CONTACT INFORMATION
Mining Records Curator
Arizona Geological Survey
3550 N. Central Ave, 2nd floor
Phoenix, AZ, 85012
602-771-1601
http://www.azgs.az.gov
inquiries@azgs.az.gov

3-10-14.1
Job No 0124

JEK Copy 5
for Cordex

Edwards Copper (CAP No 110-143)
Pima County, Arizona

Preliminary Geologic Evaluation

John E. Kinnison
7/12/76

Mining Geologist
Registered: Arizona
California

JOHN E. KINNISON
5450 N. Bowes Rd.
Tucson Arizona
85715

(602)749-3453

July 12, 1976

Mr. John S. Livermore,
Manager,
Cordex Exploration Company
511 E. 2nd Street
Reno, Nevada 89502

Subject: Edwards Copper Prospect, Pima Mining District, Pima County, Arizona.

Dear Sir:

The following is a review of drilling information and geology on and surrounding the subject prospect, south of Tucson. Data on Anaconda (Anamax) drilling were supplied by Mr. George Edwards, holder of the claims being considered, and by Mr. Vic Crawl, a consulting geologist of Taos, New Mexico. Originally, I had only assay data for holes on the Dynamite group, South of Edwards' claims, which had been recorded as an affidavit of labor. Following our joint meeting of June 19, Mr. Crawl was able to obtain more complete data from Vernon Smith, who holds the Dynamite claims. The old Bear Creek drill data are partly from my personal files, partly from Richard Weaver's 1965 thesis (Univ. of Ariz.), and partly from Bear Creek reports on the Dynamite area drilling.

Interpretations are based on a framework of district geology as described by John R. Cooper (USGS Bull. 1112-C and subsequent Quadrangle map by Cooper and Drewes). I have drawn heavily on my own files and knowledge from detailed work in the district during 1957-60.

Mr. Crawl has cautioned me that, due to legal points of the current litigation between Edwards and Anaconda, now in process of appeal by Mr. Edwards, the Anaconda drill data obtained indirectly during the trial is highly confidential. My report and maps, since they incorporate these data, should not be circulated outside the offices of yourself and your joint venture principals.

ATTACHMENTS

Appendix A: Origin of erratic blocks and breccia, Helmet Fanglomerate, excerpt from Cooper.

Appendix B: San Xavier fault: theory of movement, excerpt from Cooper.

Attachment A: District geologic map: 1" = 1 mile.

Attachment B: Ruby Star Area, geology and drilling interpretation: 1" = 500 ft. (in pocket).

Attachment C: Subsidiary faults in upper plate of a low-angle fault; Ajo, Arizona.

Attachment D: Ore Deposits, showing direction of separation by low-angle fault strands: 1" = 1 mile.

Attachment E: Cross Section A-A': 1" = 500 ft.

Attachment F: Cross Section B-B': 1" = 500 ft.

Attachment G: Cross Section C-C': 1" = 500 ft.

REFERENCES

1. Cooper, John R., Some Geologic Features of the Pima Mining District, Pima County, Arizona, 1960; Geol. Survey Bull. 1112-C, 103 pp.

2. Cooper, John R., and Drewes, Harald, 1973, Geologic Map of the Twin Buttes Quadrangle, Pima County, Arizona; U.S. Geol. Survey Map I-745, Scale 1: 48,000.

3. Kinnison, John E., 1966, The Mission Copper Deposit, Arizona; in Geology of the Porphyry Copper Deposits: Titley and Hicks, pp. 281-87.

SUMMARY OF GEOLOGY; CONCLUSIONS AND RECOMMENDATIONS

The Pima Mining District contains four major copper producing centers: Esperanza/Sierrita, Twin Buttes, Mission/Pima, and San Xavier North. The pre-ore rocks of this district consist of a Paleozoic through Mesozoic sedimentary and volcanic sequence, overlying a basement of Precambrian granite; these strata were complexly folded, faulted, and intruded by granodiorite and porphyry stocks during the Laramide Revolution. Mineralization is closely associated with porphyry, and disseminated copper mineralization occurs in porphyry and in altered sediments and volcanics. Nearly all ore mined from the current open pits is primary; chalcocite enrichment is important only at Esperanza and San Xavier North.

Following mineralization, a thick basin south of Twin Buttes was filled with conglomerates, mudflows, and landslide debris, named the Helmet Fanglomerate. Low-angle faulting tilted the fanglomerate, and effected pronounced displacement of the mineralized zones. Mission-Pima are believed to represent the upper part of the Twin Buttes deposit, which is in the footwall of the San Xavier fault. Displacement of Mission-Pima, in the upper plate, was N-NW a distance of 6½ miles. The San Xavier North deposit may be interpreted as resulting from a 2½ mile displacement from the upper part of the Mission-Pima zone.

Drilling on the property held by Vernon Smith, and on the Anamax (Anaconda) land adjacent on the north, has delineated a zone of primary copper mineralization of sub-marginal tonnage/grade/stripping ratio. This zone is either an imbricate reverse fault in the upper plate of the San Xavier fault, or is a landslide block in the Helmet Fanglomerate. This mineralization will not extend onto the Edwards property to the north and northeast.

Exploration on Edwards' claims would have to be aimed at one or more of the following possibilities:

1. It has been theorized by Mr. Edwards and by Vic Crawl that other mineralized landslide/imbricate fault blocks could exist in the Helmet Fanglomerate. While this is possible, it offers a poor exploration bet, if only from the standpoint that these blocks are steeply inclined, generally thin lenses; and would probably be sub-marginal due to tonnage/stripping ratio considerations.

2. Exploration for a mineralized tactite fault slice (drag), along the path of movement between Twin Buttes and Mission, has also been suggested by Vic Crawl. There is a reasonable hope that such a mineralized slice might be found. Limestone drag slices are present in many areas of the San Xavier fault zone, and one

Anaconda hole near Edwards' ground actually penetrated a thin tactite slice with a strand of high-grade chalcopyrite (hole 981 at 2100 feet.) The problem with this target is that it will represent a tactite zone similar to Twin Buttes and Mission. These open pit mines utilize selective mine planning to keep the average grade of better zones in the .8-1.0% Cu range. If such a deposit exists on the Edwards land, projections of the fault and existing drill hole data indicate that it would be deeper than 2000 feet, and would necessarily be a block-cave proposition. The grade available to a non-selective caving operation would be .6% Cu, and would therefore be marginal, even with $1.00/lb copper.

3. A zone of spotty tactite mineralization in the footwall of the San Xavier fault, with weakly mineralized porphyry intrusives, appears to project towards the eastern block of Edwards' claims. Moreover, a single penetration of tactite (without evidence of sulphides) was made in the southeast corner of the Edwards east block (hole 442). If these occurrences are the fringes of an unexplored center of copper mineralization in the footwall of the San Xavier fault, this new center would probably lie beneath Edwards' eastern group of claims. The risks here are that (1) these occurrences of tactite and porphyry may only be isolated deposits satellitic to the large Twin Buttes deposit to the south, and that (2) the primary mineralization may not be block-cave <u>ore</u>, even if such a new and separate center exists.

Exploration possibility No. 3, above--despite the risks involved--in my opinion has sufficient merit to warrant two rotary holes to a maximum of 1000 feet, followed by diamond drilling in bedrock for a distance of 500 feet in each hole. The first hole would be near the Sahuarita Road about 1500 feet N 45° W, from Anaconda hole 442. Bedrock beneath Helmet Fanglomerate should be less than 1000 feet at this location, if the San Xavier fault dips as expected. The second hole also would be along the Sahuarita Road, about 2000 feet W-SW from No. 1. If either hole encounters mineralization, a decision to continue or not, into the area of deeper bedrock, would then be made on the strength of drilling information obtained.

The contract cost of two 1500 foot holes would be about $30,000. A further investigation of drilling methods and costs can be made if the project is undertaken.

These recommendations, of course, are predicated on the assumptions that a land and legal investigation will confirm the Edwards property status, and that a reasonable deal can be negotiated with Mr. Edwards.

LOCATION

The Pima Mining District is about 20 miles south of Tucson, Arizona. The elevation is from 3000-3800 feet, and the topography consists of a low rolling pediment with a few higher hills, which merges easterly into an alluvial desert slope.

The Edwards prospect is 3 miles north of the Twin Buttes open pit (Anamax), and about 3 miles south of the Mission-Pima pits.

LAND STATUS

The location of the Edwards unpatented mining claims (Atts. A, B, D) was taken from maps supplied by Mr. George Edwards, and is in substantial agreement with a map prepared by Anamax, which controls the ground surrounding Edwards' claims. The location of Vernon Smith's Dynamite group is also from the Anamax map.

The land held by Wilson, Chilson, and Todd, west of Edwards' claims, has not been found delineated on any of the claim maps in my private files. It formerly included the area around the old Paymaster mine, and included also the Continental materials deposit. The names of the claim groups, in 1957, were the Colorado, Utah, and Nevada. Additional land may have been subsequently acquired, and some may have been sold to Anamax.

I determined, while obtaining assay data filed as public record for the Dynamite group, that the Hanna Mining Company's option on those claims apparently was terminated about 1970--which has been verified by Vic Crawl. No title or claims search as such was made, however, for this report. I am not informed of the current status of the Chilson-Todd group.

The attachments show the old Anaconda-Banner holdings simply as "Anaconda." These properties are all now under the control of Anamax, the operating corporation held jointly by Amax and Anaconda. The Banner Mining Company was merged into Anamax.

GENERAL GEOLOGY

Pre-Mineral Rocks:

The stratigraphic column of the Pima District records a complex history, here briefly summarized.

Older Precambrian granite is the basement rock, and underlies the Cambrian Bolsa Quartzite. Near Mineral Hill and Twin Buttes (refer to Att. A as necessary for geolographic names and general geology) the granite displays intricate "intrusive" relationships with the overlying lower Paleozoic section. These anomalous contacts are probably the result of plastic flow under compressional stress, and may account for the unusual K-Ar age date published for this unit (850 m.y.).

The Paleozoic section is dominantly limestone, with minor quartzite. About 5000 feet of sediments are represented.

Mesozoic rocks are represented by a thick sequence of redbeds and volcanics of Triassic/Jurassic age, which were folded prior to the Cretaceous period. The Cretaceous beds are arkoses and quartzites, folded and distorted during the Laramide revolution.

The Late Cretaceous and Early Tertiary (essentially "Laramide") are represented by volcanics and by igneous intrusives. The Ruby Star Granodiorite is an early phase granitic stock, and was followed closely by intrusion of small bodies of quartz monzonite porphyries. Ore deposition was the last event of the Laramide, and is closely related to the porphyry bodies. The granodiorite is not spatially associated with major mineralization, and for the most part is a barren rock.

Post-Mineral Rocks:

The Helmet Fanglomerate of middle Tertiary age is an important formation with respect to structural interpretation of the Pima District. It is a coarse, generally ill-sorted conglomerate, probably of an alluvial fan environment; many of the beds are mudflows. It is entirely post-mineral, and contains all of the older rocks of the District. An andesite flow, in the lower half of the formation, interrupted deposition only briefly. This volcanic, locally named the "Turkey Track Andesite," yields K-Ar dates of 28-31 m.y. The entire Helmet Fanglomerate is evidently older than rhyolitic to andesitic flows to the south, which are dated at about 24 m.y.

An outstanding feature of the Helmet is the presence of evidently interlayered lentils, and oval shaped, wide bodies of rock. These are usually monolithologic, in the sense of representing an identifiable stratigraphic unit or sequence. The Paleozoic limestones and quartzites are generally brecciated, but the fragments are neither rotated nor moved. The larger, more complex blocks, such as the one at the Continental Materials deposit (consisting of Cretaceous arkose overlying Paleozoic limestone) are less noticeably brecciated.

Appendix A, reproduced from Cooper, discusses these "erratic" breccia blocks. He concludes--correctly, I believe--that they are huge landslide blocks.

The thickness of the Helmet can be only approximated. Part of its present dip may be original dip; and there may be subsidiary faults in the upper plate of the major San Xavier fault. Both features tend to expand the apparent thickness of the formation. Duplication of fanglomerate beds in the upper plate of a regional low-angle fault is illustrated by Att. C, which is a portion of an interpretive section based on work I have done near Ajo, Arizona.

Imbrication may also take place in the upper plate, of course, and would tend to shorten the apparent thickness.

The point that the unit is a thick accumulation, however, is well taken; even if Cooper's 10,000 ft. estimate is too high (Appendix A), the formation must certainly be at least 5000 feet thick. It was deposited in a basin, probably tectonic in origin, south of the Twin Buttes deposit, and has been shifted to its present position by northward movement in the upper plate of the San Xavier fault.

ORE DEPOSITS

The major deposits are all of the porphyry copper type. The Mission, Pima, and Twin Buttes deposits are primarily in a lime silicate (altered Paleozoic) host, and in Mesozoic argillite and arkose. The porphyry intrusives in these deposits are typical of many protore porphyry copper zones, whereas the production is made from higher grades of chalcopyrite mineralization in tactite (or skarn) and in altered argillite. The porphyry at Mission grades .15-.20% Cu, and the porphyry at Twin Buttes, within the pit, grades .20-.25% Cu. Much of the deep potential ore at Twin Buttes is in porphyry, grading less than .7% Cu. I have not been able to get a firm statement concerning the Twin Buttes porphyry grade--it could be as low as .5 or .6% Cu.

For reference, the detailed description of the Mission deposit in my 1966 paper is a fair representation of the character of ore deposits at both Pima and Twin Buttes.

THE SAN XAVIER FAULT

The most important structural feature of the district is the San Xavier fault--a low-angle fault zone which has sliced across and drastically shifted the mineral deposits of the district.

It was named the "San Xavier Thrust" by John Cooper in his Bull. 1112-C (1960), but the non-genetic term "fault" is here substituted, in recognition of its uncertain origin.

By recognizing a crude "match" of geologic features in the upper and lower plates, Cooper postulated a N-NW movement of $6\frac{1}{2}$ miles, and suggested that the Mission-Pima deposits might have their footwall counterparts located beneath alluvial cover east of the old Twin Buttes underground mines (Glance and others.) Subsequent exploration did, in fact, discover the Twin Buttes open pit ore body.

Cooper's reasoning is reproduced in Appendix B. He describes, in detail, the features within a larger structure which is essen- a breached and faulted anticline, plunging southeast, with a Pre-cambrian granite core and overturned beds on the northeast limb. In the upper plate, the axis of the anticline extends from the granitic core south of Mineral Hill, southeast through Helmet Peak. The axis of its lower plate counterpart trends southeast through the granite core separating the Contention and Glance Mines. In addition to the matching mineralization noted by Cooper, the Pb-Ag zone represented by veins in andesite at the Paymaster-Olive Camp areas in the upper plate, find footwall representation at the old Calamina-Esperanza southwest of Twin Buttes. That part of the upper plate which contained the Esperanza-Sierrita deposits has been eroded from the area west of the Paymaster.

The upper plate is no doubt complex. In addition to possible reverse or imbricate faults at Pima, and possibly on the Dynamite claims, subsidiary strands parallel or convergent into the San Xavier fault probably exist (as illustrated by Att. C). Drilling data indicate that the San Xavier North deposit may be faulted along a convergent strand, from a previous position above the Pima deposit.

The post-ore age of the San Xavier fault has been attacked by some geologists. I believe, as did Cooper, that it is entirely or largely post-Helmet Fanglomerate, and therefore entirely post-mineral.

Where the fault passes from a lower plate of granitic rocks, to the Paleozoic section near Twin Buttes, uncertainty exists in the details of interpretation. Some of these problems are illustrated by the drilling map (Att. B) and cross-sections (Atts. E, F, and G.)

EXPLORATION POSSIBILITIES

General:

An assessment of the exploration potential of the Edwards' claims rests on the interpretation given to drilling results south of Edwards, on the Dynamite claims (Vernon Smith) and on Anamax land. Some old Bear Creek drill results are also available in this area.

Attachment B shows the drilling data in summary form, outcrop patterns, and sub-surface interpretation. Due to space limitations, geology for the Dynamite drill holes is shown only on the cross-sections.

Section B-B' (Att. F) indicates a well-established dip, in this area, of the San Xavier fault. A barren limestone fault slice separates two strands of the fault, and correlates with limestone which crop out to the west (Atts. A and B), along the fault zone. The dip is principally to the north, although an easterly component is also evident from drill hole data.

To the east of section B-B', drilling results are not so easily interpreted. There is more than one way, even, to interpret the dip of the fanglomerate-limestone contact. I have identified the San Xavier fault with a measure of uncertainty, as in the Dynamite area there are two low-angle contacts which bring, on one hand, Helmet Fanglomerate above the Ruby Star Granodiorite, and on the other, limestone above "granite."

Cross section A-A' illustrates the Dynamite/Anamax deposit, and the San Xavier fault projected northerly. This deposit may be interpreted wholly as a landslide block, possibly modified by a bedding plane fault at the base of the block. Alternately, it may be an imbricate limestone fault slice, derived either from a mineralized drag lens along the San Xavier fault (from the Twin Buttes deposit), or from footwall mineralization such as penetrated by T-67 (and outlined in green on Att. B). Valid arguments may be made for both cases, as we discussed at our meeting with Vic Crawl, and by telephone. The brecciated upper part of most of the drill penetrations into the limestone block are characteristic of the landslide lentils, and lend weight to that interpretation.

The interpretations shown by Attachment G, section C-C', are even more tenuous. I reached this interpretation with the help of a pencil-sketch contour map on the base of the Helmet Fanglomerate, which is not here reproduced. The high-angle faults which offset the San Xavier fault trend northwest, as shown by Att. B. The basal fault in hole A-974 is not understood--nor is there evidence of its age relative to mineralization.

Exploration Targets:

Regardless of the interpretive difficulties, some of which were discussed in the foregoing, some specific conclusions may be made. These have been reviewed under Conclusions in the first part of this report.

1. It should be clear that the Dynamite deposit will not extend up-dip onto the Edwards claims. I do not recommend exploration in search of other "erratic" blocks, be they of landslide origin, or fault slices.

2. Hole A-973 penetrated a mineralized fault drag lens, according to the interpretation shown by section A-A'. Hole 981 certainly did (see Att. B). It is reasonable to believe that the same or other mineralized fault slices could be found by drilling along the apparent path of movement from Twin Buttes to San Xavier North (Att. D). The Edwards ground covers part of this prospective zone. I do not recommend drilling for this target, for reasons stated under "Conclusions and Recommendations."

3. Under "Conclusions and Recommendations," I have suggested a minimal effort toward exploration of possible lower-plate mineralization. Evidence that mineralization actually extends as far as Edwards' ground is lacking, and the projections made are tenuous. On Att. A I have inferred that limestone may underlie the San Xavier fault in the east group of Edwards claims. The real hope would be to find a well-mineralized porphyry instead of tactite mineralization, and on this point there is little if any sound evidence. Should the Ruby Star granodiorite mass extend that far east it would probably be barren, and the Precambrian granite--which would be a good host for uniform mineralization--is probably too far north.

On the plus side, the Pima District is certainly a "major" in terms of pounds of copper in reserve, and production; therefore I must regard the possibility of a new copper center, in this district, with cautious optimism. The cost of drilling, to provide more specific data on which to base a decision regarding a more extensive program, appears acceptable relative to risk. These long-shot ventures are now being commonly undertaken by serious exploration competitors in the Arizona copper province.

Yours very truly,

John E. Kinnison

Registered Geologist
CERTIFICATE EXPIRES
John E. Kinnison
DEC. 31, 197_
ARIZONA, U. S. A.

MONOLITHOLOGIC BRECCIAS

The lenses and tongues of breccia here interpreted as part of the Helmet fanglomerate characteristically consist of recemented breccia derived from a single pre-Helmet formation. Some breccia bodies consist of parts of two or more formations (pl. 1). In many parts of the breccia, it is clear that individual fragments have moved by rotation and translation with little if any churning movement. Formational contacts and even small-scale features like individual beds can be traced through intensely brecciated rock. To preserve these primary features, the entire mass of breccia must have been emplaced in essentially one piece. Landslides are probably the principal emplacement mechanism.

A landslide origin is best established for thin lentils wholly surrounded by conglomerate. The largest and best exposed of these lentils forms a low ridge 1½ miles south-southeast of Helmet Peak. This lentil is a few feet to about 200 feet wide and at least 3,500 feet long. The total length is not known as the eastern end is concealed by alluvium. The lentil is composed of brecciated and recemented beds of the Scherrer formation and the Concha limestone. The contacts between individual beds and between the two formations are still discernible and are parallel to the long axis of the lentil. The breccia fragments are rarely more than a few inches in diameter. Both contacts of the lentil are exposed and dip southeast parallel to bedding in the conglomerate. Although minor slippage may have taken place along the contacts, there is no evidence of large fault movement.

Other thin lentils of brecciated Paleozoic and Cretaceous (?) rocks and of granodiorite are found in the fanglomerate, but many of these lentils are too poorly exposed to map. Boulders of the same rock type that makes up the lentil are commonly abundant in the conglomerate on strike with the lentil, suggesting that the lentil was emplaced while the conglomerates were accumulating. The only alternative to contemporaneous emplacement, emplacement by post-Helmet faulting, is improbable. The concordance of the lenses and their small to moderate size and wide geographic and stratigraphic dispersal are difficult to explain by faulting. Furthermore, stratigraphic markers in the fanglomerate, such as the andesite flows and the lower red unit, are not repeated as one would expect if post-Helmet faulting had been involved.

Concordant tabular masses of monolithologic breccia that resemble the lentils just described have been reported from many localities in and on the valley-fill deposits of northern Arizona, southern Nevada, and southern California. In all the descriptions that I have found, the breccia masses have been interpreted as contemporaneous in origin with the deposits that contain them. Some have been interpreted as remnants of thrust plates that rode on the surface and as huge blocks that were shoved by such thrust plates (Longwell, 1949, p. 935, 947–50). Others have been interpreted as landslides, some of which moved 5 miles or more from their source (Woodford and Harriss, 1928, p. 279–290; Noble, 1941; Jahns and Engel, 1949, 1950; Longwell, 1951). The recent slides evidently broke off active fault scarps (Longwell, 1951) and off thrust plates that were moving on the surface (Woodford and Harriss, 1928, p. 289–90). The source of the older slides is obscure.

55

The thin lentils in the Helmet fanglomerate are similar to each other and probably have a similar origin. None of them is thick enough to transmit the force necessary to have shoved it into place. If there were only one lentil, one might suppose that it was part of a much thicker thrust plate that was eroded before burial. To assume many thrust plates all deeply eroded before burial is to stretch geologic probability beyond its limits. The most likely interpretation is that the lentils represent landslides.

The monolithologic breccias here assigned to the Helmet fanglomerate (pl. 1) include some large masses of breccia for which a landslide origin is only tentatively suggested. Near the base of the formation are large outcrops of arkose and granodiorite breccia. The distribution of these outcrops suggests that they are parts of a single body of breccia 10,000 feet long and as much as 4,000 feet wide, offset by the Ruby fault. At both ends, the body appears to lie within the red unit of the fanglomerate. In lithology, shape, and apparent geologic relations, the body resembles the probable landslide block in the SW¼ sec. 23, T. 17 S., R. 12 E. Furthermore, it appears to be out of place with respect to the pre-Helmet rocks to the north.

Interpretation of the large body as a landslide block is doubtful because it is less thoroughly brecciated than smaller landslide bodies, and some of the brecciation was pre-Helmet; it is unusually large for a landslide; and it lies so near the bottom of the Helmet that it can be interpreted as part of the basement on which the fanglomerate was deposited. In the NW¼ sec. 22, T. 17 S., R. 12 E., unbrecciated granodiorite cuts arkose breccia. In a contact hornfels zone several feet wide, the breccia has been healed by recrystallization and contains porphyroblasts of biotite and alkalic feldspar. The brecciation at this locality was older than the granodiorite, and does not indicate structural disturbance during Helmet time. If the body was emplaced as a single landslide block, this block was at least 10,000 feet long and 3,300 feet thick. Landslides of such dimensions are difficult to comprehend but probably could take place in front of large fault scarps or thrust plates moving on the surface. The mass could be a composite of several slides, but no field evidence suggesting this has been recognized.

Possibly the large outcrops of arkose and granodiorite breccia are not part of the Helmet fanglomerate but are part of the basement on which the fanglomerate was deposited. They could represent steep pre-Helmet hills that were buried by the fanglomerate; or they could have been emplaced by unrecognized intra-Helmet or post-Helmet faults.

In the SE¼ sec. 21, T. 17 S., R. 12 E., the red unit and part of the brown unit of the fanglomerate interfinger with thoroughly brecciated Cretaceous(?) rocks (pl. 1). The breccias are here interpreted as a composite of small landslides and possibly talus accumulations of Helmet age. The outcrops are poor, and some of the fingers could represent post-Helmet fault wedges. A great deal of brecciation and shearing is related in space to the San Xavier thrust, and some of the breccias tentatively assigned to the Helmet in this area are unquestionably thrust breccias, at least in part.

THICKNESS

The apparent thickness of the Helmet fanglomerate exposed south of Helmet Peak is about 10,500 feet. This section includes all parts of the formation exposed in the Pima district, but the section is faulted off at the top and therefore stratigraphically higher beds of unknown thickness and character are not represented.

No major faults duplicate the section, for the stratigraphic units—the red unit, andesite flows, brown unit, and gray unit—are not repeated. Major strike faults that cut out beds could exist, but none have been recognized. Small shear zones marked by concentrations of calcium carbonate cut the fanglomerate at some places, but neither the amount nor the direction of movement along them is known. Tiny faults offset some of the boulders (pls. 3 and 5, p. 97–98). Some of these faults would lead to overestimation and others to underestimation of the stratigraphic thickness. If the localities discussed on pages 97–98 are representative, the faulting would lead to slight overestimation, perhaps by 2 or 3 percent.

ORIGIN

The Helmet fanglomerate probably formed as fan deposits near the base of a tectonically active mountain mass. The predominant conglomerate facies is ill sorted, ill bedded, and characterized by angular to subangular fragments, suggesting rapid deposition near the source. The largest boulder found measured 8 by 7 by 4 feet and was evidently larger originally, for fragments recently broken from it littered the arroyo channel beneath the outcrop. A heterogeneous mixture of such large fragments with others as small as granules, all in an abundant fine-grained matrix, suggests emplacement as mudflows. The nearly monolithologic conglomerate units can be interpreted as mudflows or torrential stream deposits of localized source, and possibly as a result of interfingering of material from adjacent drainage channels.

Sedimentary structural features that might reveal the direction from which the material was carried are very scarce in the conglomerates. No crossbedding was found. At one locality, obscure imbrication suggests movement from the west, but in general the formation is too poorly bedded to determine whether the arrangement of the fragments is imbricate. Two shallow filled channels were found, which plunge S. 40° W. and S. 5° W., respectively. (See pl. 2.) If the bedding at the two localities is restored to an assumed original horizontal position by rotation about an axis parallel to the strike, the two channels trend S. 30° W. and S. 3° W., respectively. These few data suggest a source to the west or southwest.

While the conglomerates were accumulating, great masses of rock occasionally broke from the tectonically mobile source area and slid down the fan surface. These landslide blocks were buried by conglomerate and now appear as lentils and tongues of monolithologic breccia.

At one stage, porphyritic andesite lavas were poured out over the fan surface. Slightly later, thin interbeds of tuff and tuffaceous sediment were deposited as a result of explosive and probably more distant eruptions of rhyolitic rock.

The distribution of landslide material and the regional variations in the texture and composition of the conglomerates tend to confirm that the source area was to the west, and probably not far away. Landslides make up an increasing proportion of the formation toward the west; this increase strongly suggests a nearby source in that general direction. Tongues of breccia in the westernmost exposures could even represent ancient talus accumulations. A greater proportion of the conglomerates are monolithologic toward the west, and this further suggests a western source. In drill holes that have penetrated the formation northeast of its area of outcrop, the conglomerates are generally finer textured than those exposed. Evidently the source was to the west, but whether to the southwest, west, or northwest is not revealed by these data.

AGE AND CORRELATION

The only fossils that have been found in the Helmet fanglomerate are in boulders and breccia fragments, and are of Paleozoic age. Obviously these fossils indicate the age of the source rocks. Conclusions regarding the age of the fanglomerate must depend on lithology, geologic relations, and correlation with formations that can be dated by direct evidence.

The fanglomerate is younger than the ore deposits of the district and older than a subsequent orogeny. The fanglomerate contains boulders of the Late Cretaceous or early Tertiary intrusive bodies and of altered and mineralized Paleozoic and Cretaceous(?) rocks, indicating that these rocks were in existence and had been exposed by erosion at the time the fanglomerate was deposited. The fanglomerate now dips steeply and is cut by large faults, one of which, the San Xavier thrust, is of regional importance. The beds strike east-northeast at a large angle to the younger Basin-and-Range trend, which is northwest. The overall geologic relations suggest the fanglomerate is of middle Tertiary age.

The Helmet fanglomerate almost certainly correlates with the Pantano formation of Brennan,[3] which has its type section about 25 miles southeast of Tucson. This formation is described as a thick deformed sequence of conglomerate, sandstone, siltstone, mudstone, and scarce argillaceous limestone, with intercalated andesite flows which are lithologically like the flows in the Helmet. The pebbles and boulders are predominantly of Cretaceous(?) arkose, sandstone, and volcanic rocks. Boulders of Paleozoic limestone also are present. Schwalen and Shaw (1957, p. 15–22) present evidence that beds like the Pantano probably underlie the central part of the Santa Cruz valley beneath the cover of younger alluvial deposits. The data suggest that the Helmet and Pantano are essentially contemporaneous and are continuous beneath the younger valley fill. The Helmet evidently was deposited nearer the source than the Pantano.

In the San Pedro valley south of Redington (fig. 15), deformed fan deposits have yielded a lower Miocene rhinoceros. These beds resemble the Pantano lithologically and are cut by dikes of andesite macroscopically identical with the flows in the Pantano formation and Helmet fanglomerate. Boulders of the andesite in beds associated with the deformed fan deposits south of Redington suggest that andesite and these fan deposits are nearly contemporaneous (John F. Lance, 1958, oral communication). Tentative correlation of the Pantano, the Helmet, and the deformed fan deposits seems justified. If this correlation is correct, the Helmet fanglomerate is of early Miocene age.

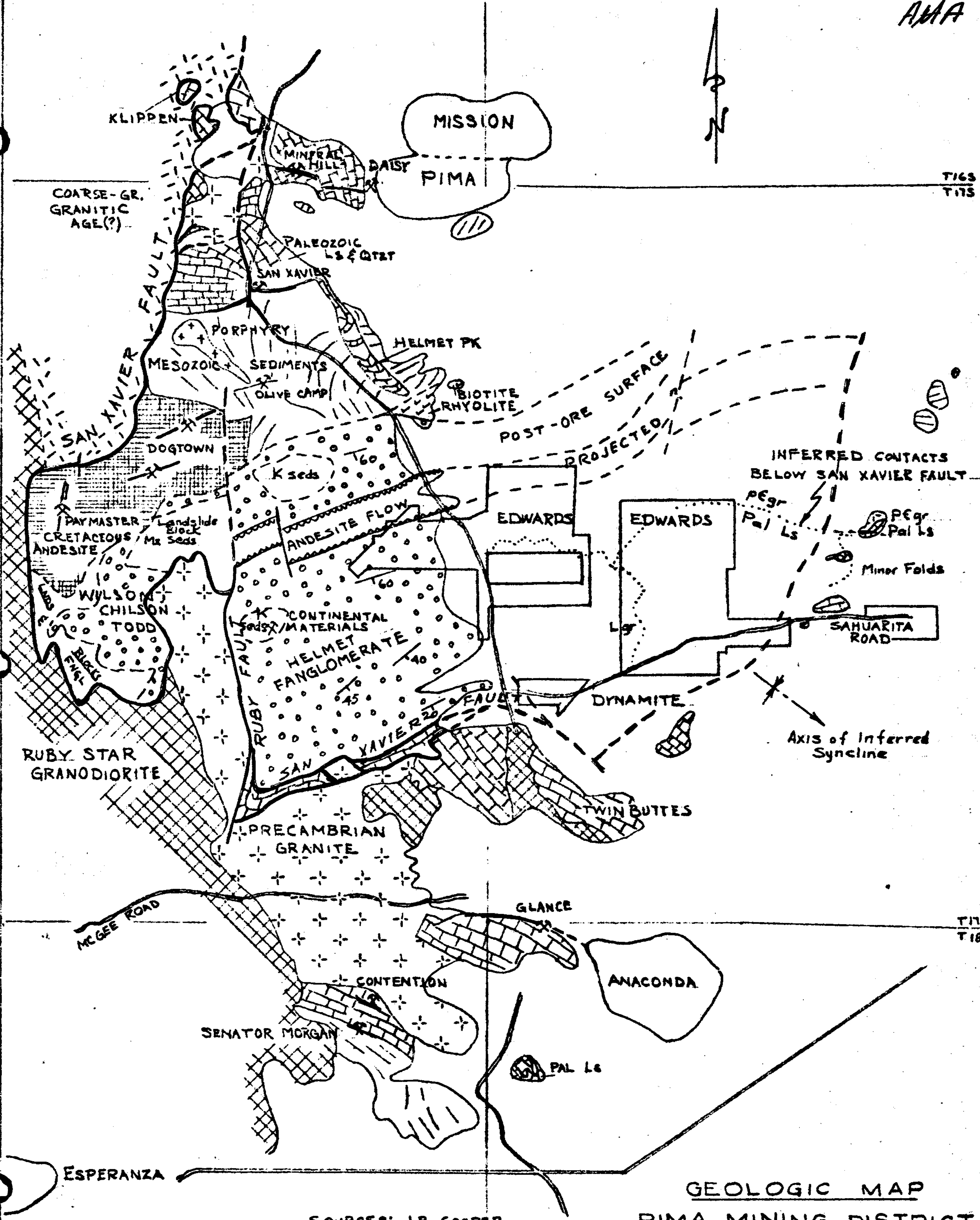
HYPOTHESIS REGARDING DISPLACEMENT

The various suggestions of the direction of movement on the San Xavier thrust are compatible with each other and are also compatible with an hypothesis regarding displacement, suggested by certain similarities in the geology of the Mineral Hill–Helmet Peak area and of the area south of Twin Buttes. The hypothesis is that the exposed part of the San Xavier thrust plate originally lay south of Twin Buttes and has been displaced about 6½ miles to the north-northwest in the direction suggested by faulting of boulders in the Helmet fanglomerate.

The hypothesis requires that prethrust rock units and structural features exposed in the Mineral Hill–Helmet Peak area have their roots south of Twin Buttes. To test whether this is probable or possible, one must imagine that the thrust plate is restored to its hypothetical source. If this is done, there is a crude match in the following geologic features:

1. The anticline on Helmet Peak would correspond with the anticline exposed in the isolated outcrop about 1½ miles southeast of Twin Buttes village. Drag folds suggest that the anticline southeast of Twin Buttes plunges about 25° SE. The Helmet Peak anticline plunges about 60° SE. (See table 5.) The Paleozoic rock in the two folds is not greatly metamorphosed and still contains recognizable fossils. The beds exposed in the Helmet Peak anticline (Concha limestone, Scherrer formation, and upper part of Colina limestone) are stratigraphicaly above those exposed in the anticline southeast of Twin Buttes (lower part of Colina limestone and upper part of Earp formation).
2. The Paleozoic rocks forming the hills near San Xavier would correspond with those containing the Senator Morgan and Contention mines. These rocks are much metamorphosed and contain the only significant concentrations of zinc in the district—at the San Xavier and San Xavier Extension mines in the thrust plate and at the Contention mine in the hypothetical footwall block.
3. The Paleozoic limestones of Mineral Hill would correspond with those immediately south of Twin Buttes village. These limestones are much metamorphosed and contain important copper deposits—the Mineral Hill, Daisy, and Pima deposits in the thrust plate and the deposits at the Minnie, King, Queen, and Glance mines in the hypothetical footwall block.
4. The Paleozoic rocks at the Mission deposit (Richard and Courtright, 1959, p. 201) would lie on the projection of the outcrops of Paleozoic rock northeast of Twin Buttes village.
5. The Cretaceous(?) rocks south and southwest of San Xavier would correspond with those south and southwest of the Senator Morgan mine. These rocks include arkose on the northeast and andesite on the southwest, and they contain small vein deposits of silver, lead, and zinc.
6. The Precambrian granite full of included material southwest of Mineral Hill would correspond with that west and southwest of Twin Buttes.

The two outcrop patterns do not match perfectly, nor should they be expected to do so. According to the hypothesis, the bottom of the thrust plate once matched with the footwall block along a shear plane that was an unknown distance above the present surface of the footwall block. To assume that the outcrop patterns should match perfectly is like assuming that the surface geology over a mine should match perfectly with the geology of a very deep level. Furthermore, the thrust plate probably contains unknown imbricate thrusts, tear faults, or other structural complications formed during the thrusting and confined to the thrust plate; such structural features would tend to obscure an original match.



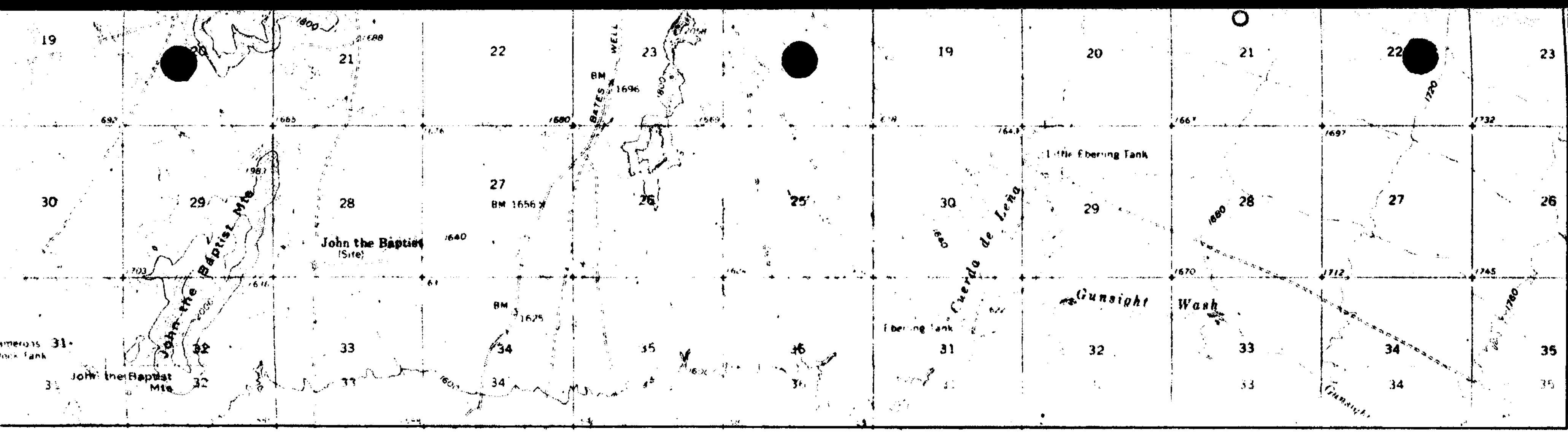
SOURCES: J.R. COOPER, H. DREWES, J.E. KINNISON

GEOLOGIC MAP
PIMA MINING DISTRICT

1 inch = 1 mile

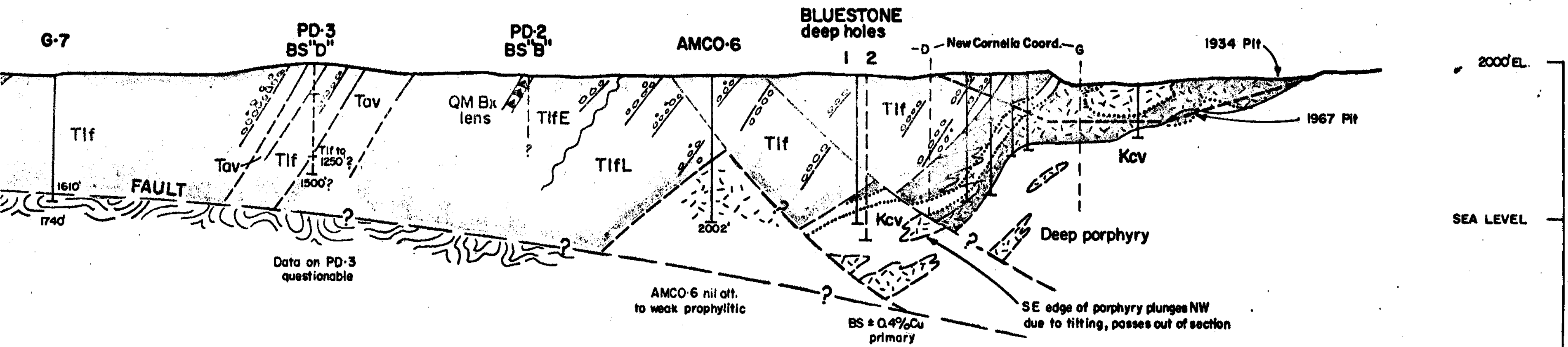
JOHN E. KINNISON JUNE 1976


RUBY STAR AREA
PIMA DISTRICT
PIMA COUNTY, ARIZONA
0 500 1000
FEET
STRATIGRAPHIC ABBREVIATIONS
Post-Mineral (Tertiary) Qal Alluvium
Thf Helmet fanglomerate
Tta Turkey track andesite flow
Laramide Lgr Ruby Star granodiorite
Qmp Quartz monzonite porphyry
Cretaceous Ka Arkosic sediments
Paleozoic Ls Mostly limestone (some quartzite and limy shale): No mineralization
Tac Tactite, and other lime-silicate metasomatic alteration facies
Precambrian P€gr Granite
Copper Averages A-973 Drill Hole
925-43, 1.23
Top of ore, length of penetration, Grade, % Cu
T-7 905' BR reported ± 500' Ls
Penetration below San Xavier fault in Ls
Penetration below San Xavier fault in Lgr or P€gr
I'll have to maybe go over roads on orig. - this is a lousy print because the mylar of the base was too light ?!
Julie - please send to John K -
Synthesis and interpretation by John E Kinnison June 1976
ANACONDA
EDWARDS
ANACONDA (FEE MINERALS)
PATENTED CLAIM
DYNAMITE GROUP
VERNON SMITH
SAN XAVIER FAULT
FOY RIDGE
TWIN BUTTES
TWIN BUTTES OPEN PIT - 1 MILE
T.17S., R.12E.
T.17S., R.13E.
Scherrer fm.
Concha fm.
graben
Bolsa Qtzt
Ls (slide block)



DRILL HOLE LOCATION MAP

1"- 1 MILE

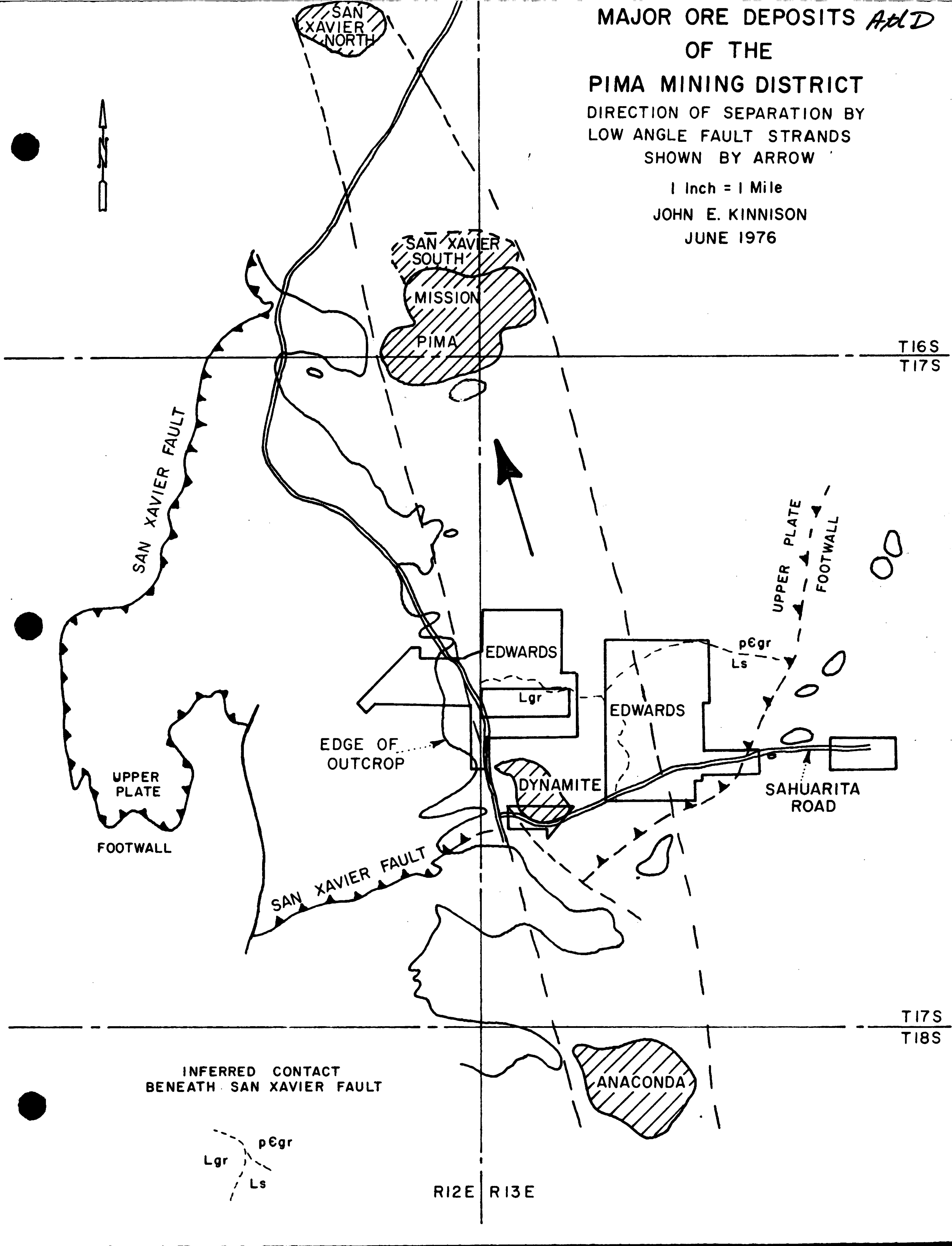


CROSS SECTION

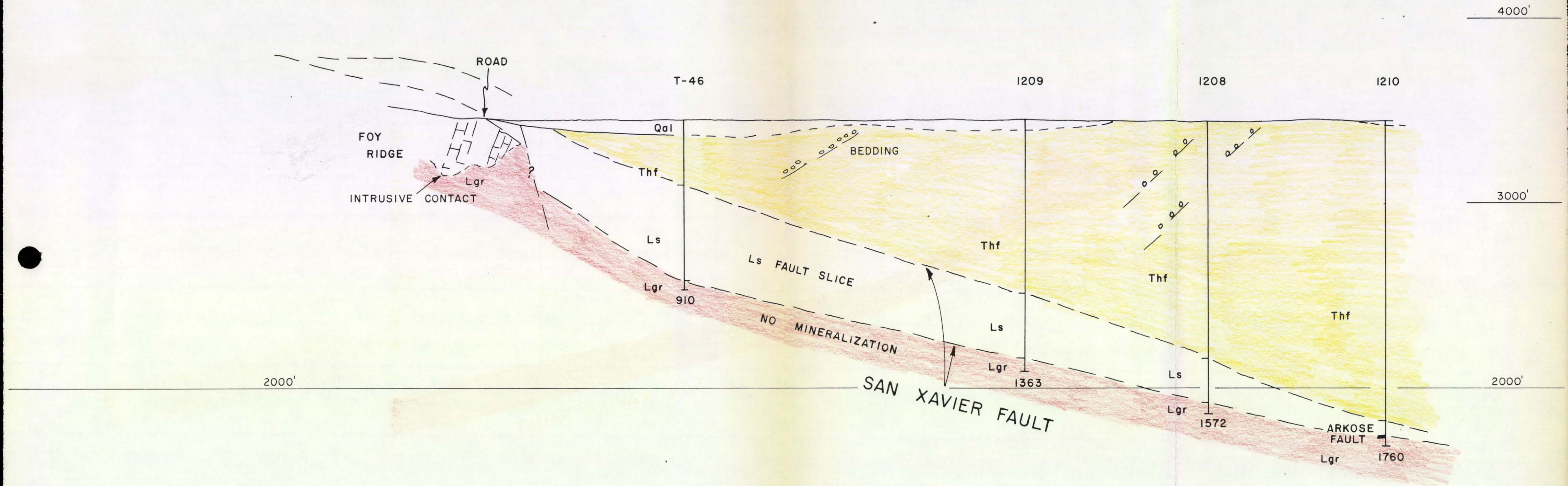
LOOKING WESTERLY

1"- 2000'

Att C


MAJOR ORE DEPOSITS
Att D
OF THE
PIMA MINING DISTRICT
DIRECTION OF SEPARATION BY
LOW ANGLE FAULT STRANDS
SHOWN BY ARROW
1 Inch = 1 Mile
JOHN E. KINNISON
JUNE 1976
N
SAN XAVIER NORTH
SAN XAVIER SOUTH
MISSION
PIMA
T16S
T17S
SAN XAVIER FAULT
UPPER PLATE
FOOTWALL
EDWARDS
Lgr
EDWARDS
pЄgr
Ls
EDGE OF OUTCROP
DYNAMITE
SAHUARITA ROAD
UPPER PLATE
FOOTWALL
SAN XAVIER FAULT
T17S
T18S
ANACONDA
INFERRED CONTACT
BENEATH SAN XAVIER FAULT
pЄgr
Lgr
Ls
R12E
R13E


Ad E
TWIN BUTTES
PALEOZOIC Ls
Lgr
SAHUARITA ROAD
SMITH
ANACONDA
EDWARDS
ANACONDA
EDWARDS
ANACONDA
T-67
T-47
A-970
A-969
A-973
975 984
971
444
1183
Qal
Thf
Qmp
11'-1.31% Cu
121'-.78
25'-1.44
Ls
1126'
1074
Vol bx
Qtzt bx
Tac
14'-.70% (oxide)
43'-1.23% Cu (oxide)
17'-.63
7'-1.45
20'-.74
150'-.42
FAULT
ANDESITE FAULT
25° FAULT
L?gr
L(?)gr
1560
1568
1703
RED Cgl Thf(?)
Ls &Tac
Ls Bx OR
Cgl.
1246
MINERALIZED Ls FAULT SLICE
FAULT ZONE
2'-8.5% Cu
6'-0.3% Cu
Lgr BOTTOM 10'
2111
HOLE 981 - PROJ. 1200' W.
1526
SAN XAVIER FAULT
Tta
BEDDING
BIOTITE RHYOLITE
2514
pЄgr
INFERRED CONTACT
4000'
3000'
2000'
1000'
HOLE 975
① 176'-.56% Cu
② 93'-.22
③ 52'-.7
HOLE 984
④ 56'-.3% Cu
⑤ 97'-.6
EDWARDS COPPER
SECTION A-A'
LOOKING WEST
SCALE: 1"=500'
J.E KINNISON
JUNE, 1976



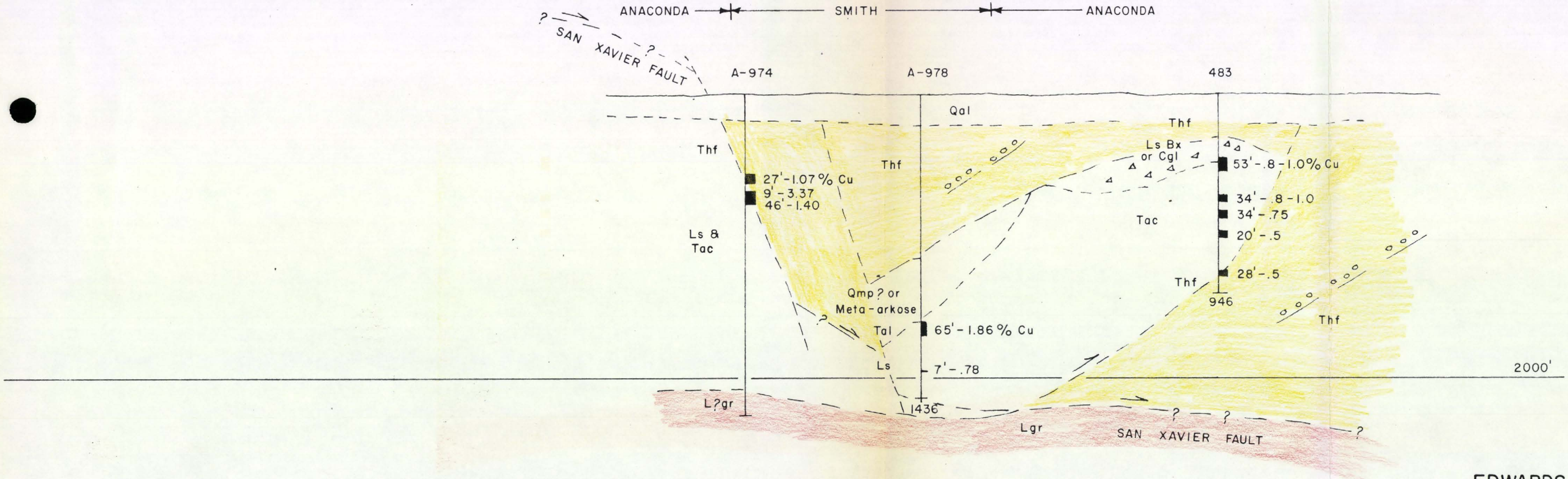
EDWARDS COPPER
SECTION B-B'
LOOKING WEST

SCALE: 1"=500'

J.E. KINNISON

JUNE, 1976

Att G



EDWARDS COPPER

SECTION C-C'

LOOKING WEST

SCALE: 1" = 500'

J. E. KINNISON

JUNE, 1976