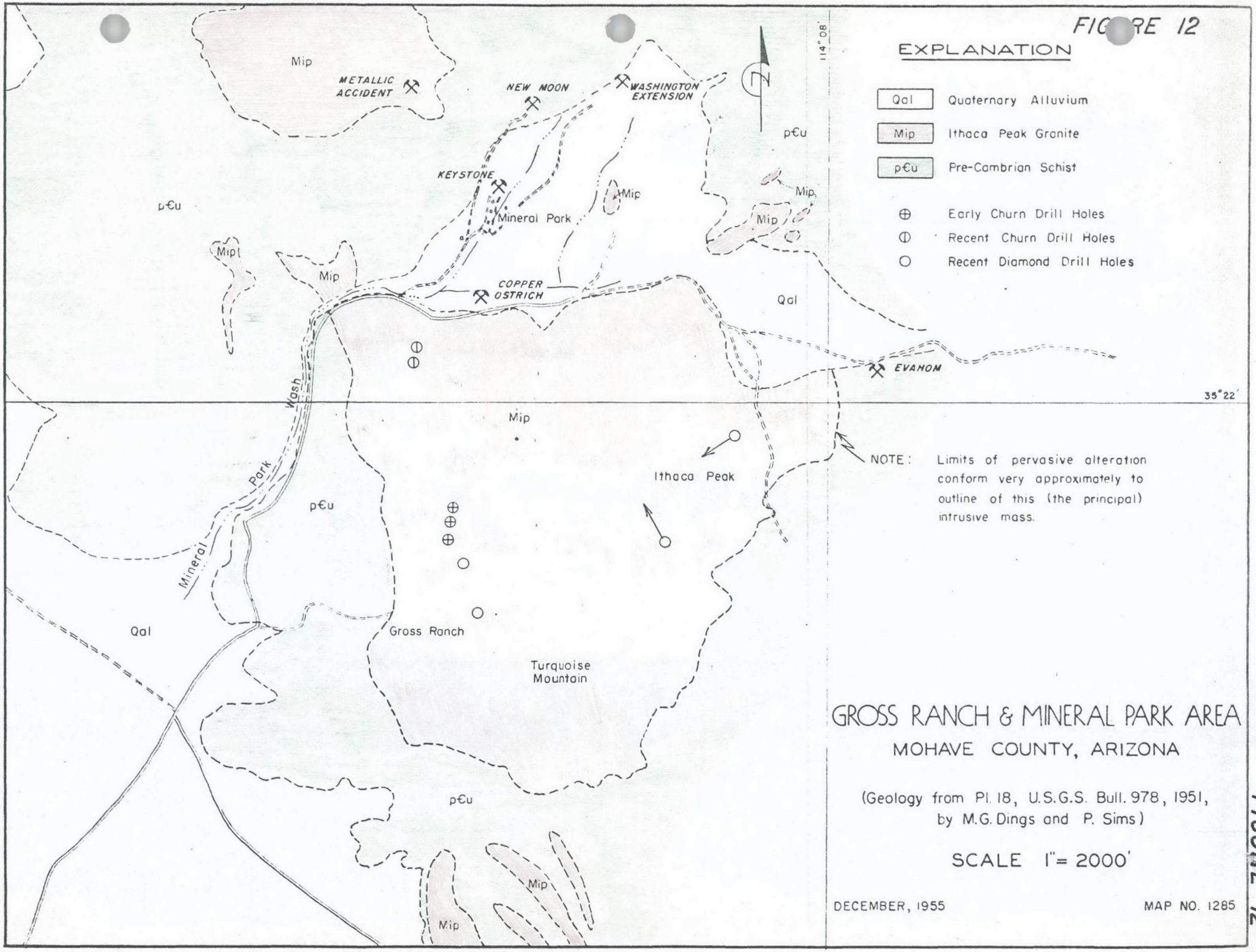


FIGURE 12

FIGURE 13

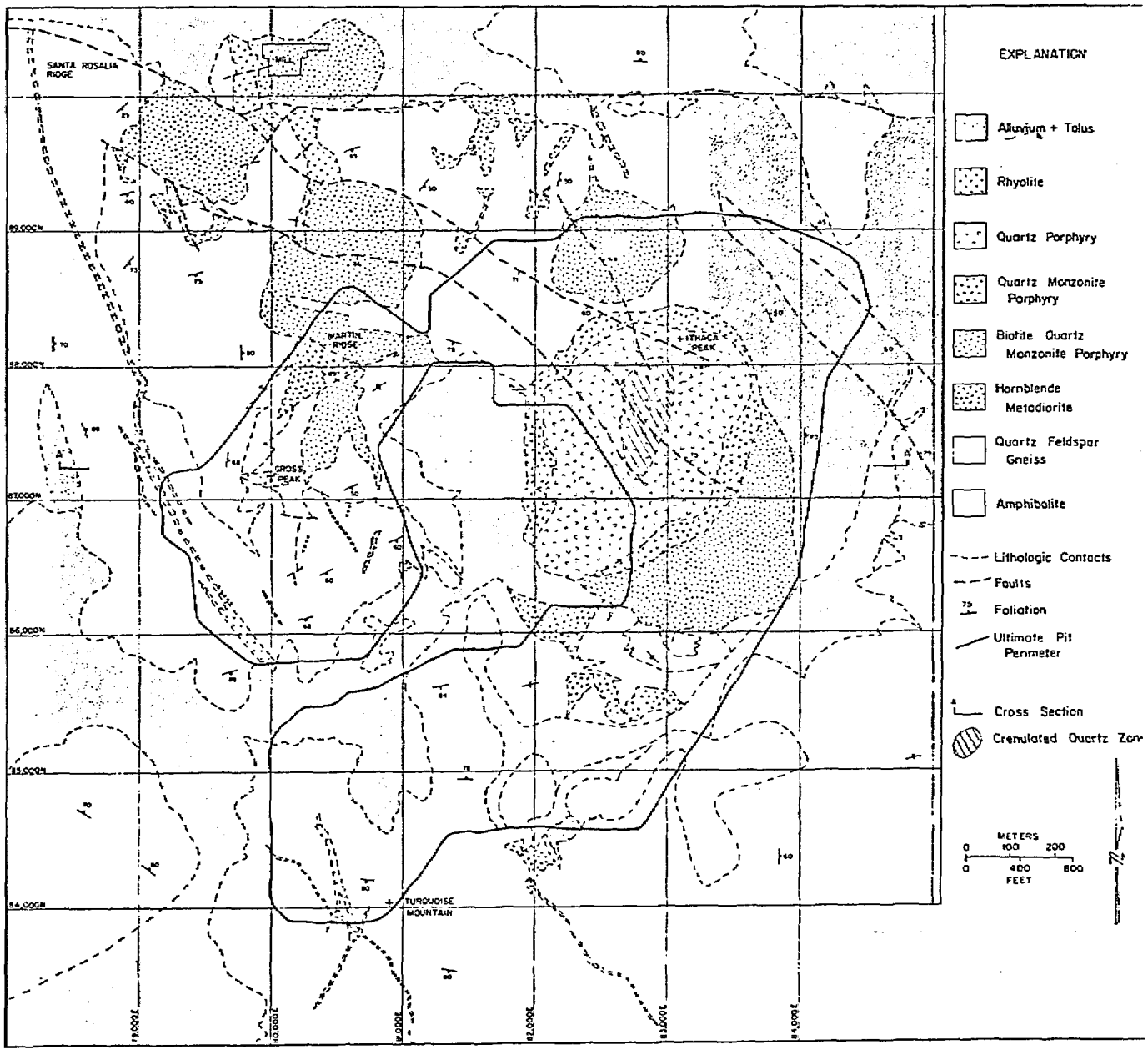


Figure 26.1. Geologic map of the Mineral Park mine area. Most of the rocks of the Wallapi mining district are present in this area.

FIGURE 14

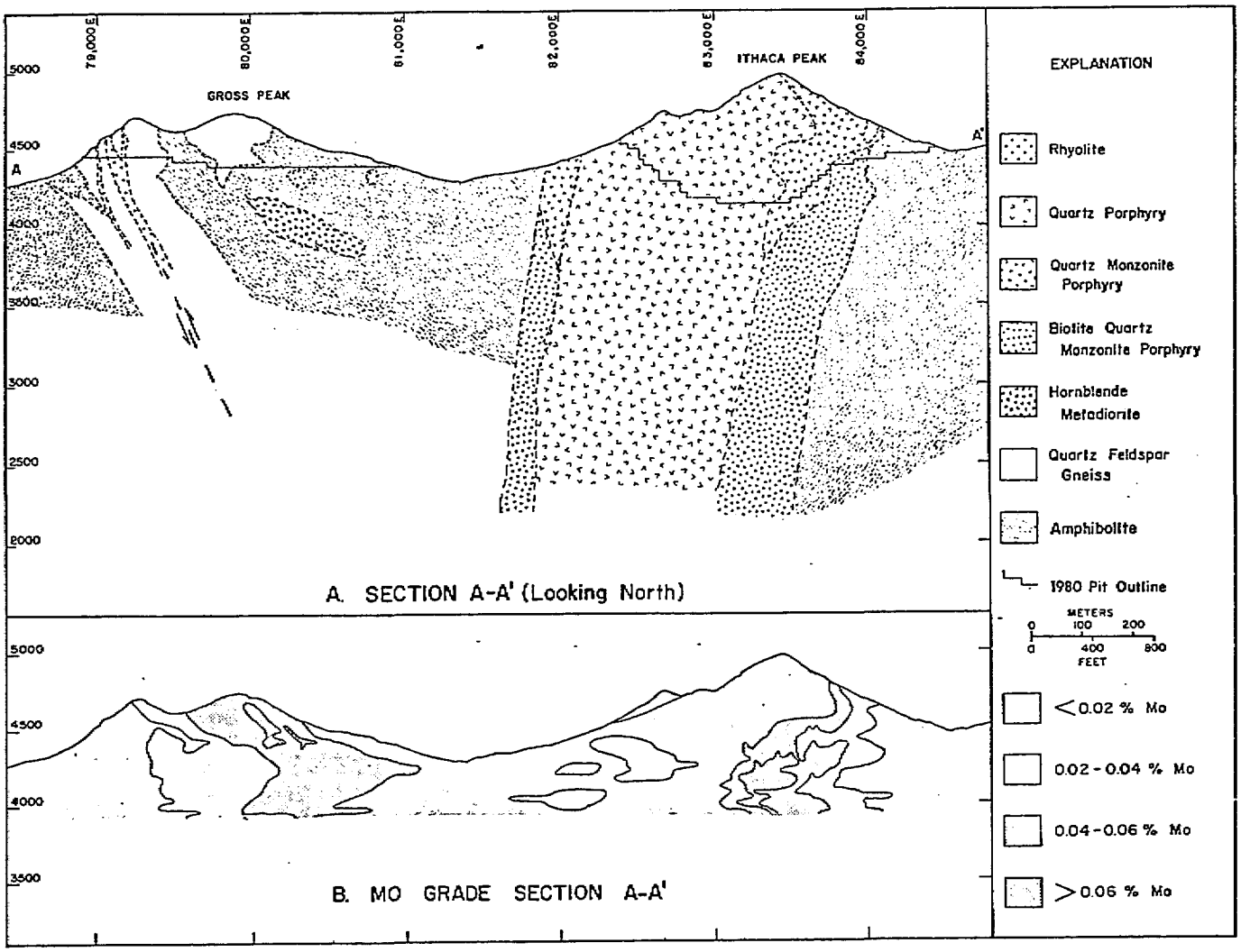


Figure 26.3. Cross sections in the Ithaca Peak–Gross Peak area: *A*, rock distribution at section *A-A'* (looking north); *B*, molybdenum grades at section *A-A'*. Location of section shown in Figure 26.1.

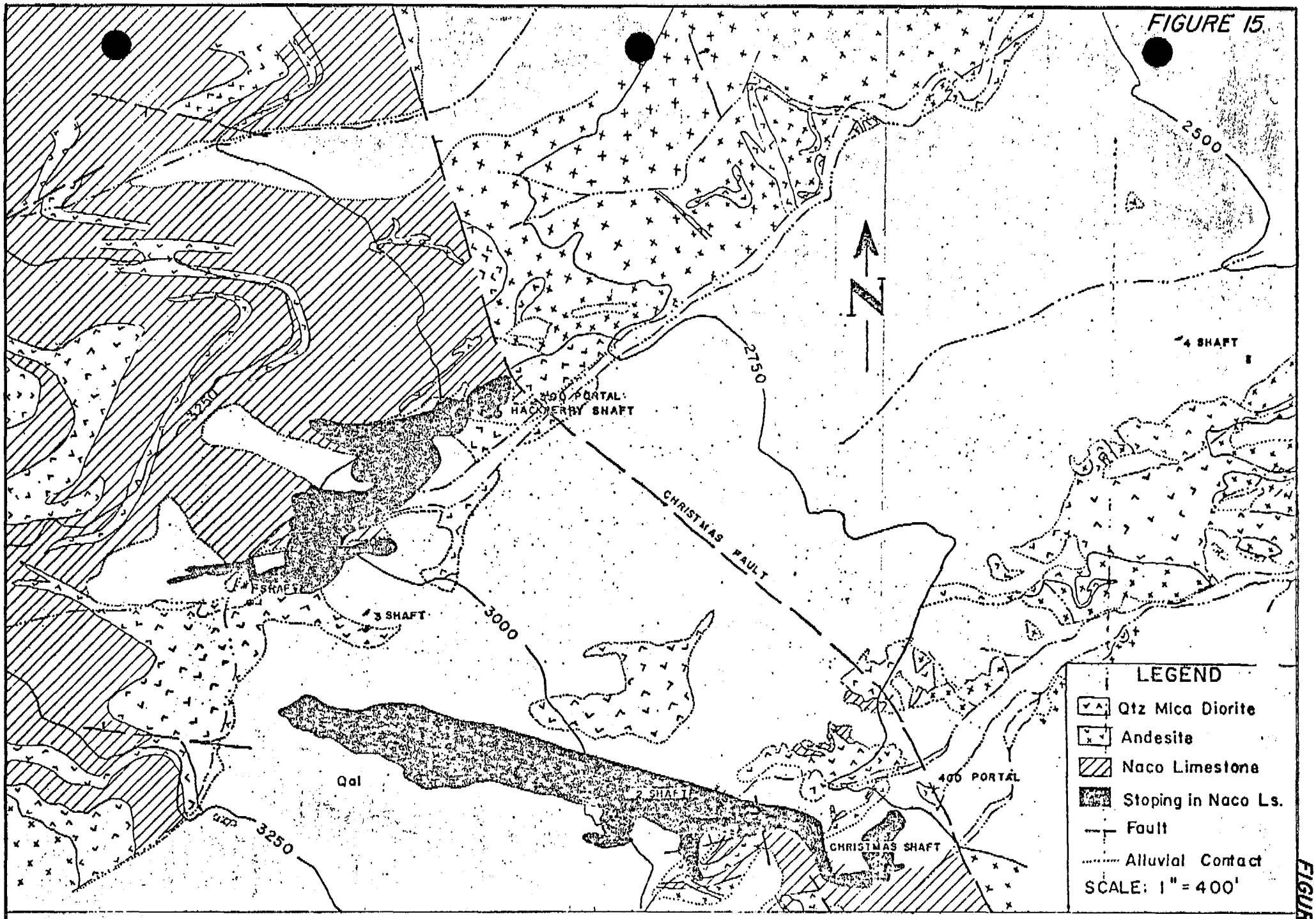


PLATE I, GENERALIZED SURFACE GEOLOGY, CHRISTMAS MINE, I.C.C.COMPANY

After Peterson and Swanson, USGS, with additions by Company Geological Staff and Anaconda Exploration Dept.
John T. Eastlick, 1957

FIGURE 15

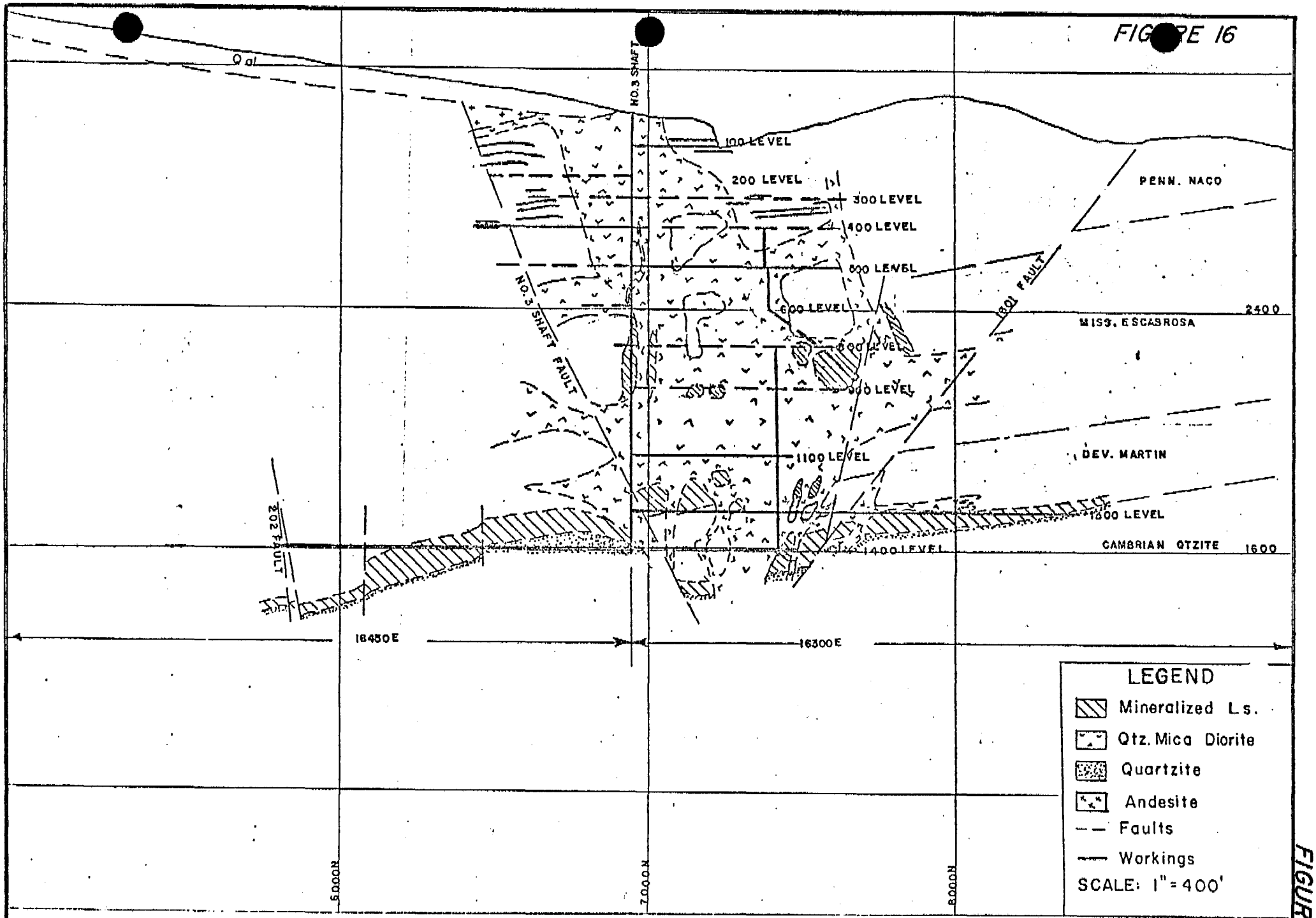


PLATE 5, GENERALIZED N-S SECTION THRU NO.3 SHAFT, LOOKING WEST; CHRISTMAS MINE

John T. Eastlick, 1957

FIGURE 16

FIGURE 17

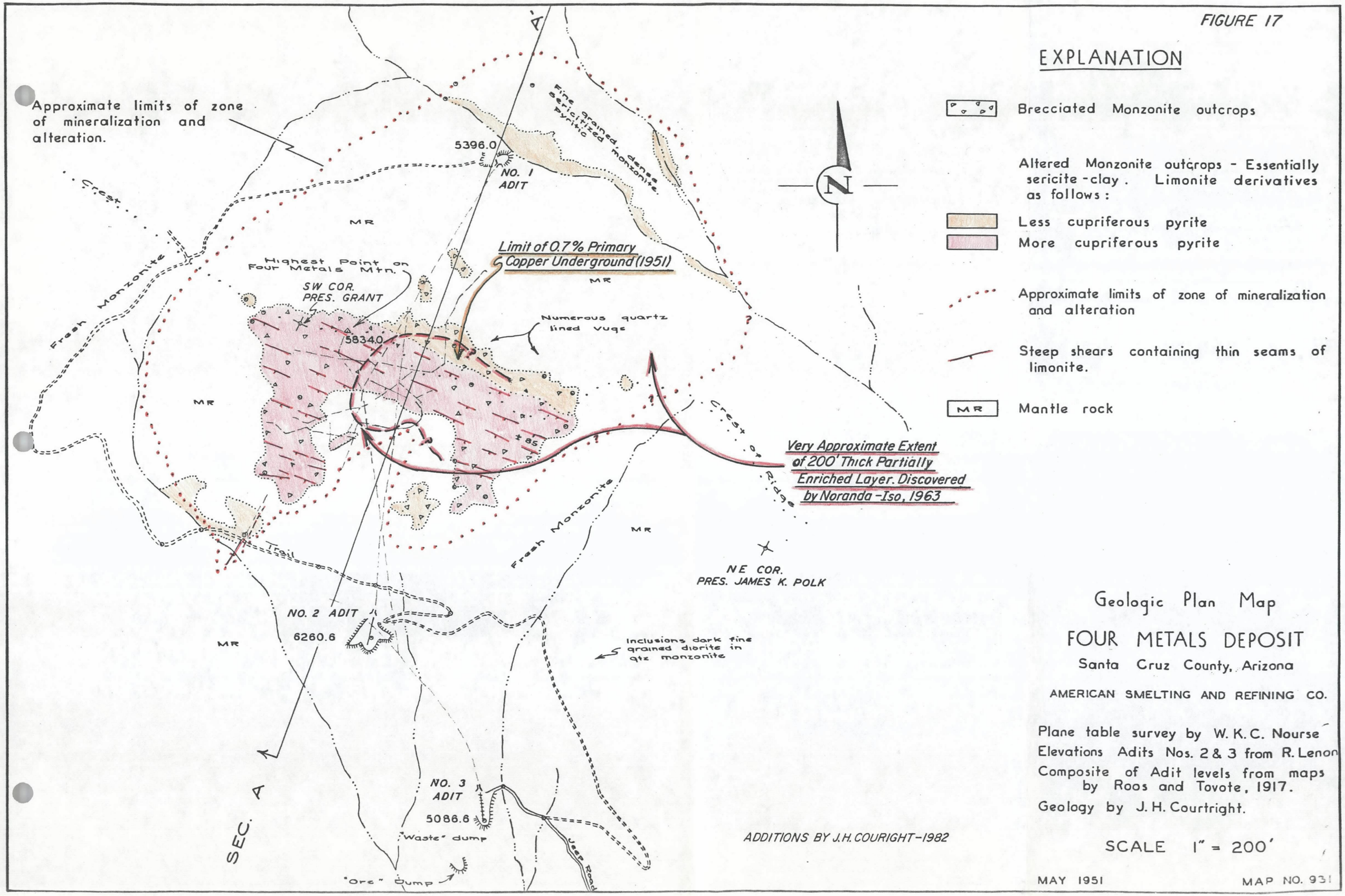
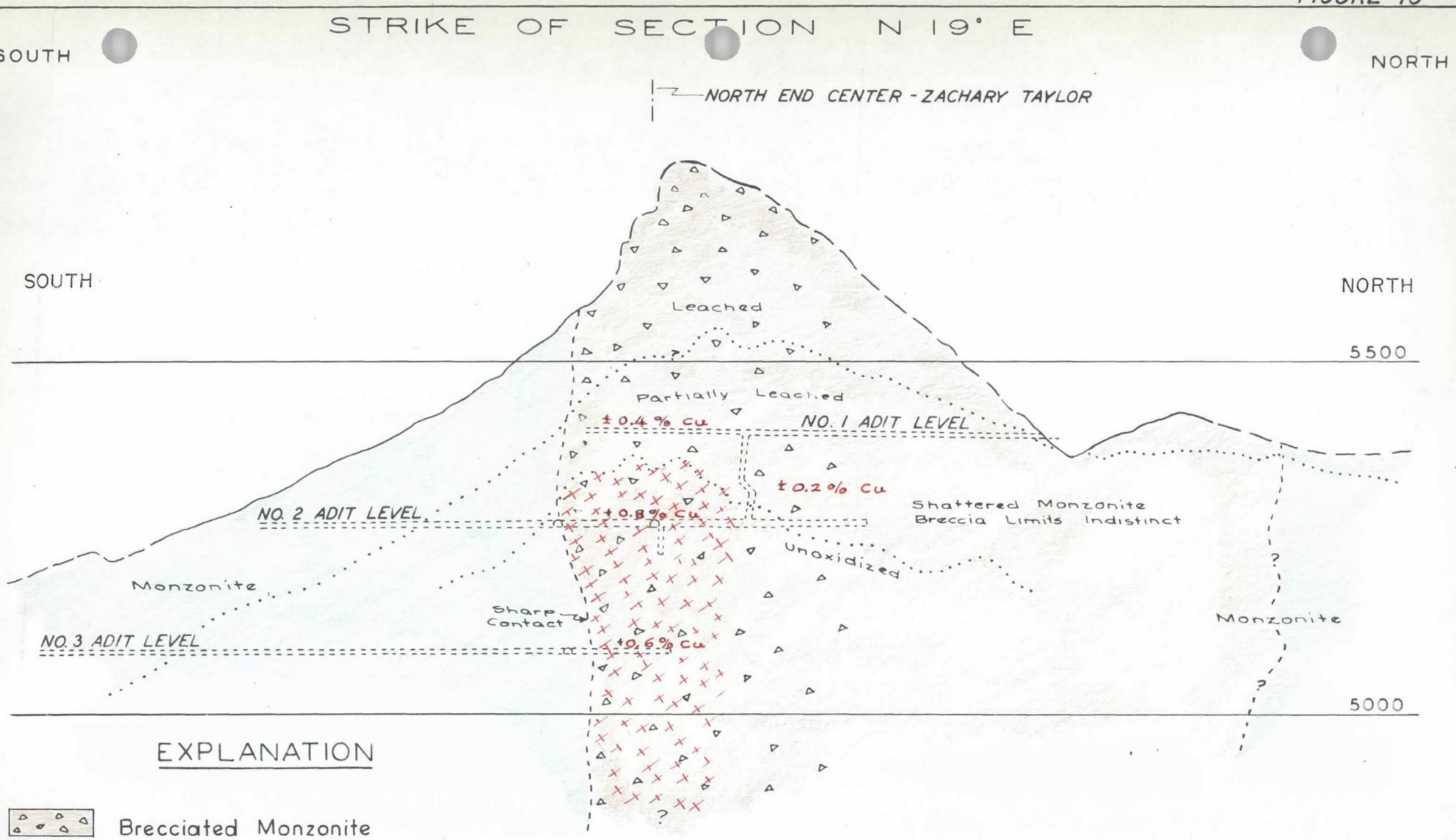

Approximate limits of zone of mineralization and alteration.
A
5396.0
NO. 1 ADIT
Fine grained, dense sericitized pyritic monzonite.
Crest
MR
Limit of 0.7% Primary Copper Underground (1951)
Highest Point on Four Metals Mtn.
SW COR. PRES. GRANT
Numerous quartz lined vugs
5834.0
Fresh Monzonite
Crest of Ridge
Very Approximate Extent of 200' Thick Partially Enriched Layer. Discovered by Noranda-Iso, 1963
Trail
NE COR. PRES. JAMES K. POLK
NO. 2 ADIT
6260.6
Inclusions dark fine grained diorite in qtz monzonite
NO. 3 ADIT
5086.6
"Waste" dump
"Ore" Dump
Jeep Road
SEC. A
ADDITIONS BY J.H. COURIGHT-1982
N
EXPLANATION
Brecciated Monzonite outcrops
Altered Monzonite outcrops - Essentially sericite-clay. Limonite derivatives as follows:
Less cupriferous pyrite
More cupriferous pyrite
Approximate limits of zone of mineralization and alteration
Steep shears containing thin seams of limonite.
MR
Mantle rock
Geologic Plan Map
FOUR METALS DEPOSIT
Santa Cruz County, Arizona
AMERICAN SMELTING AND REFINING CO.
Plane table survey by W. K. C. Nourse
Elevations Adits Nos. 2 & 3 from R. Lenon
Composite of Adit levels from maps by Roos and Tovote, 1917.
Geology by J. H. Courtright.
SCALE 1" = 200'
MAY 1951
MAP NO. 931

FIGURE 18



EXPLANATION

- Brecciated Monzonite
- Zone of Alteration and Disseminated Sulphide Mineralization
- Relatively Fresh Monzonite
- Extent of plus 0.6 % Cu (present essentially as primary chalcopyrite)

Red figures indicate approximate average copper content

SECTION A-A'

Looking Westerly

FOUR METALS MINE

Santa Cruz County, Arizona

AMERICAN SMELTING AND REFINING CO.

SCALE 1" = 200'

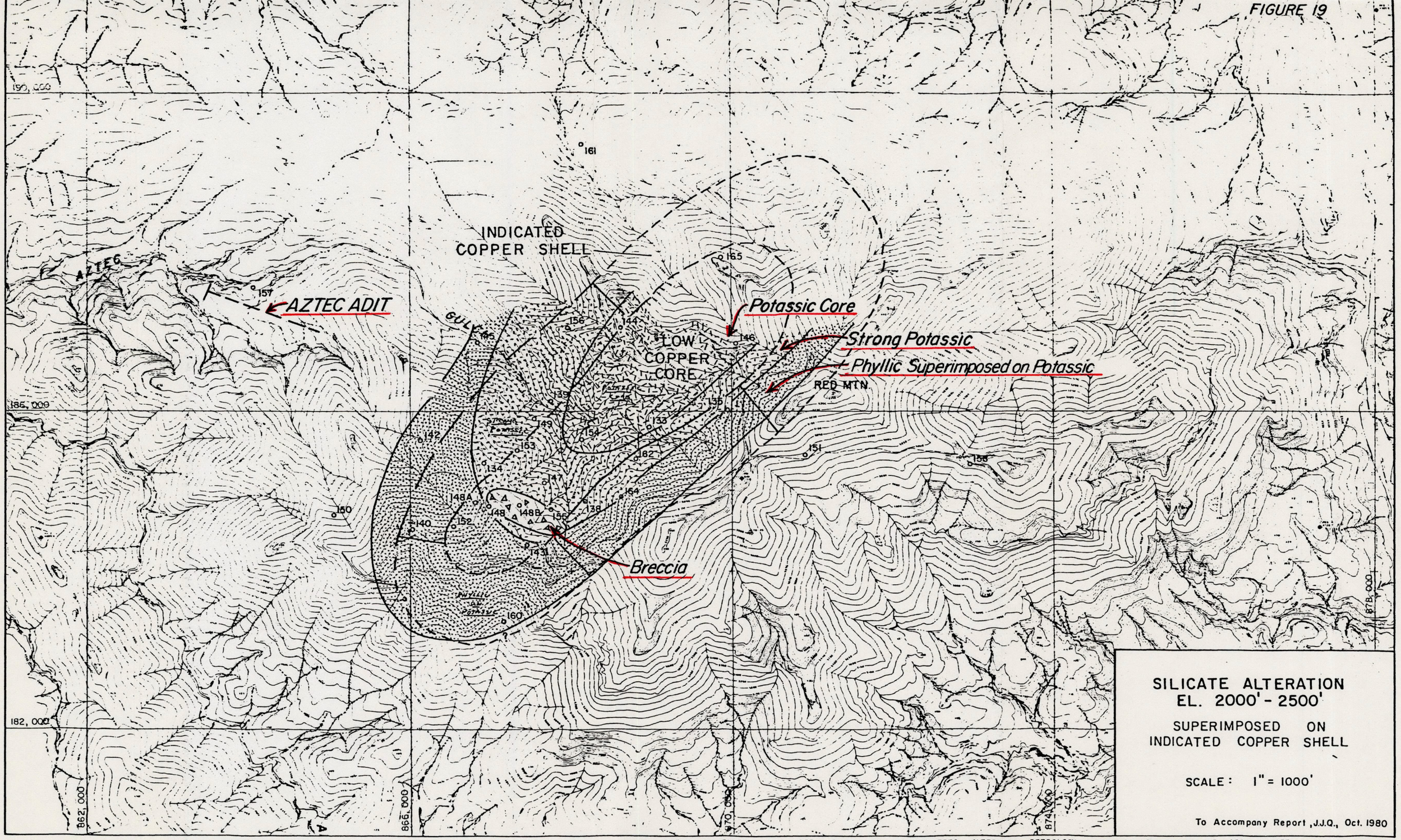
J.H. COURTRIGHT

MAY 1950

MAP NO. 932

FIGURE 18

FIGURE 19



SILICATE ALTERATION
EL. 2000' - 2500'

SUPERIMPOSED ON
INDICATED COPPER SHELL

SCALE: 1" = 1000'

To Accompany Report, J.J.Q., Oct. 1980

AFTER V.L. SMITH, APRIL 1977, BASED ON J.M. GUILBERTS ALTERATION PETROLOGY PROGRESS MEMORANDUM OF APRIL 4, 1977

~~FIGURE 6~~

ADDITIONS BY J.H. COURTRIGHT - 1982

FIGURE 20

EXPLANATION

CORE ZONE ± 0.75% Cu

ENRICHED SHELL 1.25% TO 3.00% Cu

POSITION OF HOLE AT TOTAL DEPTH

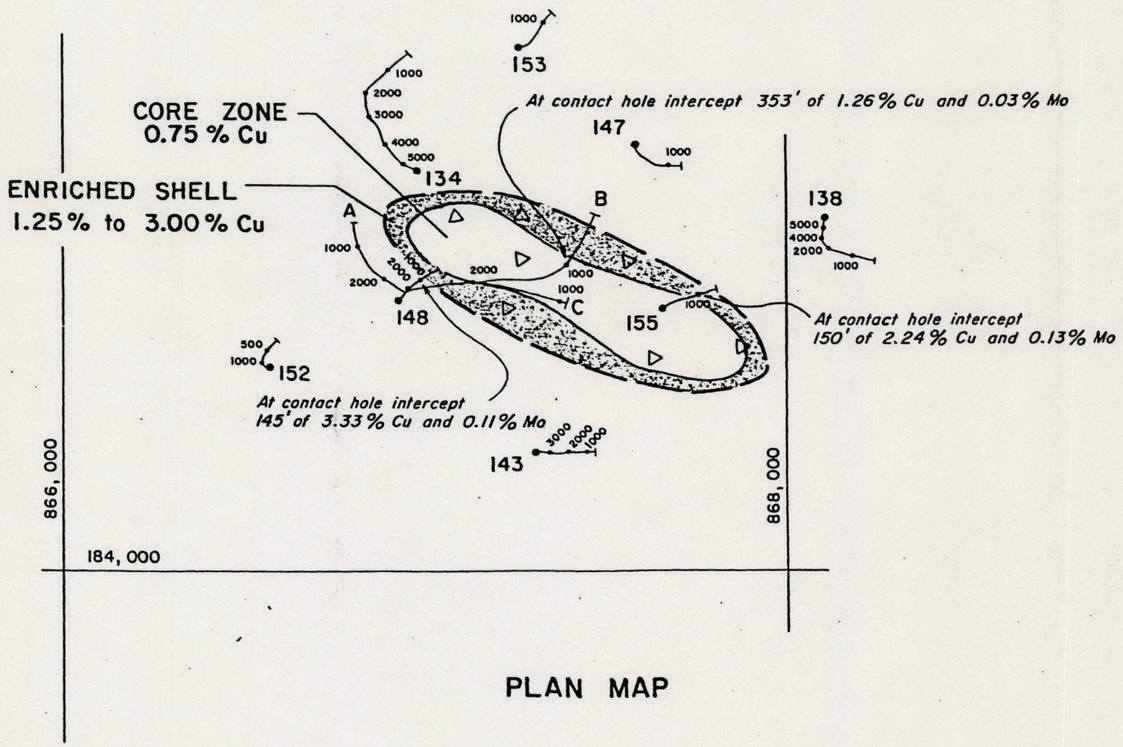
DRIFT OF HOLE SHOWING POSITIONS AT VARIOUS ELEVATIONS

POSITION OF HOLE AT COLLAR

+ 2.0% Cu

1.0% TO 1.99% Cu

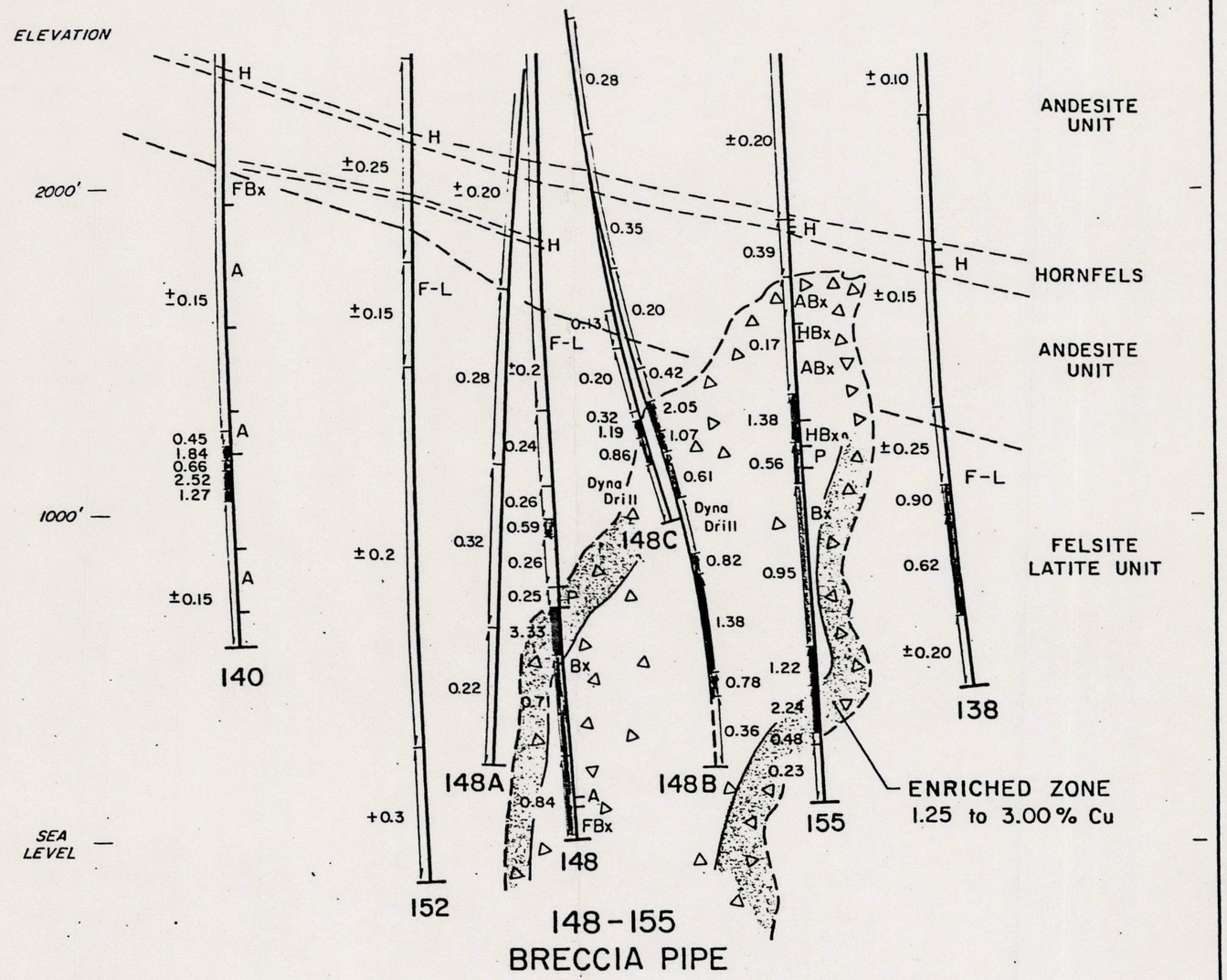
0.5% TO 0.99% Cu



PLAN MAP

FIGURE 12 A

SCALE: 1" = 400'



CROSS SECTION

LOOKING NORTH

FIGURE 12 B

SCALE: 1" = 400'
H = V

PLAN and SECTION
148 - 155 BRECCIA PIPE

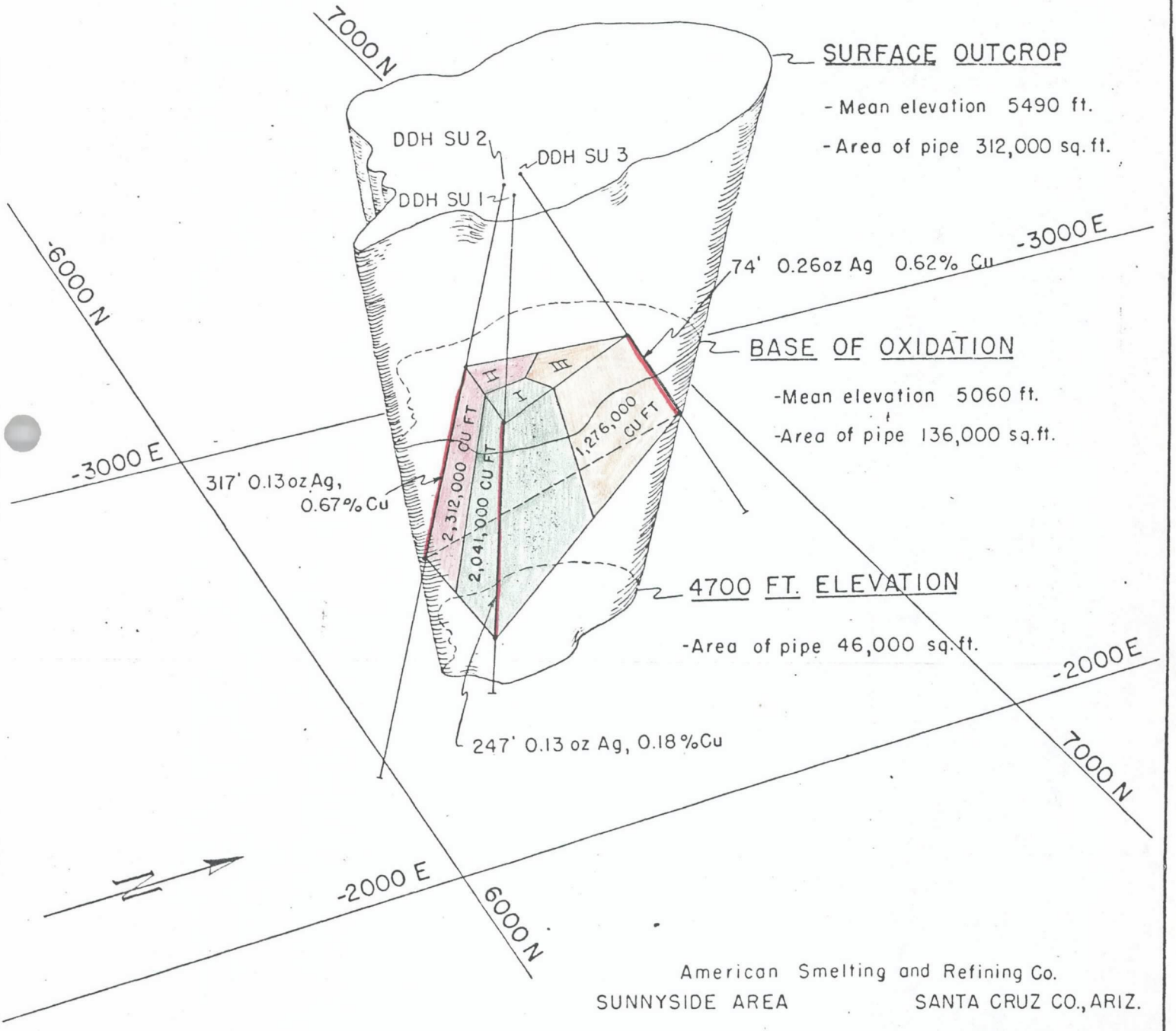
SCALE: 1" = 400'

To Accompany Report, J.J.Q., June 1980

~~FIGURE 12~~

FIGURE 21

LOOKING NORTHWESTERLY



American Smelting and Refining Co.

SUNNYSIDE AREA SANTA CRUZ CO., ARIZ.

ISOMETRIC SKETCH OF BX PIPE

SHOWING METHOD USED IN WEIGHTING DRILL CORE ASSAYS

By: A. L. Payne December, 1951