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AMERICAN SMELTING AND REFINING COMPANY
Tucson Arizona

Ga 16.16.0
Pima Mng Dist

November 21, 1967

Mr. C. P. Pollock, Vice President
ASARCO - New York Office

Basement Fault
Mission San Xavier Area

Dear Sir:

This transmits Mr. J. E. Kinnison's review of information on the Basement Fault, Mission San Xavier area, accompanied by geologic plans, sections and detailed graphic drill logs of selected penetrations.

A total of over 60 drill penetrations have been reported. Of these, 26 are in the Mission and San Xavier Reservation ground. In the Eisenhower ground there are 22 penetrations and 8 in Pima ground. A few penetrations by rotary drill were made SW of Pima by Bear Creek.

The drill intercepts and outcrop information define a gentle east dipping structure extending north-south a distance of over six miles. The evidence that this structure is a fault of post-ore age is clearly depicted on several of the detailed graphic logs which show mineralized sediments in fault contact with the underlying barren granite. This relationship was observable only in certain areas; elsewhere the sediments immediately overlying the fault were barren.

Yours very truly,

J. H. Courtright

JHC:lmi
encl.

cc: WESaegart
JEKinnison

AMERICAN SMELTING AND REFINING COMPANY
Tucson Arizona

October 26, 1967

Mr. J. H. Courtright
Tucson Office

REPORT ON THE "BASEMENT FAULT"
MISSION-SAN XAVIER AREA
PIMA MINING DISTRICT
PIMA COUNTY, ARIZONA

Dear Sir:

Pursuant to your request, I have reviewed all our data pertaining to the subject heading and herewith submit my report thereon.

CONCLUSION

Having now reviewed all available information from our old files and published literature, I draw the same conclusion which we had reached before. Namely, that the contact between unmineralized granite below, and mineralized sediments and other rocks above, is a post-ore fault of district-wide magnitude. It is not an intrusive contact.

There are numerous references, in company correspondence and on maps, to this "basement fault" (the same structure referred to by J. R. Cooper, as the San Xavier thrust - U.S.G.S. Bulletin 1112-C). The only pertinent new information is a drill penetration near the San Xavier North deposit (D.D.H. 2 SX-18). All other data is contained in our older files and drill hole logs. No serious or persistent question of interpretations regarding this fault had been made in the past, and thus there was no occasion to describe and document the fault as I do in the following.

Very truly yours,

John E. Kinnison

JEK:mc
cc: JHCourtright - 4 extra

BASEMENT FAULT
PIMA MINING DISTRICT, ARIZONA

SUMMARY

The basement fault (Cooper's San Xavier thrust) is, beyond doubt, the single greatest structural feature of the district. During the earlier half of this century, such notable men as F. L. Ransom, B. S. Butler, and Eldred Wilson had made brief reconnaissances in different parts of the district and had interpreted the contact between granite and the mineralized rocks as one of intrusion. Since the work of Butler and Wilson during the depression and World War II, there has been little doubt that it is also a fault contact, but it was believed by them that the evidence of faulting was only evidence of a pre-intrusive structural feature. Shortly following J. R. Cooper's excellent work in the district in which he proposed that the contact was entirely post-intrusive in age and probably middle Tertiary, other geologists -- notably, Professors Lacy and Titley, of the University of Arizona -- have disagreed with this interpretation. Asarco's geologic mapping of the surface and interpretation of drill core intercepts of the same fault led independently to the same conclusion as that reached by Cooper.

Please refer to the district map (Attachment G) for place names when necessary.

The basement fault lies at a depth beneath the Mission Mine (East Pima) of about 1500 feet. As known through drill core intercepts, it rises slowly towards the west and comes to the surface about a mile west of Mineral Hill. In every drill intercept, the contact between sediments above and granite below is one of a fault nature. The fault gouge and breccia at the contact vary in thickness, but they are always present. The magnitude of the fault, while open to some dispute, is certainly large because it "cuts off" the mineralized porphyry copper altered zone at Mission. My current belief is that the displacement of the upper plate is approximately 6-1/2 miles, as stated in my Cholla Flat report of April 12, 1961 (Kinnison to Richard). Our Cholla Flat program was predicated on this theory. This interpretation was not made hastily or without good cause. Our Company had mapped the entire district, mostly on a large scale, with attention given to all details. The outcrop trace of the fault, based on this mapping alone, lends direct support to the belief that it is a large fault of major significance. Every drill hole prior to 1960 had substantiated that conclusion, and had furnished us with enough data to understand the geometry of the fault.

The post-ore age is established unquestionably by the presence of gouge and breccia along the fault contact as seen in drill holes, and crushed sulfides within the fault zone. Also, the alteration and mineralization at Mission would normally extend to great depths, but instead is sharply cut off by the fault and the barren granite beneath it. To this there is no exception.

The great magnitude of the fault is illustrated diagrammatically by Attachment A (the upper half) which illustrates the general course of the fault from Twin Buttes northerly to Black Mountain. An enlarged portion of this section, shown in the lower half of the same Attachment, diagrammatically illustrates the details in the Mission vicinity. In order to provide a view looking north, reference may be had to Attachment B, in the Mission Mine area. The details which form parts of these diagrammatic sections referred to in the foregoing are shown on Attachment C, which is plotted to scale.

I have selected 10 drill holes which are representative and plotted them on a scale of one inch to 30 feet (Attachment D). This Attachment is perhaps the most significant of those which are included within this report. The locations of these holes are shown on Attachment E.

Attachment F illustrates a penetration at the Daisy Mine, and it is significant in the fact that there is no thermal metamorphism at the contact.

There is no really new information obtained from the recent drilling since the mine has been in production. All holes which have been drilled deep enough to penetrate the fault have done so. One hole of recent date near the San Xavier North has penetrated the fault, and thus allows us to project the fault directly into this area (Attachment C).

Attachment G has been prepared to show: (1) that the district has been mapped in detail, and; (2) a simplified overlay shows the general geology of the Pima District, as well as certain place names.

Attachment H is a sketch which I made in the field to illustrate the general appearance of the fault in outcrop (refer to Attachment G for location).

ATTACHMENTS

A. Upper illustration:

Diagrammatic section illustrating Basement Fault from Twin Buttes North through Reservation, looking west.

Lower illustration:

Diagrammatic section looking west through Mission Mine.

B. Diagrammatic section looking North through Mission Mine.

C. Section to scale, through Mission Mine-San Xavier, looking westerly.

D. Representative diamond drill holes (Graphic logs), as follows:

Att D Diamond Drill Holes

Mission (East Pima)	No. 137
Mission (East Pima)	No. 158
San Xavier No. 2	SX- 18
" "	Sx- 217
" "	SX 264
Banner	No. 254
Banner	No. 260
Banner	No. 274
Banner	No. 277
Banner	No. 278

E. Drill hole location map.

F. Section through Daisy Mine.

G. Map of Pima District and simplified overlay, showing fault trace on surface, 1"=1 mi.

H. Diagrammatic section of surface outcrop, near Wilson-Todd claims.

AMERICAN SMELTING AND REFINING COMPANY
Tucson Arizona

October 26, 1967

REPORT ON BASEMENT FAULT
MISSION-SAN XAVIER AREA
PIMA MINING DISTRICT
PIMA COUNTY, ARIZONA

SUPPORTING EVIDENCE

There are three main lines of analysis to approach a logical conclusion concerning the subject.

1) Features of the fault as seen in drill core.
2) Features of the surface outcrop of the fault (contact).
3) The over-all features of the mining district as related to this fault (contact). This includes the features both in the hanging wall and footwall blocks, such as mineralization, or the lack of it, and other geologic indications.

I find that each of these three methods of analysis will apply to the basement fault, in the common agreement that it is a post-ore fault contact. Those geologists who have objected to the fault-contact conclusion have (1) not had access to as many drill penetrations as has our company (and by inference have interpreted those contacts which were seen, incorrectly); and (2) have relied on some rather vague generalizations of the surface exposure of the fault and other geologic features of the Pima district.

INTRUSIVE CONTACT INTERPRETATION - REVIEW

I believe it will serve a purpose as background to set forth the logic which has caused others to interpret the contact as one of intrusion. Also, this review is a necessity; I do not drag up forgotten history, but summarize beliefs which are still held by some geologists.

Ransom's Reconnaissance

F. L. Ransom[1] spent but a few days in the entire Sierrita Range, and reported his impressions on the geology and ore deposits thereof. He states, "the Sierrita Mountains consist essentially of an intrusive granitic core flanked by more or less metamorphosed rock of sedimentary and eruptive origin. On the east...these

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[1]F. L. Ransom, U.S.G.S. Bulletin 725-J, 1922

rocks are folded and faulted, have been invaded by granite, and, in places, show pronounced contact metamorphism." Ransom attributed the various tactite deposits, such as Mineral Hill, San Xavier Mine, and Twin Buttes Mines, as being of "contact metamorphic" origin. He related these deposits, by inference, to the granite core of the mountain range.[1]

This thought on the genesis of ores in silicated limestones was then - as it is still - a fashionable line of reasoning. There may well be deposits of this type in the western states. Ransom states in this bulletin, concerning the Mineral Hill Mine, that the limestone "is underlain by granite that is apparently intrusive into it..." I believe it is significant that in the same bulletin another paper by Hess and Larsen is entitled "contact-metamorphic tungsten deposits," and that these authors coin the word "tactite" for the silicated limestones.

B. S. Butler and Eldred Wilson

The Pima district was studied by students from the University of Arizona during the 1930's under the direction of the late Dr. B. S. Butler. One such study resulted in a doctoral dissertation by M. N. Mayuga in which he attempted to show a spatial relationship of the granite-sedimentary contact as exposed at the surface with the type of mineral deposit. In brief, garnetized limestone and copper ore were believed by him to be the most close, garnet-hedenbergite-copper-lead-lead-zinc, intermediate in distance, and lead-zinc, silver, the farthest from the granite contact. At a later date, Eldred Wilson[2] of the Bureau of Mines, stated: "the fault planes and breccia exposed above the granite indicate the contact to be a low-angle fault zone of general eastward dip. This fault zone may have localized the granite intrusion, or movement may have occurred along it after the intrusion." I was present on a field trip to the district in 1952, guided by Dr. Butler and Eldred Wilson, and I recall that after observing the tactite deposits at Mineral Hill, the group then went down a small wash and viewed a granite. A genetic inference was made very clear.

J. R. Cooper and Asarco

The Pima Mining district became, during the 1950's, the object of intense exploration and clearly a major metal producer for the future. J. R. Cooper of the U. S. Geologic

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[1]F. L. Ransom, U.S.G.S. Bulletin 725-J, 1922, Pg. 412. "The rocks underlying the plain...are not continuously exposed, and detailed geologic mapping would be necessary to establish their relations. In the neighborhood Mineral Hill and Twin Buttes are bodies of rather coarse porphyritic light-gray granite that is intrusive into the limestone and quartzite and has effected pronounced contact metamorphism."

[2]Arizona Bureau Mines Bulletin 156, Part I, Pg 42.

Survey, in 1957, began a district wide geological mapping program. His work resulted in a short bulletin[1] published in 1960, in which he correctly interpreted the significance of the basement fault (his San Xavier thrust). ASARCO's exploration at Cholla Flat was predicated on the same line of reason, although we had access to drill hole information which Mr. Cooper at that time did not have. Cooper's work consisted of outcrop mapping which has displayed a high degree of professional competence and interpretation.

W. C. Lacy and S. R. Titley

Two years later, Professors W. C. Lacy and S. R. Titley co-authored a short paper[2] in contradiction of the post-ore age of the basement fault. They state, in part:

> "The Twin Buttes (Pima) Mining district occurs within a stack of thrust sheets that fringe the eastern edge of a large Laramide granodiorite batholithic complex which forms the core of the Sierrita Mountains...The thrusting has produced imbricate structures that appear to have formed pene-contemporaneously with, and later than, the period of granodiorite intrusive activity."

Both Dr. Lacy and Titley are well known and respected within the profession of geology and ore deposits. They have both studied in a rather hasty fashion some of the features of Pima district[2], with special emphasis on the basement fault (Copper's San Xavier thrust) and its relationship to the geologic history of the Sierrita Mountains and to the ore deposits therein.

Thesis work in the early 1960's was supervised by Dr. Lacy. Some of these have been completed and are in the University of Arizona Library as unpublished manuscripts. Because these works so strongly reflect Dr. Lacy's opinions, which are amply stated in the 1962 Mining Congress Paper heretofore quoted, no purpose will be served by commenting on them here.

INTRUSIVE INTERPRETATION - DISCUSSION

The Years Prior To 1952

When F. L. Ransom first visited Pima district, in 1920, he was strongly influenced by certain laboratory studies and by field evidence which applied to many of the "contact" deposits as they were then known. He had not even a topographic map upon which to rely. His statements are restricted

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[1]U.S.G.S. Bulletin 1112-C, 1960
[2]Mining Congress Journal, April, 1962

to factual observation, and his interpretation to those theories of ore deposits which were then known. Also, he cautioned that a sufficient and detailed geologic map would need to be prepared before obviously complex structure could be interpreted.

Both Butler and Wilson mapped portions of the district near the mines and made observations at widely scattered points. When I visited the Pima district in 1952, guided by Butler and Wilson, I was shown a "granite" near Mineral Hill. This particular granite is Precambrian and obviously has no genetic connection with the ore deposits at Mineral Hill. In like manner Dr. Butler prepared a map of the old Twin Buttes Mining district ---we have a copy in our files---and mapped granite on the footwall side of the Glance fault. As the high-grade deposits are related to the Glance fault, with a granite footwall, Dr. Butler was no doubt influenced in his belief that these are true "contact metamorphic" deposits. This granite, also, is Precambrian.

The above statements are not meant to cast any adverse reflection on Ransom or Butler. I had the privilege of knowing Dr. Butler and believe he was one of the outstanding men in the field of ore deposits. Butler and Ransom, together with Lindgren, collectively advanced the understanding of ore deposits and also general field and mining geology to a higher level than any other trio of their time. Errors are to be expected in some individual cases.[1]

> Within Asarco, it should be remembered, the concept that tactite ores could result from oridinary hydrothermal activity began first with the evidence derived from Mission, in the middle 1950's. It is no longer a "built-in" assumption that tactites must be near an intrusive granite or porphyry, or that a zone-distribution be found in relationship to such intrusives as may be present.

Ransom, Lindgren and Butler were pioneers in the development of the hydrothermal theory of the genesis of ore deposits. The high-grade copper ores and tungsten deposits are indeed related in space, in many areas, to an intrusive igneous rock. Eldred Wilson, of the Arizona Bureau of Mines, was an associate of Dr. Butler, and their views largely coincide.

Laboratory synthesis of the tactite minerals suggested high temperature, and thereby backed up the field association of tactite ores and granitic or porphyry intrusives. Laboratory synthesis indicates an intermediate temperature for sericite.

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[1]I should note that it took ASARCO some four years of very detailed mapping to arrive at an accurate geologic map. This map and related study, also brought to light the distinct characteristics by which the Laramide granite may be distinguished from the Precambrian.

At this time, I can offer no explanation for the contradiction between laboratory data which indicates a high temperature for the lime-silicates and a lower temperature for sericite. We do know, however, that they occur together in a mutual environment at Mission, Emperial, and other such deposits.

The Years Following 1952

John Cooper's map of Pima district, and the interpretations he made from this map, represent a high degree of excellence.

Lacy and Titley---in the article heretofore mentioned---observe that: "J. R. Cooper...noted the striking coincidence of rock pattern and structure between the Pima area at Mineral Hill and the Twin Buttes area..." They further summarize his findings as follows:

"...(and he) suggested the hypothesis that: (1) Thrusting was post-mineralization and had separated the Pima, Mission and Palo Verde ore bodies from their roots, (2) similarities in the geology of the northern plate and the block to the south suggest that it moved 6-1/2 miles to the north-northwest."

They then stated:

"The proposed post-mineralization timing of this thrusting and the mechanics by which such a thin sheet could be displaced such a distance without total destruction is questioned. An alternative hypothesis, more acceptable to the writers, is as follows:

(1) The major period of thrusting was penecontemporaneous with the intrusion of the Sierrita batholith, and these thrust sheets which fringe the intrusive represent rock shed from the roof of the batholith, domed up during intrusion. Thus, the movement of the sheets was aided by gravity, the shouldering action of the intrusions, and partial rafting by the liquid magma.

(2) Mineralization was essentially post-thrusting and was partially controlled by the thrust faults, by the location of the later intrusive differentiates, and by the lateral breaks."

INTRODUCTORY

If a person will stand on the edge of one of the spurs which radiate outward from the mountainous portion of the Sierritas, and look east and north, he will see spread out before him a landscape which consists of a wide bajada which slopes gently downward to the Santa Cruz River bottom. This slope also will be seen to curve, towards the north, arcuately around the mountains. The eye will notice immediately that there are three principal subdivisions on this sloping plain. Nearest to the mountains, extending for about 3 miles easterly, are incised rocky plains. This slope is separated from the alluvial plain which lies farther to the east by a series of isolated hills which, from the vicinity of Twin Buttes, extends northerly to Mineral Hill. In the very northern portion, these hills are characterized by the colors of the Paleozoic sediments, although bedding planes are not apparent. The southerly portion of these hills are characterized by low relief and by mutted brown and gray colors. The alluvial fill of the third division laps upon and between these isolated hills. If a traverse be made across this same area, beginning at the base of the steep declivity of the mountainous center of the Sierritas, a rocky pediment carved on granite will at once be evident. This surface is considerably trenched by arroyos and mantled by a veneer of rocky granitic detritus. The second division (the hill cluster) is more complex. It consists, in the northern part, of Paleozoic limestone and quartzite, and on the south, of andesites of the Silver Bell formation. Between this area of andesite and the Paleozoic limestone at Twin Buttes, are long smoothly rounded ridges which give the appearance of being flat-lying, dissected conglomerate, but which from detailed mapping are known to be steeply dipping beds of the San Xavier formation (Cooper's Helmet Fanglomerate). The arroyos which headwater about Samaniego Peak, in the central core of the Sierritas, traverse through the area of hills heretofore described and merge into the alluvial basin of the Santa Cruz.

The cluster of hills which stretch north from Twin Buttes to Mineral Hill defines, in a sense, the Pima Mining District. No mineralization is known to occur to the west of these hills in the Sierrita pediment, with the exception of those mineral deposits centered about Twin Buttes. The contact between granite on the one hand, and sediments and volcanics on the other, is the surface trace of the basement fault. Attachment G shows the essential features of the Pima District, and also the surface trace of the basement fault and of the Ruby fault which offsets it a few hundred feet.

The outcrop trace

The contact at the surface is not often cleanly exposed, for it is frequently obscured by talus, alluvium and loose detritus. It may be located very closely, however, over most of its trace; there being but a single step required to cross the contact between granite and the overlying rock.

In the vicinity west of Mineral Hill, the fault may be traced southward to the region west of the San Xavier Mine. At this point, it curves westerly and then southerly near the Paymaster Mine, and south of this in the old Wilson-Chilson-Todd claims it circles in an arc, forming a partial half circle, and there is cut off by the Ruby fault.

Details of mapping methods

A study of the basement fault came naturally into Asarco's geologic mapping program. At the same time that we were drilling the Mission (East Pima) deposit, a systematic mapping program was done concurrently for the entire Pima District. In the mineralized area north of the San Xavier formation, mapping was done on a scale of 1 inch to 200 feet using an aerial photograph base. The region of San Xavier formation and near the Paymaster were also mapped in detail, on a scale of 400 feet to the inch. When compiling data in connection with the Cholla Flat drilling, I completed the map into the Twin Buttes region, using in part some detailed maps by B.S. Butler, and some recent master's thesis maps west of Twin Buttes. The Twin Buttes and adjoining regions were mapped by me on a scale of one inch to a mile, thus forming a connection with A. G. Blucher's reconnaissance of the central and western Sierrita Mountains.

Asarco's maps were made originally by various staff members including J. H. Courtright, O. D. Evans and R. E. Cribbs. Prior to compiling these several maps into a single one for my Cholla Flat report, I had field checked all previous mapping -- our own work, as well as that of others which I used -- with special emphasis on the outcrop appearance, and trace of the basement fault. These maps, plotted to various scales, were synthesized first to a scale of 1,000 feet to an inch and then further reduced (by the use of personal judgement in the combination, inference, and, in some cases, elimination of detail) to a scale of 2 inches to 1 mile.

Surface character

The surface character and appearance of the fault is related to the rock types through which it cuts. These may be divided, in a general way, as follows:

1) In the area of limestone west of the San Xavier Mine and Mineral Hill, the fault consists of thin gougy seams coated with serpentine. The granite beneath, for distances ranging from 10 feet to 50 feet, is strongly sheared and the original biotite is altered to chlorite which is streaked out along the sheared planes. The shearing fades gradually away from the fault.

2) In the area of arkose south of the San Xavier Mine, the fault is marked by a more or less brecciated zone of arkose, lying above sheared granite.

3) Further south still, near the old Paymaster Mine, the rock is dominantly an andesite. There the fault shows a low east dip with gouge seams in the andesite. A single fault plane 3 to 5 feet wide made of silicified gougy andesite forms the base of the fault zone.

4) South of the Paymaster Mine and in the area near the Wilson-Todd claims (reference to Attachment H), a fault slice of rock which I interpret to be post-ore batomote andesite is present. This andesite is sheared to the point where recognition is not completely possible, and the rock has been argillized and seams of calcedonic quartz appear along the shears.

Surficial Mineralization

In several areas the fault zone at the surface gives evidence which, to the casual observer, would seem to indicate that the fault was mineralized. None of these are present at depth in the drill holes which penetrate the fault, and they are all of a nature which is probably caused by supergene solutions.

a) Silicification and argillization is prominent in the surface outcrop near the Paymaster Mine and at various points from there on south.

b) A little transported limonite is present in the silicified zones of "A" above.

c) There are minor amounts of chrysocolla, scattered at widely-spaced intervals from the hill west of the San Xavier Mine, south to the Wilson-Todd claims.

There is no evidence of the former presence of hypogene sulphides anywhere along the fault trace. One possible source of confusion might lie in the two areas where the fault cuts across small breccia pipes. Pyrite has been leached from these pre-mineral pipes in the hanging wall block and also limonite is dispersed in the fault zone beneath. These breccia pipes could easily be confused for mineralized fault breccia.

Drill Holes (Attachment G)

There is little that can be said for the representative drill holes which have been plotted to scale to show the details of the fault zone. The graphical representation speaks for itself. I should take note, however, of the section through the Daisy Mine (Attachment F). The Daisy ore zone, operated by the Banner Company, was a good producer of oxide direct shipping ore, and latter of sulphide concentrates. It is close by the Mission altered zone, but nonetheless, is beyond the limits of pervasive alteration. The drill hole near the Daisy shaft penetrated the basement fault -- but the core was not recovered at the contact. It is noteworthy that the shaly limestone which abuts the granite shows no evidence of metamorphism, as would be the case if it were an intrusive contact.

The Ruby Fault

The Ruby fault quite definitely cuts across the post-ore San Xavier formation. Although there is much alluvium in this area, it is, nonetheless, exposed in several places, and is seen to be a high angle narrow fault zone which separates granite from San Xavier formation. In that area where it cuts across the beds of the San Xavier formation, it would appear that it must be a fault of great magnitude; but it cannot be traced as a fault of any great magnitude to the north. A rather simple explanation of this may be had, and I will refer to my report on the Ajo District of 1961 (to Kenyon Richards).

> "....The Chico Shuni fault may have only a few hundred feet of displacement to drop the low-dipping fault out of sight on the east; all but a small remnant of the hangingwall plate was eroded from the west side while 2 miles of tilted strata were preserved on the east, down-dropped side. The Ruby fault in the Pima district effects precisely this outcrop pattern, by dropping the "basement fault" about 200 feet on the east (refer to Pima district map), causing 3 miles of tilted San Xavier formation to be preserved on the east side and leaving a few erosional Klippen on the west. In both these examples, the high angle fault -- the one easily recognized on the surface-- is caused to have an <u>apparently</u> great vertical displacement and hinge-fault action, whereas the great movement actually took place along a low-angle fault."

Post-ore rocks affected

If my interpretation in regard to the Ruby fault (mentioned in the foregoing) is correct, then the fault must pass beneath the San Xavier formation. East of

Wilson-Todd claims, some Bear Creek holes have passed from San Xavier formation directly into granite. These, however, are rotary holes and no core was taken of the contact. Another possibility of post-ore rock affected by the fault is the fault slice of batomote andesite shown in Attachment H.

Mechanics of faulting

W. C. Lacy has objected to a post-ore fault movement on the grounds that he knows of no method by which a thin thrust sheet could move such a distance without total destruction. This objection is not really material, because we know that the fault exists -- regarless of how it got there. Other faults of similar type are known in southern Arizona. I have nothing to add concerning these low-dipping faults since I commented on them in the Ajo report as follows:

> "I have expressly refrained from using the term "thrust fault" in connection with the Ajo basement fault. The Pima basement fault shown on Attachment B is known to have moved the hangingwall plate down-dip, in part at least, as if it were a free-sliding detached mass, propelled by gravity. Thick sections of fanglomerate appear at many places in southern Arizona, and are frequently found to be tilted and involved in low-angle faulting of this type. Little is known at this time concerning the formation of these excessively thick alluvial basins, or of the mountain building processes which then act to tilt and slide them about."

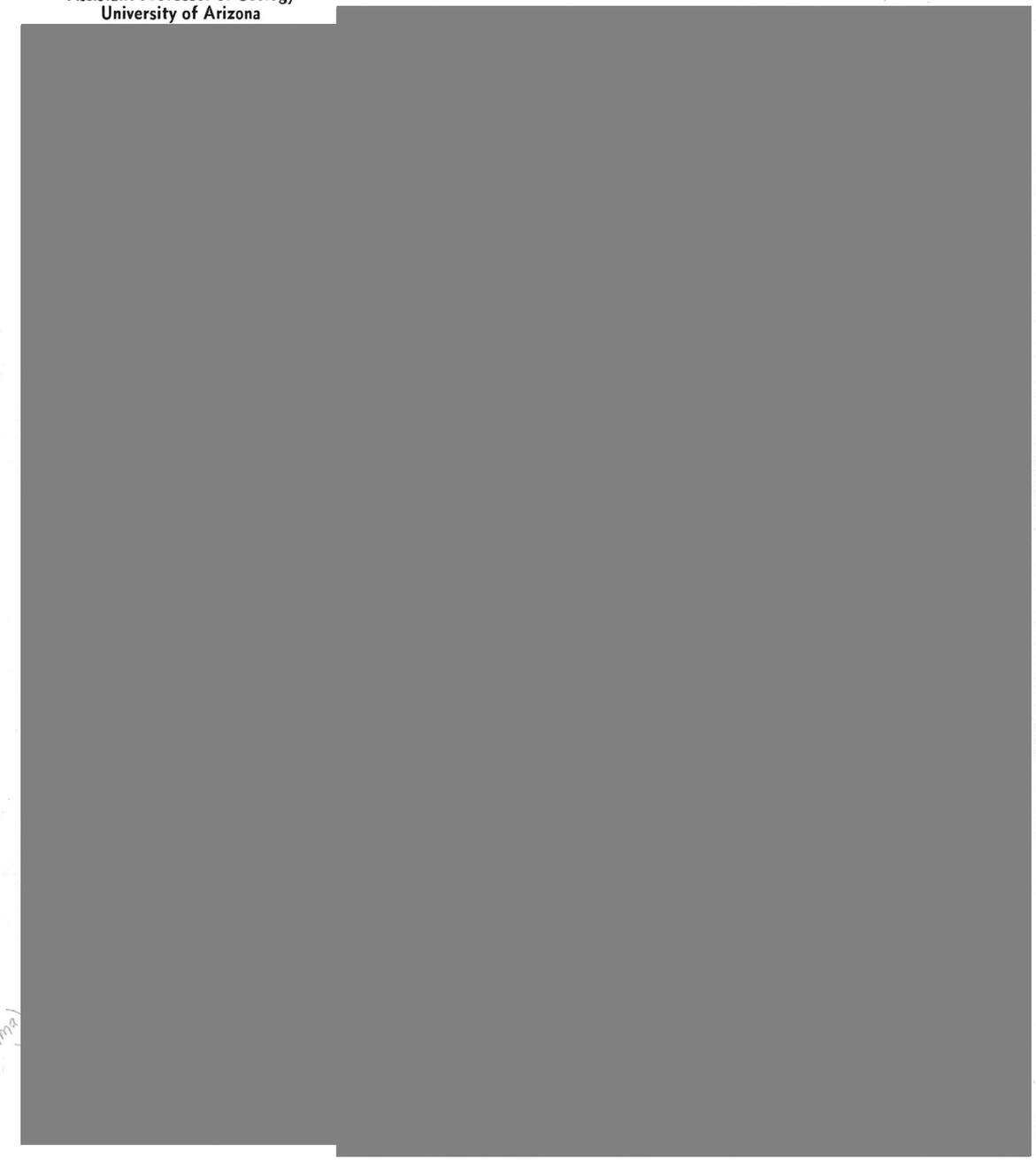
JEK:mc

END OF REPORT

AMERICAN MINING CONGRESS
Ring Bldg., Washington, D.C.

Geological Developments in the Twin Buttes District

By W. C. LACY
Professor of Geology
and
S. R. TITLEY
Assistant Professor of Geology
University of Arizona



Reprinted from
MINING CONGRESS JOURNAL
APRIL 1962

MEMORANDUM TO J. H. COURTRIGHT

November 11, 1967

The summary that has been prepared today will take care of the barest description of the attachments. I believe that this, while it might serve the purpose of satisfying certain people in New York, will leave others with the impression of incompleteness. A full description, adequate for all concerned, can be prepared on Monday and make a full and complete report. I recommend that you do not transmit the report until this is done. It will be ready upon your return.

John E. Kinnison

John E. Kinnison

JEK:mc

MEMORANDUM TO MR. VON DE STEINEN

November 11, 1967

Mrs. Margie Chamberlain, worked three hours overtime on Saturday in an attempt to finish a report prior to Mr. Courtright's departure Monday.

John E. Kinnison

JEK;mc
cc: JHCourtright

From my notes of
oct - Nov
(late) 59 ~~Early 60~~ —
- Banner Core shack —
Recollection - I saw
hand specimen of vy crushed
and sheared granite
labeled DDH 188 - 750'
MacKenzie said got plain
granite just below.

Later checked in field
Sec 9 - found hole and
Tbp cuttings. This is
the one Cooper Mentions

BANNER

260 1033 - 1223 TD

254 1085 - 1335 TD

~~267 1000 - 1383 TD~~ omit

274 1137 - 1278 TD

277 1004 - 1220 TD

278 1169 - 1241 TD

X - 217

1186. to 1397 TD

X - 264

1081.6 - 1178 TD

E.P. 158

1009.2 - 1101 TD

E.P. 137

1180.9 - 1353 TD

add 2 SX 18

J. E. K.

MAY 26 1967

AMERICAN SMELTING AND REFINING COMPANY
Tucson Arizona

May 25, 1967

Memorandum for: John E. Kinnison

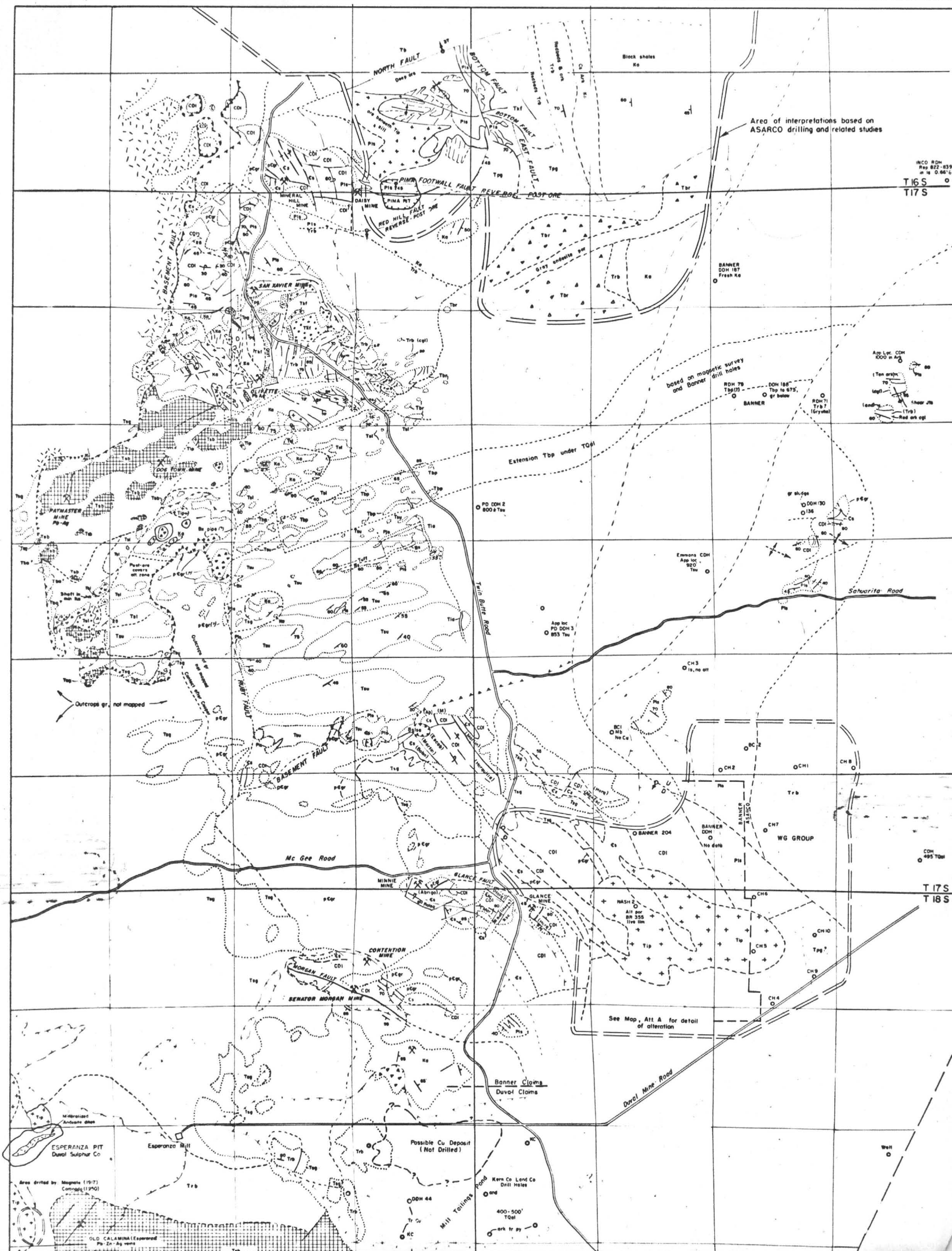
As you know, certain geologists have questioned our conclusions with respect to the basement fault (San Xavier Thrust) in the Pima Mining District. The New York Office has asked for up-to-date information.

Please prepare a brief summary of data on the fault including (1) a list of all drill holes for which we have logs, with depth of penetration through the fault; (2) evidence for a fault contact rather than through an intrusive contact; (3) evidence for the post-mineral age.

J. H. Courtright

JHC:lmi

cc: W. E. Saegart



Area of interpretations based on ASARCO drilling and related studies
NORTH FAULT
BOTTOM FAULT
EAST FAULT
Black shales Ka
PIMA FOOTWALL FAULT REVERSE POST ORE
RED HILL FAULT REVERSE POST ORE
MINERAL HILL MINE
DAISY MINE
PIMA PIT
T16S
T17S
INCO RDH
BASEMENT FAULT
SAN XAVIER MINE
Gray andesite por
BANNER DDH 187 Fresh Ka
OLIVETTE
based on magnetic survey and Banner drill holes
RDH 79 Tbp(?)
BANNER
DDH 188 Tbp to 675', gr below
RDH 71 Trb ? (Grysha)
Extension Tbp under TQal
DOG TOWN MINE
PAYMASTER MINE Pb-Ag
PD DDH 2 800 @ Tsu
Post-ore covers alt zone
Emmons CDH App loc 920' Tsu
Sahuarita Road
Twin Butte Road
App loc PD DDH 3 853 Tsu
CH3 ls, no alt
RUBY FAULT
Outcrops gr, not mapped
BASEMENT FAULT
BC1 Mb No Cu
BC2
CH2
CH1
CH8
BANNER ASARCO
WG GROUP
CH7
BANNER 204
BANNER DDH No data
Mc Gee Road
MINNIE MINE
GLANCE FAULT
GLANCE MINE
NASH 2
T17S
T18S
CH6
CH10
CH5
CH9
CH4
CONTENTION MINE
MORGAN FAULT
SENATOR MORGAN MINE
See Map, Att A for detail of alteration
Banner Claims
Duval Claims
Duval Mine Road
Mineralized Andesite dikes
ESPERANZA PIT Duval Sulphur Co
Esperanza Mill
Possible Cu Deposit (Not Drilled)
Well
Area drilled by Magnate (1917) Coronado (1950)
DDH 44
Kern Co Land Co Drill Holes
400-500' TQal
Mill Tailings Pond
OLD CALAMINA (Esperanza) Pb-Zn-Ag veins

East Puna

SUMMARY - D. D. HOLE NO. 137 - Continued

From	To	Interval	Core Rec.%	% Cu Core	Geology
1031.2'	1041.3'	10.1'	95	.14	Quartzite. Similar to above. Highly fractured with numerous 40 to 65° slips and bleaching along the fractures. Sulphides weak.
1041.3'	1051.6'	10.3'	97	.10	Quartzite. Similar to above. Below 1042.0' the rock is highly brecciated with numerous 40 to 60° slips. Sulphides weak.
1051.6'	1061.7'	10.1'	100	.04	Quartzite. Similar to above. The entire run is brecciated and recemented. Sulphides rare.
1061.7'	1070.9'	9.2'	99	.06	Quartzite. Similar to above. Sulphides sparse.
1070.9'	1081.0'	10.1'	98	.03	Quartzite. Similar to above. Sulphides rare.
1081.0'	1088.8'	7.8'	100	.13	Quartzite. Similar to above. Sulphides weak.
1088.8'	1098.9'	10.1'	98	.16	Quartzite. Similar to above. Numerous 40 to 60° slips with pyrite throughout and traces of sphalerite and molybdenite. Sulphides weak.
1098.9'	1106.6'	7.7'	96	.10	Quartzite. Similar to above. Numerous brecciated intervals and some white calcareous veinlets and spots. Sulphides weak.
1106.6'	1116.8'	10.2'	97	.10	Quartzite. Similar to above. Sulphides weak.
1116.8'	1126.8'	10.0'	93	.07	Quartzite. Similar to above. Sulphides sparse.
1126.8'	1141.4'	14.6'	94	.11	Quartzite. Similar to above. Sulphides weak.
1141.4'	1150.6'	9.2'	100	.26	Quartzite. Grey, with dark recrystallized intercepts and slips dipping 45 to 90°. There is abundant pyrite throughout and some chalcopyrite. Sulphides weak.
1150.6'	1160.7'	10.1'	100	.41	Quartzite. Similar to above. Some pyrite and chalcopyrite scattered throughout. Sulphides weak to moderate.
1160.7'	1170.8'	10.1'	98	.13	Quartzite. Similar to above. Sulphides weak.

SUMMARY - D. D. HOLE NO. 137 - Continued

From	To	Interval	Core Rec.%	% Cu Core	Geology
1170.8'	1180.9'	10.1'	94	.13	Quartzite. Similar to above. Sulphides weak.
1180.9'	1190.9'	10.0'	100	.16	Quartzite. Similar to above. Sulphides weak.
1190.9'	1201.1'	10.2'	98	.22	Quartzite. Similar to above. Almost completely brecciated and recemented with some fine disseminated pyrite and chalcopyrite. Sulphides weak.
1201.1'	1211.2'	10.1'	94	.08	Quartzite. Similar to above. Sulphides sparse.
1211.2'	1221.2'	10.0'	93	.06	Quartzite. Similar to above. Sulphides sparse.
1221.2'	1231.2'	10.0'	100	.05	Quartzite. Similar to above. Sulphides sparse.
1231.2'	1241.4'	10.2'	99	.05	Quartzite. Similar to above. Sulphides sparse.
1241.4'	1251.7'	10.3'	98	.28	Quartzite. Similar to above. Sulphides weak.
1251.7'	1261.8'	10.1'	89	.28	Quartzite, silicated limestone and hornfels. Quartzite to a highly serpentinized zone at 1255.7' where there is a gradational change into silicated limestone with abundant epidote and massive garnet. At 1260.4' a brecciated 50° slip forms a contact with cream colored argillaceous hornfels which contain fine pyrite veinlets and traces of molybdenite. Sulphides weak.
1261.8'	1268.1'	6.3'	97	.12	Hornfels. Similar to above, becoming less argillaceous with a breccia zone with much gouge material below 1264.8'. Sulphides weak.
1268.1'	1273.6'	5.5'	97	.26	Hornfels. Lightly serpentinized, with several 5° to 10° pyrite veins with narrow boundaries of actinolite and/or tremolite, and some slip face deposits and spots of a very pale blue anhydrite. Sulphides weak.
1273.6'	1283.3'	9.7'	99	.21	Hornfels, silicated limestone and andesite. Hornfels, similar to above, grading into a serpentinized silicated limestone with several brecciated intervals to 1280.6' where a serpentinized slip forms a contact with a dark gray to olive-green andesite porphyry. The andesite is highly magnetic and contains many small white calcite blebs. Sulphides weak.

SUMMARY - D. D. HOLE NO. 137 - Continued

From	To	Interval	Core Rec.%	% Cu Core	Geology
1283.3'	1289.7'	6.4'	89	.03	Andesite porphyry. Similar to above. Sulphides rare.
1289.7'	1296.8'	7.1'	98	.04	Andesite porphyry. Similar to above. Sulphides rare.
1296.8'	1308.9'	12.1'	97	.03	Andesite porphyry. Similar to above. Sulphides rare.
1308.9'	1314.8'	5.9'	78	.08	Andesite porphyry and sheared granite. Andesite porphyry to 1313.0' where there is a contact with a sheared granite. There are angular to rounded fragments of quartz and feldspar up to 10 mm. in diameter. These fragments are set in a deep green, very fine sandy or silty chloritic matrix. There are several fine white calcareous veinlets and some disseminated hematite. Sulphides sparse.
1314.8'	1325.0'	10.2'	98	.03	Sheared granite. Similar to above. Below 1316.8' the matrix becomes siliceous, still with abundant chlorite.
1325.0'	1335.2'	10.2'	93	.03	Sheared granite. Similar to above. Sulphides rare.
1335.2'	1341.7'	6.5'	91	.05	Sheared granite. Similar to above. Lighter colored and more silicified, creating a mottled texture. Sulphides sparse.
1341.7'	1353.4'	11.7'	43	.04	Sheared granite. Similar to above. Sulphides rare.
542.2'	1353.4'	811.2'	94		Total for month.
0.0'	542.2'*	542.2'	86		Previous advance.
*0.0'	199.0'	199.0'			Drilled with rock bit.

SUMMARY - DIAMOND DRILL HOLE NO. 137
23 + 00 N 15 + 50 W Collar Elevation 3221.8'

From	To	Interval	Core Rec.%	% Cu Core	Geology
1353.4'	1361.8'	8.4'	73	.02	Sheared Granite. Fragments of feldspar and quartz set in a chloritic matrix with some hematite and white calcareous material. Sulphides rare.
1361.8'	1371.1'	9.3'	99	.03	Sheared Granite. Similar to above with one clean 80° slip. Sulphides rare.
1371.1'	1380.7'	9.6'	89	.06	Sheared Granite. Similar to above. Sulphides sparse.
1380.7'	1390.7'	10.0'	100	.03	Sheared Granite. Similar to above, possibly coarser grained. Sulphides rare.
1390.7'	1397.6'	6.9'	70	.03	Sheared Granite. Similar to above. Sulphides rare.
1397.6'	1401.5'	3.9'	77	.05	Sheared Granite. Similar to above. Sulphides sparse.
1401.5'	1411.3'	9.8'	94	.03	Sheared Granite. Similar to above with several 45° to 75° slips. Sulphides rare.
1411.3'	1418.2'	6.9'	89	.02	Sheared Granite. Similar to above, developing rather large granitic fragments in a chloritic matrix. Sulphides rare.
1418.2'	1425.1'	6.9'	95	.02	Sheared Granite. Becoming generally flesh colored as percentage of chloritic matrix decreases. Sulphides rare.
1425.1'	1435.2'	10.1'	100	.03	Sheared Granite. Similar to above. Sulphides rare.
1435.2'	1442.3'	7.1'	89	.02	Sheared Granite. Similar to above. Sulphides rare.
1442.3'	1452.5'	10.2'	91	.03	Sheared Granite. Similar to above with some highly chloritic patches and exhibiting white to gray siliceous spots and patches associated with a few flakes of pyrite and chalcopyrite. Sulphides rare.
1452.5'	1462.5'	10.0'	93	.05	Sheared Granite. Similar to above. Sulphides sparse.
1462.5'	1470.7'	8.2'	99	.03	Sheared Granite. Similar to above with several hematite stained intervals and with one 0.8' fragment which may be a coarse grained quartzite. Sulphides rare.

SUMMARY - D.D. Hole No. 137 Continued

From	To	Interval	Core Rec.%	% Cu Core	Geology
1470.7'	1478.4'	7.7'	71	.02	Granite. Sheared Granite with a heavy chloritic matrix exhibiting secondary brecciation with some gouge to 1472.3' where a 45° broken zone initiates a light orange to flesh colored rock of granitic texture which is broken and gouged. Sulphides rare.
1478.4'	1488.6'	10.2'	97	.02	Granite. Similar to above with highly altered mafics, magnetite altered to hematite. The rock is generally broken and contains some gouge. Sulphides rare.
1488.6'	1501.8'	13.2'	92	.04	Granite. Similar to above with 60-80° slips. Sulphides rare.
1353.4'	1501.8'	148.4'	90		Total for month.
0.0'	1353.4'	1353.4'*	91		(Approx.) Previous advance.
0.0'	1501.8'	1501.8'	91		Total for hole.
*0.0'	199.0'	199.0'			Drilled with rock bit.

East Pima

SUMMARY - D. D. HOLE NO. 158 - Continued

From	To	Interval	Core Rec.%	% Cu Core	Geology
608.8'	618.7'	9.9'	96	.04	Recrystallized limestone. Similar to above blue-grey and distorted, with serpentine or chlorite veinlets. Copper mineralization rare.
618.7'	627.3'	8.6'	90	.02	Recrystallized limestone. Similar to above but below 621.7' and a 70° fracture, it is highly vuggy and crushed. Two 30° breccia zones. Copper mineralization rare.
627.3'	642.0'	14.7'	93	.03	Recrystallized limestone. Similar to above becoming lighter in color, vuggy and rotten. Below 632' becomes more competent, light greenish-gray, and serpentinized to end of run. Copper mineralization rare.
642.0'	652.4'	10.4'	92	.02	Recrystallized limestone. Similar to above generally rotten and vuggy along slips, intervals of gouge and serpentinized throughout. Copper mineralization rare.
652.4'	662.6'	10.2'	97	.03	Recrystallized limestone. Similar to above becoming distorted toward end of run, and blue-gray in color. Copper mineralization rare.
662.6'	671.7'	9.1'	100	.03	Recrystallized limestone, and hornfels. Similar to above but with patches altered to a light grey hornfels. Copper mineralization rare.
671.7'	684.5'	12.8'	88	.03	Recrystallized limestone, hornfels and quartz or siltstone. Similar to above down to 676.7' and a serpentinized hornfelic zone. This type continues down to 678.6' where it makes a 30° contact with a tan, fine-grained quartz or siltstone. This rock type exhibits limy and lime-silicate patches which contain serpentine and are stained with hematite. Copper mineralization rare.
684.5'	694.6'	10.1'	88	.04	Quartzite or siltstone, hornfels and recrystallized limestone. Fine-grained, greyish-greenish quartzite or siltstone. Somewhat broken, and recemented brecciation. At 686.3' a 30°-40° contact is made with a white calcareous hornfels. Grading into a blue-gray recrystallized limestone. Another intercept of fine-grained, greyish quartz or siltstone comes in a broken contact at 690.3'. Generally broken and distorted. Copper mineralization rare.

SUMMARY - D. D. HOLE NO. 158 - Continued

From	To	Interval	Core Rec.%	% Cu Core	Geology
694.6'	704.7'	10.1'	100	.02	Hornfels, quartzite or siltstone, massive anhydrite and gypsum and recrystallized limestone. Hornfels lightly serpentinized. Fine-grained quartzite or siltstone with patches of massive anhydrite and gypsum. Some blue-gray recrystallized limestone at end of run, all distorted and intermixed. Copper mineralization rare.
704.7'	714.6'	9.9'	97	.02	Recrystallized limestone and arkose. Similar to above light, blue-gray, to gray-green, somewhat serpentinized, recrystallized limestone. At about 709.2' a 30° contact is made with a highly altered, and sericitic (?) arkose. The arkose is light, yellowish-gray, and exhibiting some small siliceous patches. Minor pyrite. Copper mineralization rare.
714.6'	721.8'	7.2	95	.03	Arkose. As above with small quartz fragments or pebbles. Several high angle slips with dark gouge and breccia. 1/4" pyrite cubes. Copper mineralization rare.
721.8'	732.0'	10.2'	97	.03	Arkose conglomerate. Similar to above with angular to rounded fragments. Numerous small brecciated areas along slips. Copper mineralization rare.
732.0'	740.6'	8.6'	92	.04	Arkose conglomerate. Similar to above with some calcite. Breccia long 30°-60° slips. Copper mineralization rare.
740.6'	753.0'	12.4'	97	.02	Arkose conglomerate. Similar to above but but with several fine-grained quartz patches and some scattered pyrite. Breccia as above. Copper mineralization rare.
753.0'	761.8'	8.8'	95	.03	Arkose conglomerate. Similar to above, generally broken and brecciated. Copper mineralization rare.
761.8'	771.0'	9.2'	91	.02	Arkose conglomerate. Similar to above but becoming finer-grained and more siliceous toward base of run. One strong serpentine streak. Copper mineralization rare.
771.0'	777.5'	6.5'	91	.04	Arkose. Similar to above with some breakage and gouge. Copper mineralization rare.
777.5'	789.6'	12.1'	96	.03	Arkose. Similar to above with fine-grained intervals alternating with a coarser, more altered phase. Generally broken, with some gouge. Some conglomerate patches and intercepts of fine-grained, bluish-gray material. Copper mineralization rare.

SUMMARY - D. D. HOLE NO. 158 - Continued

From	To	Interval	Core Rec.%	% Cu Core	Geology
789.6'	797.3'	7.7'	98	.04	Arkose. Similar to above, predominately the finer-grained phase. Broken, with slips about 30°-45°-60°. Copper mineralization rare.
797.3'	809.3'	12.0'	95	.03	Arkose, and Arkose Conglomerate. Similar to above down to 805.0'. There becoming a more siliceous pebble conglomerate. Copper mineralization rare.
809.3'	822.7'	13.4'	95	.02	Arkose. Similar to above, with patches of pebble conglomerate, a little serpentine and hematite on slips. Copper mineralization rare.
822.7'	832.7'	10.0'	92	.03	Arkose. Similar to above, more broken, chloritic, and serpentinized. Copper mineralization rare.
832.7'	843.2'	10.5'	88	.03	Arkose. Similar to above in all respects. Copper mineralization rare.
843.2'	857.8'	14.6'	94	.02	Arkose. Similar to above, but with a fine-grained, blue-gray intercept at end of run. Contact is 40° and somewhat lightly serpentinized. Copper mineralization rare.
857.8'	866.9'	9.1'	96	.03	Arkose. Similar to above, but with longer intercepts of fine-grained, blue-gray material. Copper mineralization rare.
866.9'	873.3'	6.4'	88	.03	Arkose. Similar to above in all respects. Copper mineralization rare.
873.3'	883.4'	10.1'	92	.03	Arkose. Similar to above in all respects. Copper mineralization rare.
883.4'	890.9'	7.5'	80	.03	Arkose. Similar to above, but with pink to orange siliceous streaks. Becoming gray, and coarser grained to a near pebble conglomerate. Copper mineralization rare.
890.9'	900.1'	9.2'	89	.03	Arkose. Similar to above, generally broken and finer grained. Copper mineralization rare.
900.1'	910.2'	10.1'	96	.03	Arkose, and Fossiliferous Limestone. Similar to above, down to a slightly irregular contact at 905.5' with a dark, blue-gray, fossiliferous limestone. This limestone has a white veinlet system and irregular stylolitic fractures. Copper mineralization rare.
910.2'	918.4'	8.2'	95	.02	Limestone. Similar to above, with some intervals nearly black. Graphite occurs on irregular slips and fractures. Copper mineralization rare.
918.4'	928.6'	10.2'	95	.03	Limestone. Similar to above, very nearly all dark blue-gray to black, with a few vuggy channels, and graphite on some slips. Copper mineralization rare.
928.6'	938.7'	10.1'	100	.03	Limestone. Similar to above in all respects. Copper mineralization rare.

SUMMARY - D. D. HOLE NO. 158 - Continued

From	To	Interval	Core Rec.%	% Cu Core	Geology
938.7'	948.8'	10.1'	99	.03	Limestone. Similar to above in all respects. Copper mineralization rare.
948.8'	959.0'	10.2'	98	.02	Limestone. Similar to above, although lighter in color below 958.2'. Copper mineralization rare.
959.0'	969.0'	10.0'	98	.02	Limestone. Similar to above, but with alternate light and dark intervals. Copper mineralization rare.
969.0'	979.3'	10.3'	95	.03	Limestone. Similar to above in all respects. Copper mineralization rare.
979.3'	989.5'	10.2'	97	.02	Limestone. Similar to above in all respects. Copper mineralization rare.
989.5'	999.1'	9.6'	97	.04	Limestone. Similar to above in all respects. Copper mineralization rare.
999.1'	1009.2'	10.1'	94	.02	Limestone. Similar to above, but with a light grey intercept above base of run which is highly brecciated and recemented. Copper mineralization rare.
1009.2'	1019.4'	10.2'	92	.03	Limestone and Quartzite. Similar to above, but with a 2' intercept of grey, medium-to coarse-grained, sericitic quartzite below 1017.4'. Thick deposits of graphite on limestone slips. Copper mineralization rare.
1019.4'	1029.5'	10.1'	96	.03	Limestone. Similar to above, very dark, blue-grey limestone with white veinlet system. Copper mineralization rare.
1029.5'	1039.6'	10.1'	96	.02	Limestone and Quartzite. Similar to above but with a 1' intercept of grey quartzite between irregular 10±°contacts. Some slips exhibit massive graphite. Copper mineralization rare.
1039.6'	1050.0'	10.4'	94	.03	Limestone. Similar to above in all respects. Copper mineralization rare.
1050.0'	1060.1'	10.1'	96	.03	Limestone. Similar to above, but highly distorted. Copper mineralization rare.
1060.1'	1070.1'	10.0'	97	.02	Limestone, and Granitic Breccia. Limestone as above down to 1067.1' where a 5° ± contact is made with granitic breccia which is similar to that in D. D. H. No. 137, and D. D. H. No. 140. The breccia is a serpentine or chlorite matrix, with smeared quartz and feldspar fragments. Copper mineralization rare.
1070.1'	1084.4'	14.3'	100	.02	Granitic Breccia and Granite. Similar to above, but with more unbrecciated intercepts. Fractures 0° - 5° - 45°. Copper mineralization rare.

SUMMARY - D. D. HOLE NO. 158 - Continued

From	To	Interval	Core Rec.%	% Cu Core	Geology
1084.4'	1094.2'	9.8'	100	.03	Granite. Similar to above, with a few sheared and healed zones, containing some serpentine and chlorite. Copper mineralization rare.
1094.2'	1101.1'	6.9'	90	.02	Granite. Similar to above, but with little or no shearing. Copper mineralization rare.
0.0'	1101.1'	1101.1'*	94	--	Total for period and total for hole.
*0.0'	191.0'	191.0'	--	--	Drilled with rock bit.