THE GEOLOGY AND ORE DEPOSITS OF THE MOWRY MINE AREA, SANTA CRUZ COUNTY, ARIZONA

by

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ABSTRACT

The Mowry Mine is located 75 miles southeast of Tucson, in Santa Cruz County, Arizona. Between 1858 and 1910, approximately 1.6 million dollars worth of silver-lead ores were extracted from the mine. Ore minerals were argentiferous galena, cerussite and anglesite, averaging approximately forty dollars to the ton. The ore bodies were replacements in limestone and true fissure fillings.

Sedimentary rocks in the Mowry Mine area range in age from middle Cambrian to early Cretaceous, overlying a Pre-cambrian igneous complex. Two periods of igneous intrusion are recognized. Mineralization is believed to be Tertiary in age.

INTRODUCTION

Location

The Mowry Mine is located 75 miles southeast of Tucson and 20 miles northeast of Nogales in the Patagonia Mountains of north-central Santa Cruz County, Arizona.

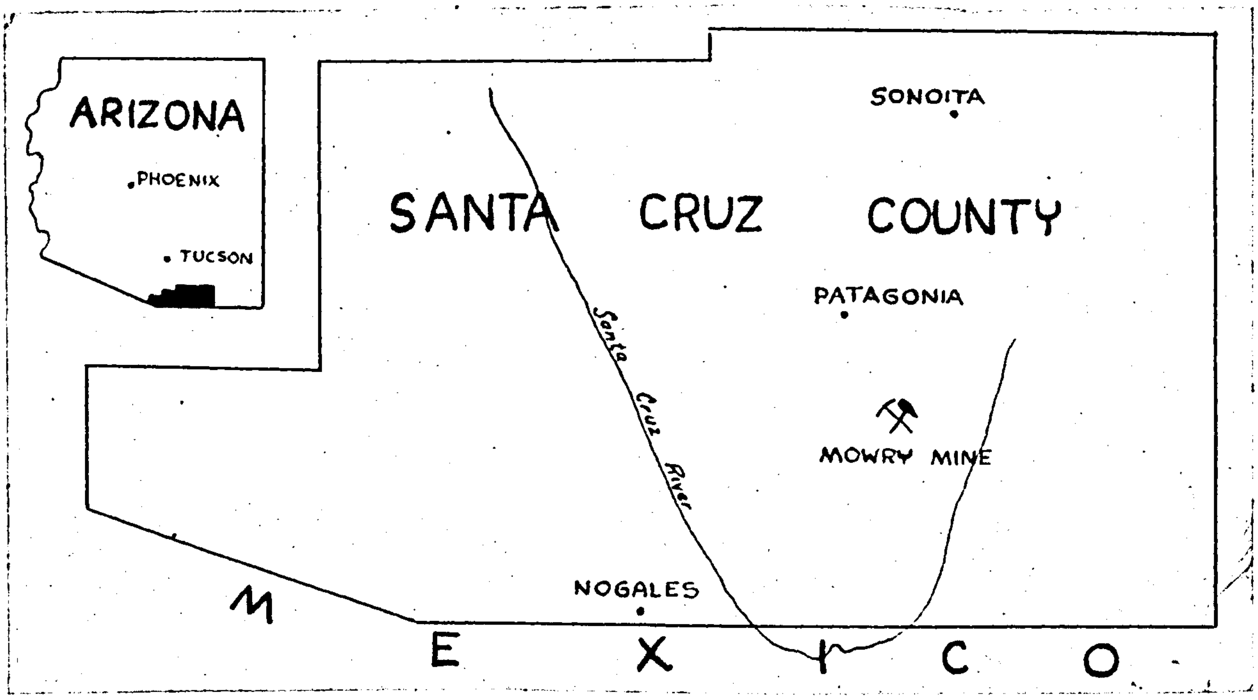


Figure 1. Location Map

Excellent state highways, bus and rail service connect Tucson and Nogales with Patagonia. West from the Tombstone-Bisbee area, the mine is accessible by a well graded gravel road which links Fort Huachuca with Nogales via Patagonia.

All of sections 15, 22, and parts of 16, 21, T 23 S, R 16 E (Harshaw Quadrangle, Arizona), comprising approximately three square miles were studied for this report.

History and Production

The Mowry Mine lies within the Patagonia mining district, which has produced approximately 8 million dollars worth of silver, gold, lead, zinc and copper since 1850. Available production figures for the Mowry Mine, as received from D. S. Stranahan, mining engineer for Ventures Limited of Canada, are as follows:

Lieutenant Sylvester Mowry	1858-1864	$1,500,000
Fish and Silverberg	1870-1880	75,000
Steinfelt and Swain	1880-1890	80,000
Mowry Mines	1904-1909	?
Consolidated Mines, Smelter and Transportation	?	?
Mowry Exploration Company	?	200 Tons, Ag-Pb
Beyerle Manganese Operations	1955	15,000
Total		$1,700,000

Jesuit and Franciscan priests probably initiated mining operations in the Patagonia region in the late 17th century (Kartchner, 1944). In 1853, the Gadsden Purchase stimulated active prospecting, which resulted in the discovery of the Mowry Mine in 1858. Between 1858 and 1864, Lieutenant Mowry developed the property and produced $1.5 millions in silver and lead. In 1864, Lieutenant Mowry was apprehended for supporting the Confederate cause with lead for ammunition, and sent to prison at Yuma, Arizona for two years.

From 1864 through the early 1900's, the mine was worked intermittently, but then abandoned, as gophering and subsequent caving had ruined the workings (Brinsmade, 1907). Since the early 1900's, production has been sporadic, with minor amounts of ore being mined through 1955.

Topography

The Patagonia Mountains lie within the central mountain region of Arizona, within the Basin and Range physiographic province. This mountain range trends north and is characterized by steep western slopes and a gentle eastern limb.

The Mowry Mine area in the Patagonia Mountains is at an elevation of 5,500 feet between the south slope of Mowry Hill and the northern limit of Mowry Wash. Terrain is generally moderate, with maximum relief in excess of 500 feet. Four prominent topographic highs surround the mine; Mowry Hill on the north, and three rounded, elongate north trending hills on the east.

Climate, Drainage and Vegetation

Climate in the Mowry Mine area is characterized by hot summers and mild winters, with recorded extremes of 108 and 12 degrees. Precipitation varies with elevation, and has averaged 16.95 inches since 1914, with 50 per cent falling during the summer months (Kartchner, 1944). Snow is common during the winter months, usually melting by early April.

Streams of the Patagonia Mountains, mostly intermittent, ultimately drain eastward to the Santa Cruz River. Mowry Wash, an intermittent type, is the principal drainage feature in the Mowry Mine area. Numerous minor streams feed into the main drainage from the east and west.

Vegetation is principally sub-tropical, with pinon, juniper, pine, ironwood, yucca and small oak trees prevelant. The region is a very productive agricultural center, and is also excellent for cattle raising.

Previous Work

In 1907, J. W. Prout wrote a thesis for an Engineer of Mines Degree at the University of Arizona, describing the ore deposits and mining methods at the Mowry Mine. The same year, R. B. Brinsmade published an excellent report on the local geology and on the mining and metallurgical practises employed at the mine.

In 1915, F. C. Schrader wrote USGS Bulletin 582, which is the best reference available for the regional geology of the Patagonia Mountains and descriptions of individual mines. Several pages are devoted to the ore deposits, structure and stratigraphy in the Mowry Mine area.

Through 1915, it was believed that the large body of granite, which forms the footwall at the Mowry Mine, was intrusive into Carboniferous limestone.

Locke, Billingsley, Mayo and Lovelace evaluated the mine in 1941, but regarded the granite as Precambrian in age. Geological investigations by the late H. M. Kingsbury (1955) supported this theory. Mr. Kingsbury also studied the occurrence of the silica breccia in the

Mowry Mine area, and regarded it as due to mineralization stoping.

Method of Investigation

Geologic field studies of the Mowry Mine area were made during the fall semester of 1955 and early 1956. The mine and immediate vicinity were mapped on a topographic sheet enlarged from the Harshaw, Arizona Quadrangle, at a scale of one inch equals 500 feet. Prior to mapping, six control points were surveyed with transit and stadia rod to facilitate accurate compass and pace traverses. Approximately forty-five days were spent in the field under the direction of Dr. W. C. Lacy, while a minimum of fifteen days were utilized in petrographic studies. All rocks were described and named according to R. B. Travis, Classification of Rocks, 1955.

Purpose of Investigation

This project was undertaken in partial fulfillment of requirements for a Master of Science Degree at the University of Arizona. The Mowry Mine was chosen for study to evaluate previous writings, and clarify the stratigraphy, structure and genesis of the ore deposits. Special attention was given to the Precambrian complex and mode of emplacement of the silica breccia.

Acknowledgements

The writer is grateful to the faculty of the Department of Geology, University of Arizona, for help given him during the preparation of this report. Dr. W. C. Lacy visited the Mowry Mine area several times, and was most helpful during field mapping. Dr. D. L.

Bryant assisted in the identification of fossils. Dr. R. L. Dubois advised on petrographic studies. Special thanks are due Mr. R. B. Cubley, who assisted the writer in transit and stadia surveying. The late H. M. Kingsbury and D. S. Stranahan, who supervised a drilling program for Ventures Limited of Canada, offered several suggestions related to ore deposition and the mode of emplacement of silica breccia.

This thesis was supported by a Kennecott Research Fellowship, granted for 1955-1956.

GEOLOGY

General Statement

Within the Mowry Mine area, rocks range in age from Precambrian to Tertiary (?). Paleozoic and Mesozoic sediments attain a thickness of approximately 2,700 feet. Igneous activity took place during Archeozoic, Mesozoic and Cenozoic time. The mine and immediate vicinity is characterized by a complex structure, with high angle normal faulting the most prevalent type. Late Paleozoic fossils were discovered at several localities.

Sedimentary Rocks

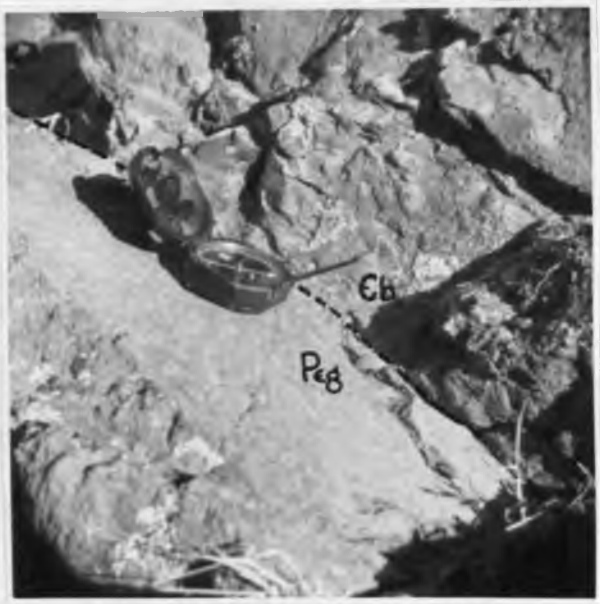
General Statement

Sediments ranging in age from middle Cambrian to lower Cretaceous were recognized in the Mowry Mine area during field mapping. Though widespread folding and faulting is prevalent, a representative stratigraphic section is present, excepting the Martin limestone, which probably has been faulted and eroded. South of the Mowry Mine, in the vicinity of Washington Camp, the Martin limestone is recognized.

Conformably overlying the Bolsa quartzite, a thick sequence of finely laminated shales was designated by the writer as the Cochise formation Stoyanow (1936). No sediments of Ordovician or Silurian age were recognized.

Papers by Gilluly, Cooper and Williams (1954) and Stoyanow

PLATE V



A. Depositional contact separating Precambrian igneous complex and Bolsa quartzite, north base of Hill #5625.

(1936), were the principal reference source during the study of the late Paleozoic and lower Cretaceous respectively.

Middle Cambrian

Bolsa Quartzite

In the type locality at Bisbee, Arizona, Ransome (1904, p. 3), described the Bolsa quartzite as composed of basal conglomerates, pebbly grits, and cross-bedded vitreous quartzites. At Bisbee, the Bolsa quartzite unconformably overlies the Pinal schist, and attains a thickness of 430 feet.

The Bolsa quartzite is widespread in the Mowry Mine area. The quartzites and a few shaly members, representing a local change in environment, form prominent cappings on Hills #5400, #5625, and #5700, and may be seen in a small fault block on the north side of the Mowry Fault. On all these hills, the quartzite strikes north, and dips 45 to 70 degrees east, unconformably overlying the Precambrian igneous complex. In the Mowry Mine area, faults, shears, and folds are common in the Bolsa quartzite at all localities.

In the draw between Hills #5625 and #5700, the Bolsa quartzite is separated from Precambrian igneous rocks by a transitional granite pebble conglomerate 15 feet thick. The conglomerate is tan to purple in color, composed of granite pebbles up to one inch in diameter with a matrix of quartz, feldspar, mica, kaolin, sericite and chlorite. The pebbles and cobbles are generally sub-angular to round, which serves to distinguish the rock as sedimentary, rather than a coarse-grained porphyritic igneous intrusive. The most complete section of Bolsa quartzite (393 feet) was measured between Hills #5625 and #5700 (see Appendix I).

In the Mowry Mine area, the transition zone of granite pebble conglomerate is overlain by 3 to 12 foot beds of medium to coarse-grained gritty quartzites, containing small feldspar fragments, and thinner bedded, white to gray vitreous quartzites. The shaly members vary from 1 to 3 inches in thickness, and are gray, tan, brown, green, and maroon. Cross-bedding and etching are common, and the quartzites generally are stained red to black by iron and manganese solutions. No sulfide mineralization was noted in the Bolsa quartzite.

Cochise Formation

The Cochise formation was first described by Stoyanow (1936, p. 30), with the type locality in the Whetstone Mountains. Here, the formation was measured to be 311 feet thick, conformably overlying 4 feet of buff, hard sandstone (Pima sandstone). Three distinct members were noted: (1) 30 feet of pink, reddish thin-bedded sandstones, (2) 116 feet of vari-colored shales, alternating with calcareous shale and thin, rubbly limestone in the upper horizon, (3) 165 feet of alternating mottled limestone and shales, with blue limestone dominating the upper part of the formation. Stoyanow (1936) dated the Cochise formation as middle Cambrian on the basis of trilobites.

In the Mowry Mine area, the Cochise formation conformably overlies the Bolsa quartzite and is well exposed on dip slopes of Hills

#5400, #5625, and #5700. The Pima sandstone was not recognized during field studies. Because all exposures of the Cochise formation are found on dip slopes, a reliable thickness of the rock unit is impossible, as talus, brush, and recent soils form a thick veneer. However, approximately 300 feet of the Cochise formation is exposed on the east flank of Hill #5625, where deep gullies cut through tilted beds of shales, sandstones and limy sediments.

Generally, the Cochise formation consists of a sequence of sediments remarkably similar to those in the type area. Thinly bedded pink sandstones are overlain by red, tan, brown, and green finely laminated shales, which become limy upward in the section. Alternating brown and black mottled limestone and shale overlie the varicolored shales. The characteristic blue limestone of the upper part of the formation (Stoyanow 1936, p. 31), was not recognized. No fossils were discovered, but lithologic similarities with the type section seem to confirm its identity as Cochise.

Devonian

Although the Martin limestone is widespread in the Patagonia region, the formation was not recognized in the Mowry Mine area.

Mississippian

Escabrosa Limestone

Ransome (1904, p. 4), first described the Escabrosa limestone as a "cliff-forming, thick-bedded, white to dark, granular limestone made up largely of crinoidal fragments."

In the Mowry Mine area, at the southeast base of Hill #5700, the Cochise formation of middle Cambrian age is separated from the overlying Mississippian Escabrosa limestone by a fault. The limestone was dated as Mississippian in age on the basis of the guide fossil Archimedes. No attempt was made to determine the thickness of the limestone, because it is badly broken by faulting. Kartchner (1944), measured 338 feet of Escabrosa limestone approximately five miles to the north.

In the area mapped, the Escabrosa limestone is dense, blue-gray in color, with numerous chert concretions which are characteristically stained tan to dark brown on the surface. Beds generally vary from a few inches to a foot in thickness, and are cut by numerous red calcite veinlets. Light brown to red shaly members are present locally. On the surface the limestone weathers smooth. It is locally dolomitic. The Escabrosa limestone was distinguished from the overlying Naco group by its Mississippian guide fossil Archimedes. This formation is not known to be a favorable host rock for ore deposition at the Mowry Mine.

Pennsylvanian-Permian

Naco Group

The Naco limestone was first defined by Ransome (1904, p. 4), as an "assemblage of post Mississippian Paleozoic rocks" at Bisbee, Arizona. Gilluly, Cooper and Williams (1954) elevated the original Naco formation to group status and defined six new formations within it. They are, in order from oldest to youngest: Horquilla limestone, Earp formation, Colina limestone, Epitaph dolomite, Scherrer formation, and the Concha limestone. Although a revision of Pennsylvanian-Permian stratigraphy has been proposed (Bryant, 1955), the writer was guided by the published work of Schrader (1915), and Gilluly, Cooper and Williams (1954) in field studies. No attempt was made to map the separate formations of the Naco group.

Schrader (1915), recognized the limestones composing Mowry Hill as post-Mississippian in age, and further stated, "though the section is incomplete, they aggregate 800 feet in thickness, of which 330 feet are shown in the mine." In field mapping, the author collected the following fossil specimens, which served to positively identify the rocks of Mowry Hill as Pennsylvanian-Permian in age (D. L. Bryant, oral communication, 1956).

Crinoid stems	Rhynconellids
Composita	Lophophyllidium
Dictyoclostus	Bellerophontids
Echinoconchus	Euomphalids
Fenestrellina	Linoproductus

Though no exposure of the contact was observed in the Mowry Mine area, the Naco group overlies the Mississippian Escabrosa limestone unconformably (?) in most areas in southern Arizona (Gilluly, Cooper, Williams, 1954). The base and top of the Naco group were not recognized in the field, but lithologic correlation with Pennsylvanian-Permian limestones at Bisbee, Tombstone and the Dragoon Mountains suggest that the lower and middle portions of the group are exposed in the Mowry Mine area. Thin shaly limestones and deep red shales of the Earp formation were noted in a draw about 500 feet northeast of the Bullwhacker Mine. Structure in close proximity to the Earp formation exposure is relatively simple, and lithologic similarities indicate the underlying sediments to be the Horquilla limestone. Overlying the Earp formation is the Colina limestone, which in the Mowry Mine area is light gray in color, and relatively pure, with numerous crinoid fragments and a few chert nodules. The summit and west slope of Mowry Hill, which forms the west limit of a northwest trending anticline, are locally faulted. Subsequent erosion and vegetation mask the former picture. However, tan limy sandstones, sandy limestones, dolomites and quartzitic sandstone members indicate that at least parts of the Epitaph dolomite and Scherrer formation are present. No field data were observed which proved the presence of the Concha limestone, the uppermost formation of the Naco group.

At several places on Mowry Hill, the Pennsylvanian-Permian limestones surround brecciated siliceous rocks, which are believed to be of intrusive origin along zones of weakness. Close to the mineralized zone, the limestones are silicified and dolomitized. The Naco group was the primary host rock of the silver-lead ores at the Mowry Mine.

Cretaceous

Patagonia Group

The only published information on Cretaceous stratigraphy in the Patagonia mining district was written by Stoyanow (1949). He designated the lower Cretaceous sequence as the Patagonia group, with an estimated maximum thickness of 4,500 to 5,500 feet. Five main subdivisions of the Patagonia group, including the Molly Gibson formation, were described by Stoyanow (1949, p. 30), in the American Peak area.

PLATE VI

A. Etched Naco limestone, north-
east of Mowry Hill, note compass
for scale.

B. Altered Cretaceous red shales
and agglomerates, north of Mowry
Hill looking north.

(1) Thin shales overlie Precambrian schist and granite which are capped by andesitic agglomerate, hard reddish sandstones containing lenses of conglomerate and quartzite, grading upward into fine-grained arenaceous shales.

(2) Thin beds of andesite, with associated gray and purple agglomerates, aggregating 250 feet in thickness.

(3) Folded and crumpled brown, white, gray and red argillaceous shales in layers up to 6 inches thick, approximately 3400 feet in thickness.

(4) Brown, gray, chocolate and red argillaceous and siliceous shales are overlain by blue limestone beds, vari-colored shales and gray to pink arenaceous limestones. These 1500 feet of sediments compose the Molly Gibson formation.

(5) Dark blue-black hornstones alternate intermittently with siliceous and argillaceous shales; total thickness about 1500 feet.

Though not correlative lithologically with the Bisbee group due to the presence of volcanics, Stoyanow (1949, p. 31), believes the Patagonia group to be lower Cretaceous in age.

Cretaceous sediments occur at three localities in the Mowry Mine area; at the north base of Mowry Hill, at the southwest base of Mowry Hill, and west of the Flying R Ranch. North of Mowry Hill, Recent valley fill, talus and vegetation obscure the contact, but it appears that Cretaceous sediments rest unconformably on Permian (?) limestone. At the southwest base of Mowry Hill, Cretaceous sediments are separated from the underlying Naco group by a fault. West of the Flying R Ranch, sediments of Cretaceous age are separated from Precambrian igneous rocks by a fault.

Although folding and faulting have obscured the present picture of Cretaceous stratigraphy in the Mowry Mine area, the writer believes at least portions of sub-divisions 1, 2, and 3 of the Patagonia group are present.

West of the Flying R Ranch conglomerates, overlain by quartzites and shales, form a sequence of beds dipping south, aggregating about 1200 feet in thickness. The conglomerate consists of granitic and limestone cobbles and boulders, is gray in color, and is overlain by fine-grained, equigranular pure white to gray quartzites and varicolored thinly bedded shales.

A thin sequence of gray, bedded volcanics (andesite) is overlain by at least 800 feet of brown, gray, purple and red shales, which sometimes contain feldspar fragments. The shaly members are locally faulted and crumpled, and cut by basic dikes. The sediments extending from the Flying R Ranch northward to the southwest slope of Mowry Hill are believed to be correlative with Stoyanow's first three subdivisions, although the 250 feet of andesite was not recognized.

North of Mowry Hill, a volcanic agglomerate (andesite), purple and gray in color, approximately 60 feet thick, is overlain by brown, gray and red shales which total about 250 feet. This sequence is believed to be continuous with subdivisions 2 and 3 of the Patagonia group.

Blue limestones, characteristic of the Molly Gibson formation were not observed. It is believed that only the lower three formations of the Patagonia group as described by Stoyanow (1949) are present in the Mowry Mine area. No fossils were discovered.

Igneous Rocks

General Statement

Igneous rocks occurring in the Mowry Mine area range in age from Precambrian to Tertiary (?). The Precambrian complex is composed of at least three distinct rock types; actinolite gneiss, granite and diorite. Well exposed in the East End shaft, "A" shaft and west of the mine is a basalt, which Schrader (1915), noted as a dike along the limestone-granite contact of the Mowry Fault. The youngest igneous rock recognized in the Mowry Mine area is a monzonite of probable tertiary age, which is tentatively correlated with a large igneous mass occurring at Washington Camp and another, two miles north of the mine.

Post-Cretaceous basic dikes cut the Precambrian complex and Cretaceous sediments. A Tertiary (?) granite sill was observed east of Hill #5700.

Precambrian

At least three distinct rock types comprise the Precambrian igneous complex in the Mowry Mine area; actinolite gneiss, granite and diorite. In field mapping, the rocks were not differentiated, though localities of excellent exposures of each rock type were recorded (see Plate I). Actinolite Gneiss: Actinolite gneiss of Precambrian age crops out approximately 700 feet south of the Flying R Ranch. The rock is fine to medium grained, dark green in color,

PLATE VII

A. Epidotized pegmatite cutting Precambrian gneiss, south of Flying R Ranch.

B. Pegmatite approximately 18 inches in width cutting Precambrian gneiss, south of Flying R Ranch.

and weathers dark rust-brown on surface. Pegmatites, ranging in width from 1/4 inch to 18 inches cut the gneiss, and commonly exhibit a complex network.

Petrography

Actinolite: 40 per cent. Light green in color, occurs as long prismatic crystals, closely associated with green hornblende. Differentiated from hornblende by lack of pleochrism. Weak orientation.

Plagioclase: 30 per cent. Tan to gray, fine grained anhedral crystals. Though clay minerals and sericite have coated the plagioclase crystals, the refractive index is approximately 1.54 or equal to that of Oligoclase (Ab_8 An_2).

Hornblende: 20 per cent. Brown, light green in color, pleochroic, occurs as prismatic crystals in close association with actinolite. Minor preferred orientation.

Accessories: Small particles of orthoclase (?) are highly altered. Clay, sericite and epidote are alteration products of plagioclase. Minute secondary veinlets of quartz and limonite present.

Due to the predominance of actinolite in relation to plagioclase and hornblende, and the minor degree of orientation, the rock is designated an actinolite gneiss. Some foliation in the rock was observed south of the Flying R Ranch, but petrographic studies did not reveal a definite preferred lineation of crystals. The high intensity of alteration of plagioclase particles to kaolin, epidote and sericite is believed to be due to the intrusion of basalt, which apparently cuts the actinolite gneiss. However, no opaque minerals suggestive of sulfide mineralization, such as that found at the Mowry Mine were observed in thin section.

The degree of alteration of the rock is so intense that a statement concerning an igneous or sedimentary origin would be purely speculative. Metamorphism is believed to be regional, of low grade intensity.

Granite: Granite is the dominant igneous rock exposed in the Mowry Mine area, forming the footwall of the Mowry Fault and continuing south for at least one-half mile. The mineralogy of the granite is generally uniform, but texture and color vary to a considerable degree. Near the Mowry Fault, the rock is coarse-grained, porphyritic, and tan, pink to dark gray in color. In the vicinity of Mowry Wash, the granite is medium-grained, equigranular, and pink-gray in color. At contacts with overlying sediments and in fault and shear zones, the rock is usually stained red and black from supergene iron and manganese-bearing solutions.

Petrography

Microcline: 35 per cent. Microcline crystals are subhedral, medium-grained, and intimately associated with orthoclase and quartz to form a complex implication structure.

Orthoclase: 30 per cent. Crystals are subhedral to anhedral, medium-grained, crackled, implication texture well exhibited. Generally, alteration is incipient.

Quartz: 20 per cent. Intergrown with microcline and orthoclase, crystals are subhedral, unaltered and fractured locally.

Plagioclase: 10 per cent (?). Occurs in intergrowths with microcline, orthoclase and quartz as a minor constituent.

Accessories: Opaque minerals (magnetite?), chlorite, sericite and clay minerals present in minor amounts.

The foregoing information is based on petrographic studies of a single specimen collected south of Mowry Wash. This granite is relatively unaltered and believed to closely represent an average analysis of the rock type occurring between the Mowry Fault and Hills #5700 and #5625. Petrographic studies indicate the granite in close proximity to the Mowry Fault is intensely altered, with a high percentage of clay minerals, sericite, chlorite, hemetite, limonite and sulfides present.

Studies by Schrader (1915) of a specimen collected at the 400 foot level of the mine revealed the same essential minerals, plus biotite, hornblende, chlorite, iron oxides, apatite, pyrite, marcasite, and chalcopyrite.

Though the granite footwall was mineralized, no appreciable ore was mined from the rock.

<u>Diorite:</u> Precambrian diorite is exposed at two localities in the Mowry Mine area; in a prospect pit approximately 750 feet northwest of the Flying R Ranch, and west of Hill #5700. At the Flying R Ranch prospect pit, the rock is mottled white-green in color, fresh, medium-grained and equigranular. West of Hill #5700, the diorite is dark green in color, fine-grained, equigranular and weathers dark brown to black on surface.

Petrography: (Diorite at Flying R Ranch Prospect Pit)

Plagioclase: 60 per cent. Extinction angle determined from albite twinning of approximately 10° indicates oligoclase ($Ab_8\ An_2$). Plagioclase crystals are subhedral, highly altered to clay minerals and sericite.

Chlorite: 20 per cent. Occurs as green film on altered oligoclase crystals.

Hornblende: 10 per cent. Observed as prismatic crystals, pleochroic, commonly alter to chlorite.

Accessories: Secondary quartz veinlets, sericite, calcite and epidote were noted in minor amounts.

<u>Petrography:</u> (Diorite West of Hill #5700)

Plagioclase: 60 per cent. Oligoclase (Ab_8 An_2) crystals are subhedral, crackled, fine-grained. Alteration is incipient.

Hornblende: 20 per cent. Prismatic crystals of green and brown hornblende observed, some crystals altered to biotite.

Biotite: 5 per cent. Crystals light green in color, subhedral, alters to chlorite locally.

Accessories: Noticeable abundance of magnetite (?), some chlorite, orthoclase and secondary quartz veinlets.

Oligoclase, hornblende, chlorite and biotite appear in both diorites described above. Hydrothermal alteration at the Flying R Ranch prospect pit is probably a result of mineralization at the Mowry Mine, approximately 1500 feet to the north. A fault west of the pit was the likely conduit for the solutions.

The relative abundance of magnetite, and possibly sulfides in the diorite near Hill #5700 may be due to its proximity to a Tertiary (?) intrusion of monzonite east of Hill #5700.

Post-Cretaceous Basalt

Basalt of Post Cretaceous age crops out within a fault block along the Mowry Fault, within a fault block southwest of the mine, and as an intrusive into Precambrian actinolite-gneiss south of the Flying R Ranch. The same basalt was observed by the writer on the 160 foot level of the East End shaft. Schrader (1915), defined the rock as a gabbro and described its occurrence as "seemingly intruding the limestone along the Mowry Fault." The time of emplacement was fixed as post-Cretaceous as evidenced by the basalt cutting Cretaceous sediments west of the Mowry Mine.

The basalt is dark green in color, fine to medium-grained, and equigranular. On weathered surfaces, the basalt is characteristically stained dark brown to black.

Petrography:

Plagioclase:	45 per cent. Probably labradorite (Ab_3 An_7), crystals are fine-grained, anhedral, crackled, highly altered to chlorite, epidote and calcite.
Chlorite:	30 per cent. Occurs as coatings on fringes of plagioclase crystals, light green in color.
Epidote:	15 per cent. Light yellow-green in color, occurs intermingled with chlorite and calcite as minute crystal aggregates.
Calcite:	5 per cent. Occurs as small anhedral crystals and as thin secondary veinlets from alteration of plagioclase.
Accessories:	Highly altered orthoclase (?), quartz occurs as minute secondary veinlets, opaque minerals (sulfides) scattered throughout. Clay minerals associated with the plagioclase crystals.

The rock is dominantly composed of plagioclase, chlorite, epidote, calcite, and minor amounts of othoclase (?), quartz, and opaque minerals. Since the rock was extremely fine-grained, the term basalt was used in preference to gabbro (Schrader, 1915). The mineralogy and texture of the basalt were remarkably similar at all localities in the Mowry Mine area. Alteration, however, varies considerably. A specimen collected from the "A" shaft revealed intense hydrothermal alteration, as did specimens studied in the vicinity of the Flying R Ranch. The basalt observed in the East End shaft was relatively fresh. Where mineralization occurred, especially in the ore zone between the

Mill Fault and the West End Fault, oxidation and weathering was most intense. Schrader further states, "the presence of the gabbro seems to have facilitated oxidation."

The intense oxidation, especially in the ore bearing zone, is believed to be due to ascending hydrothermal solutions following the intrusion of the basalt. These solutions were possibly derived from a deep seated granite, Tertiary (?) in age.

Tertiary (?) Monzonite

Monzonite of probable Tertiary age was observed in the Mowry Mine area southeast of Hill #5700, where it intrudes Mississippian limestone. The rock is tan to gray in color, weathers yellow-brown on surface, and consists of a fine-grained matrix containing biotite crystals up to 1/4 inch in length.

<u>Petrography:</u>

Orthoclase: 40 per cent (?) Fine-grained anhedral crystals, crackled, intensely altered and intergrown with plagioclase to exhibit a typical granophyric texture.

Plagioclase: 35 per cent (?). Fine-grained anhedral crystals reveal plume-like intergrowths with orthoclase. Though few extinction angle samples (practically parallel) were noted, the index of refraction indicates the plagioclase to be Obligoclase.

Biotite: 10 per cent. Crystals are dark brown in color, subhedral to euhedral and elongate. Slight bending of crystals indicates cataclastic deformation, local minor alteration to chlorite.

Accessories: Fine-grained quartz crystals, minute shreds sericite, chlorite, clay minerals and opaque minerals (sulfides) were observed in minor amounts.

Due to intense alteration, the true percentage composition and relationship of the feldspars is questionable. The matrix of fine-grained orthoclase and plagioclase exhibits a granophyric texture.

Field observations approximately 2 miles south of the Mowry Mine suggest that the monzonite is a border phase of a deep seated igneous intrusive well exposed near Washington Camp. Going south from Hill #5700, the monzonite becomes more coarse-grained, though its composition does not seem to change radically. Orthoclase, plagioclase and biotite are the essential minerals of the rock, which agrees with the foregoing petrographic studies.

It is believed by the writer that the monzonite is post-Cretaceous in age, probably Tertiary. The granophyric portion is seemingly a chilled border of an underlying monzonitic mass, which may have been the source of solutions depositing silver-lead ores at the Mowry Mine. It is believed that these ore solutions are later than the basalt (post-Cretaceous) which occurs at the Mowry Mine.

Silica Breccia

As used in this thesis, silica breccia is a rock consisting of a cryptocrystalline groundmass containing angular silicified fragments. Generally, the rock is vuggy, stained dark red and black, but varies in texture in different localities.

In the Mowry Mine area, prominent crags of silica breccia are observed occurring in limestones, quartzites, and along known fault zones. The rock is commonly stained red, but sometimes tan,

PLATE VIII

A.Siliceous breccia, northeast of Hill #5700.

B. Siliceous breccia, northeast of Hill #5700.

brown-black and gray in color, containing angular silicified fragments up to three inches in length. Flow structures within the breccia occur locally. Contacts between the silica breccia and adjacent wall rock are both transitional and sharp. Ledges of the breccia were observed lying parallel to bedding within the Naco limestone.

Petrography:

Igneous rock fragments:	Occur as rectangular kaolin ghosts after feldspars in silicified cryptocrystalline matrix, identified on basis of ghost texture and altered appearance.
Quartzite Fragments:	Crystals are rounded, characteristically stained dark red-brown, all crystals show regrowth.
Limestone Fragments:	Differentiated from quartzite and feldspars by uniform cream color, texture. Completely silicified.
Amphibole fragments:	One ghost of a prismatic crystal, highly altered and silicified, suggestive of hornblende, was noted.

The feldspar and amphibole fragments seem to indicate that the silica breccia is intrusive, and not due to mineralization stoping (Locke, 1926), collapse, or replacement. The igneous rock and amphibole fragments were probably derived from the Precambrian complex at depth. Fragments of quartzite probably are derived from the Cambrian Bolsa quartzite, which would be cut by the fault at depth. Were the silica breccia due to collapse of an overlying limestone roof, the quartzite and igneous fragments would be absent.

From the foregoing evidence, it seems likely that the silica breccia was intruded as a "mush" along zones of weakness in the country rock, possibly as a frontal phase of an underlying intrusive. Though field evidence is lacking, the silica breccia is believed to be Tertiary in age, and an ultra-acid phase of alteration by the deep (?) seated granite intrusive which was the source of ore solutions.

GEOLOGIC STRUCTURE

General Statement

Folding, faulting and subsequent erosion have played a major part in forming the topographic features existant in the Mowry Mine area. The dominant structure is an assymetric, north trending anticline which has been cut by the Mowry Fault.

On Mowry Hill, folded sediments of Pennsylvanian age reveal a former elongate, north-plunging anticline. West of the Flying R Ranch, Cretaceous sediments form an east-west trending syncline. Intense local folding of Cambrian sediments is well exposed at the north base of Hills #5700 and #5625.

Several ages of faulting were recognized, though recent gravels and alluvium obscure a true structural picture. Most known faults are normal, high angle, and generally trend north-south or east-west. Faulting is probably the most important single factor in ore localization at the Mowry Mine.

Folding

Three north-trending hogback ridges capped by Cambrian quartzites form one of the major topographic features in the Mowry Mine area. These ridges are referred to in plate #1 as Hills #5700, #5625 and #4500, and conform to a general northerly strike. South from Hill #5400 to Hill #5700, the quartzite beds increase in dip from 45 to 70 degrees east respectively.

Mowry Hill is composed of Pennsylvanian-Permiam limestones, dolomites, shales and quartzites which form a northwest-southeast trending assymetrical anticline. Local faulting has resulted in a complex structural picture. On the north and east flanks of the hill, limestones dip from 20 to 50 degrees to the northeast. At the west base of Mowry Hill, sediments dip from 25 to 70 degrees to the west. The anticlinal structure, which may be seen continuing northward from the top of Mowry Hill, is cut on the southeast by the Mowry Fault. Though folded and faulted locally, Cretaceous sediments lying at the north and southwest base of Mowry Hill reflect the same structure.

West of the Flying R Ranch, Cretaceous sediments are deformed to exhibit an east-west synclinal structure. Sediments on the south limb of the syncline dip 30 degrees north. Shales, limestones and quartzites on the north limb dip to the south at 50 to 60 degrees.

Numerous small overturned and recumbent folds were observed throughout the Mowry Mine area. A recumbent fold of Bolsa quartzite is well exposed along the Patagonia-Washington Camp road at the north base of Hill #5700. Small overturned folds were also noted on the north slope of Hill #5700.

Faulting

Mowry Fault: The Mowry Fault, forming the contact between limestone and granite, is exposed for 4,000 feet at the Mowry Mine. It is normal, strikes approximately north 75 degrees east, dips 80 degrees to the north, and is offset by the East End and West End Faults. Where the Mowry Fault is cut by the West End Fault, a lateral dis-

PLATE IX

A. Tilted Bolsa quartzite, looking east at base of Hill #5700.

B. Recumbent fold of Bolsa quartzite north base of Hill #5700 looking east.

placement of approximately 50 feet has taken place. Evidence for amount of displacement by the East End Fault is lacking.

The limestone hanging wall is separated from the Precambrian igneous complex by a wide shear zone, rather than a single fault. Drilling data received from Ventures Limited (1956) indicated 17 feet of fault gouge 350 feet below the surface of the ground.

The stratigraphic throw of the Mowry Fault is believed to be in excess of 5,000 feet. At Bisbee, Ransome (1904), measured 5,435 feet of Paleozoic sediments overlying the Precambrian igneous complex. South of the Mowry Fault, where Precambrian rocks are exposed, a somewhat equal thickness of sediments would have to be eroded to reveal the present picture.

West End Fault: The West End Fault cuts Paleozoic limestones, Cretaceous sediments, and is exposed for about 2,000 feet in a general north-south direction. Field evidence indicates the fault to be normal and high angle. The northward continuation of the West End Fault seemingly cuts several siliceous breccias. Evidence for positively plotting the southward continuation of the fault was not observed.

West End Fault Block: The West End Fault Block is composed of Cretaceous sediments cut by a basalt dike. Relative to Pennsylvanian-Permian limestones to the north, the fault block is downthrown (see Plate #1). Its southern limit is marked by the westward continuation of the Mowry Fault, along which a large body of siliceous breccia has been emplaced.

East End Fault: The East End Fault is best exposed in a prospect cut on the north slope of Hill #5400. Here, approximately 3 feet of argillaceous gouge separate the Bolsa quartzite from the overlying Cretaceous sediments. The fault strikes northwest, dips 70 degrees east, and is normal. Unlike most faults observed near the Mowry Mine, the East End Fault is relatively free from iron and manganese staining.

East End Fault Block: The East End Fault Block is also composed of Cretaceous sediments which were downthrown in relation to the adjacent Bolsa quartzite and Pennsylvanian-Permian limestones. Except where the East End Fault can be traced on surface, the limits of the fault block are speculative, due to a thick veneer of recent gravels and sands.

Mill Fault: The Mill Fault is normal, strikes north 15 degrees east, and dips 60 degrees to the west. Relative to Pennsylvanian-Permian limestones, the Mill Fault Block, composed of Bolsa quartzite and basalt, is upthrown. The main ore zone was limited on the east by the Mill Fault.

Flying R Fault: Approximately 150 feet west of the Flying R Ranch, a fault contact was observed between Cretaceous sediments and the Precambrian igneous complex. This structure will be referred to as the Flying R Fault. It is nearly vertical, and strikes generally north. Except for an exposure west of the Flying R Ranch, the fault is covered by recent gravel and soil.

<u>South Fault:</u> A fault separating Cambrian sediments and Mississippian limestone at the east base of Hill #5700 has been termed the South Fault. Here, Cambrian sediments (Cochise formation) strike north and dip 70 degrees east, while the Escabrosa limestone strikes northwest and dips 40 to 50 degrees west. Relative to Cambrian sediments, the Escabrosa limestone is seemingly downthrown, which indicates that the South Fault is reverse.

Relationship of Structural Events

Field evidence indicates several periods of igneous activity in the Mowry Mine area. The sequence of structural events is believed to be as follows:

(1) Orogenic uplift in post-Cretaceous time produced a north-south trending anticline in Paleozoic and Cretaceous sediments. Contemporaneous with uplift, the Flying R fault was formed. Normal to the longitudinal Flying R fault, the transverse Mowry Fault was developed.

(2) An intrusion of basalt, localized by the Mowry Fault, produced the Mill Fault Block.

(3) Renewed movement along the Mowry Fault.

(4) A second period of normal faulting produced the West End and East End Faults. The West End and East End Fault Blocks were developed at this time.

(5) During Tertiary (?) time, a large granitic mass was emplaced south of the Mowry Mine, and the south fault was developed. This Tertiary (?) intrusion of monzonite was accompanied by mineralization.

Several factors indicate that the Mowry Fault was formed prior to the intrusion of basalt. On the 160 foot level of the East End shaft, the basalt was observed intrusive into Pennsylvanian-Permian limestones. This contact is fresh, with no evidence for faulting present. Near the "A" shaft, where basalt intrudes Cretaceous sediments, a wide shear zone was noted which indicates movement along the Mowry fault after intrusion of the basalt. The dike-like appearance of the basalt at the mine (Schrader, 1915, p. 300), also suggests the basalt intrusion was localized by a strong structural feature, such as the Mowry Fault.

Evidence for dating the monzonitic intrusion as Tertiary is not clear. The crumpled and broken Escabrosa limestone suggests the intrusion to be post-Mississippian in age. However, a granite intrusion approximately two miles north of the mine appears to cut Cretaceous sediments. Four miles south of the Mowry Mine at Washington Camp, granite is known to intrude Pennsylvanian-Permian limestones. The writer believes all three intrusions to be genetically related, and therefore, Tertiary in age.

MINERAL DEPOSITS

General Statement

From 1858 to 1910, the Mowry Mine was worked primarily for its high grade silver-lead ores. In recent years (1955), minor amounts of manganese have been profitably extracted. By 1907, all of the known ore bodies were fully developed from the surface to the 400 foot level (Prout, 1907). Geologic investigations and especially a diamond drilling program conducted by Ventures Limited of Canada in 1954-1955 were not successful in locating new reserves.

Mining

When J. W. Prout was mine superintendent (1907), the Mowry Mine was producing 200-500 tons of silver-lead ore per day. Underground workings consisted of 15,000 feet of drifts, raises and winzes connecting to the surface by at least six shafts; with square set stoping, overhead stoping and cut and fill the principal mining methods. Previously, approximately 80% of the ore had been mined by block-caving, with minor square set stoping where the ore was too siliceous to cave (Peele, 1952). The deepest workings were to 500 feet, and water was encountered at the 400 foot level at the rate of 200 gallons per day.

In the study of the Mowry Mine, the East End shaft was examined, and found to be in good condition. On the 160 foot level, an excellent exposure of a basalt dike intruding the granite-limestone fault contact was observed. All of the contacts are fresh and sharp, with little mineralization or oxidation along the fault zone. Within the limestone hanging wall, several solution caves were noted, as well as small pockets of limonite, hematite and manganese minerals, but no silver-lead minerals were observed. Caving, poor mining methods and slumpage has made the mine generally inaccessible at the present time. Necessarily, the following information has been taken from the writings of Prout (1907), Brinsmade (1907), Schrader (1915), and personal discussions with the late H. M. Kingsbury and D. S. Stranahan (1955) of Ventures Limited.

Ore Deposits

The ore deposits of the Mowry Mine primarily consisted of argentiferous galena, cerussite and anglesite, and averaged 40 dollars to the ton, though high grade ores carried up to 68% lead, 4,000 ounces of silver, and minor amounts of gold. Pyrolusite, psilomelene, manganite and wad, extracted in 1955 from the Beyerle Pit averaged approximately 25% manganese. The lead-silver ore bodies occurred in the north or hanging wall side of the east-west Mowry Fault as replacement bodies in limestone and true fissure deposits, and were continuous on strike for 600 feet along the limestone - granite contact. Generally, the ore bodies were six to eight feet in width, dipping 80 degrees north, and striking north 75 degrees east, extending downward to the 500 foot level (Schrader, 1915).

Four main ore bodies were developed at the Mowry Mine; three were connected to each other (see Plate III). Ore body #1 was roughly pipe shaped and the source of the highest grade ores, containing 400 ounces of silver per ton and 68% lead. Connecting with ore body #1 above the 150 foot level, ore body #2 averaged 40% lead and 25 to 300 ounces of silver to the ton. Ore bodies #3 and #4 were generally similar to ore bodies #1 and #2, though siliceous ores began to appear and the grade decreased.

On surface, the ores cropped out as oxides of argentiferous galena, iron and manganese extending along the shear zone for approximately one-half mile. At the present time, mineralization along the Mowry Fault is obscured by caving and tailings. Drilling reports from Ventures Limited and field observations, especially in the Beyerle manganese pit, indicate a shear zone rather than single structure between the limestone-granite contact. Where the fault was penetrated at a depth of 350 feet, approximately twenty feet of argillaceous gouge was encountered (Stranahan, 1955).

All of the ore bodies were localized within 100 feet north of the Mowry Fault, decreasing in size and grade to the 500 foot level, where they rapidly pinched out. Laterally, the ore deposits were localized between the West End and Mill Faults, a distance of approximately 1,000 feet (see Plate IV). Several deposits occur as mantos, following the limestone bedding planes for several hundred feet from the shear zone.

The silver and lead ores were all contained within a feruginous and manganiferous gangue of hematite, limonite, psilomelene, pyrolusite and wad, which formed approximately one-fifth of the ore bodies in volume (Schrader, 1915). To the 300 foot level, the ores were oxidized to form argentiferous cerussite and anglesite, with galena the only sulfide mineral present. The richest ore was extracted from this zone (see Plate III). Below the 400 foot level, sulfides of iron and copper began to appear. In reviewing the ore deposits of the Mowry Mine, the lack of quartz and zinc are noteworthy.

The most favorable host rock for ore deposition was the low silica Pennsylvanian-Permian limestone, which forms the hanging wall of the Mowry Fault. Chemical analysis of the limestone by J. W. Prout (1907) reveal the following:

Chemical Analysis of Naco Limestone

Shear Zone		100 Feet North of Shear Zone	
CaCo3	94.36%	CaCo3	91.73%
Si02	2.10	Si02	4.0
FeO	1.46	FeO	.45
Loss, H20	2.02	Al203	1.45
	99.94%	Loss, H_2O	2.41
			100.00%

Northward from the Mowry Fault to a siliceous breccia zone midway up the slope of Mowry Hill, there is a characteristic decrease in iron and calcium and an increase of silica, with the introduction of alumina.

At the 235 foot level, a basalt dike became the hanging wall, continuing to the bottom of the mine. Little ore was mined from the basalt, but its introduction greatly facilitated oxidation, and was a likely conduit for later ore solutions. Although oxidation does not accompany the basalt at the East End shaft, minor sulfide mineralization was noted in the limestone hanging wall, consisting of pyrite and chalcopyrite. Between the 200 foot and 300 foot level, in close proximity to the basalt intrusion, ore, gangue, and wall rock were highly oxidized and stained red with iron bearing minerals. At the 400 foot level, the gangue minerals were characterized by kaolin and calcite.

In summarizing the ore deposits of the Mowry Mine, several noteworthy factors are evident:

(1) The silver-lead ores were localized, so far as is known, between the Mill fault on the east, and the West End Fault, and within 100 feet north of the Mowry Fault in the limestone hanging wall.

(2) The most favorable host rock, the Pennsylvanian-Permian Naco limestone is characteristically pure and unsilicified in the ore bearing zone.

(3) Where oxidation was most intensive (surface to 300 foot level), the ore grade was maximum.

(4) The deposits are of replacement and true fissure type, with a noteable lack of zinc and quartz.

(5) Structure and host rock favorability (limestone) were the most important factors in ore deposition.

Apparently, the ore deposits of the Mowry Mine were formed in early Tertiary time. Schrader (1915) believed the paucity of quartz in the ore deposits indicated the ore solutions originated from a basalt dike which intrudes the limestone-granite contact.

Few, if any ore deposits in southern Arizona are known to have originated from basic intrusions, and the presence of a large monzonitic body in the Washington Camp area and north of the Mowry Mine leads the writer to believe the basalt was merely a favorable conduit for later ore solutions.

The sequence of ore deposition at the Mowry Mine was probably as follows:

(1) Faulting after deposition of Cretaceous sediments produced the Mowry Fault, the governing linear structure. (Locke, Schmitt, Billingsley, 1934).

(2) Intrusion of basalt along the Mowry Fault and southwest of the mine.

(3) Renewed shearing along the Mowry Fault, followed by the formation of the West End Fault and East End Fault.

(4) Intrusion of early Tertiary (?) monzonite and deposition of silver-lead ores.

Though field evidence is lacking, it seems likely a zone of structural weakness existed prior to the intrusion of basalt to localize its present position. It is also postulated that the source of ore solutions was a monzonitic body well exposed near Washington Camp and north of the Mowry Mine. Its age-relationship is based on the assumption that the monzonite is later than the basalt, or at least later than post-Cretaceous.

Extensive work has been done to explore the possibilities of making the Mowry Mine a new ore producer in recent years. A property evaluation by the noted geologists Locke, Billingsley, Mayo and Lovelace in 1941 did not uncover any new ore reserves. The most recent development was the mining of approximately 10,000 tons of manganese ore from the Beyerle open pit in 1955. This operation has since been discontinued, although minor amounts of ore remain in the pit. During 1955-1956, Ventures Limited of Canada drilled three holes along the Mowry Fault zone, but the results did not warrant further exploratory work.

Some manganese minerals were noted at the Bullwacker Mine, but in insufficient tonnage to be of further interest. The localities of strongest mineralization are found in the vicinity of the Flying R Ranch, and at a small copper prospect at the northwest base of Mowry Hill.

Future

Although the Mowry Mine may not produce ore again, one, and possibly two features warrant further study.

Beyond the West End Fault, where the Mowry Fault is offset approximately 50 feet, Cretaceous sediments are encountered which probably overlie the favorable Pennsylvanian-Permian Naco limestone.

The westward continuation of the Mowry Fault was mapped for the first time as a part of this study. (See Plate #1).

A hole drilled along the Mowry Fault extension, to discover the underlying (?) Naco limestone could possibly yield favorable results.

It should be further noted that on the westward extension of the Mowry Fault, basalt forms the footwall, and a large silica-breccia mass is present.

Drilling in close proximity to the silica-breccia on Mowry Hill is another prospect, on the basis of research conducted by the writer which revealed similar siliceous bodies occuring over and under ore bodies as impermeable layers at Tintic, Utah; Aspen, Colorado; Stockton-Fairfield, Utah, Magdalena, New Mexico, and Bisbee, Arizona. Although the writer does not subscribe to the colloidal silica replacement of limestone theory at some of these localities, their occurrence, and use as ore guides is a question to be yet answered at the Mowry Mine.

GEOLOGIC HISTORY

Paleozoic Era

During the Paleozoic era, the Patagonia Mountain region was part of a slowly sinking shelf between the Defiance and Ensenada positive areas (McKee, 1951, p. 485). Eardley (1949), has termed this shelf the "Arizona sag".

The earliest Cambrian sea transgression resulted in the deposition of the Bolsa quartzite unconformably on a Precambrian igneous complex. Quiet seas also deposited shales of the Cochise formation during Cambrian time. The Abrigo formation and the Martin limestone were not observed in the Mowry Mine area. A long period of erosion or non-deposition followed deposition of middle Cambrian sediments. No Silurian or Devonian sediments are known to exist in the Patagonia Mountains.

During late Paleozoic time, limestones, shales and quartzites were deposited in the shelf area. A possible erosion interval (Gilluly, Cooper and Williams, 1951, p. 13), separates the Mississippian Escabrosa limestone from the Pennsylvanian-Permian Naco group. Paleozoic sediments attain an approximate thickness of 1,500 feet in the Mowry Mine area.

Mesozoic Era

No sediments of Triassic or Jurassic age have been discovered in southern Arizona. In lower Cretaceous time, southeastern Arizona occupied part of the Mexican geosyncline (McKee, 1951, p. 495) and sediments of the Patagonia group were deposited in the Mowry Mine area. Volcanic activity also took place during this period. Shales, agglomerate, dacite, limestone and quartzite of the Patagonia group aggregate approximately 1200 feet in thickness. After deposition of the Patagonia group, tectonic activity produced uplift, faulting and basaltic intrusions.

Cenozoic Era

During Cenozoic time, renewed faulting occurred in the Mowry Mine area, which was followed by an intrusion of monzonite and mineralization. Erosion since early (?) Cenozoic time has resulted in widespread deposition of valley fill, composed of gravels and sand.

APPENDIX I

The below section of Bolsa quartzite was measured between Hills #5700 and #5625 (see Plate I).

In this locality the Bolsa quartzite appears to be separated from the overlying Cochise formation by a sill-like intrusion of monzonite. Therefore, the top of the Bolsa was taken where the sill was first encountered, at 393 feet.

Quartzite is fine-grained, equigranular, red to purple to black in color, vitreous luster on fresh fracture, surface is locally etched, beds up to 2 feet in thickness...........	393.0
Sandy quartzite grades into hard vitreous quartzite, medium grained, contains some feldspar fragments, gray, red-black in color, interbedded with at least six brown-red shaly members, 2 to 4 inches in thickness........	356.0
Quartzite becomes sandy with particles of feldspar present, rock soft, light rust to gray in color, beds 6 to 18 inches thick, jointed, overlain by four foot sequence of rust, brown, dark gray finely laminated shales..	307.0
Medium-grained, equigranular quartzites; dark gray in color, 1 to 2 foot layers interbedded with eight thin shaly members up to 4 inches in thickness, colored brown, black, and dark green........................	299.0
Medium-grained quartzites, equigranular, white, gray, red, brown and black in color; locally sandy, etched, beds 1 to 3 feet in thickness.............................	271.0
Rust-brown equigranular quartzites, bedding six inches to two feet in thickness; interbedded with four crushed shaly members, two inches to 5 inches in thickness, colored brown, green and black...............	239.0
Light colored quartzite, pebbles vary from 1/4 inch in diameter to fine grained, distinct cross-bedding and graded bedding common, beds vary in thickness from 8 inches to 1 foot, joint cracks parallel to bedding about 8 inches apart, some	

layers tinted red and purple, overlain by 6 inch bed of finely laminated, rust colored shales...............	197.0
Quartzite is fine to coarse grained with white quartz pebbles up to 1/4 inch in diameter, locally etched, tan to light gray in color, somewhat vitreous, some large fragments up to 4 inches in diameter have been resilicified and "plastered" on top of the quartzites. Beds are 1 to 3 feet in thickness, cross-bedding common. Color may vary from tan and gray to deep purple, red, black, jointing comspicuous....................................	165.0
Medium to coarse grained uniform quartzite, dark brown in color, bedding 8 inches to 2 feet in thickness, interbedded with four shaly members, tan to dark brown in color, 2 to 3 inches in thickness, approximately 12 to 18 inches apart.............................	65.0
Fine shale members, 1/2 to 1 inch in thickness, interbedded with coarse, pebbly quartzites brown and red in color. Quartzite beds are from 6 inches to 2 feet in thickness...	42.0
Quartzite generally fine to medium grained, equigranular, stained deep red-black, grades upward into coarser grained quartzite with white rounded quartz pebbles, becomes similar to medium grained quartz conglomerate with some red chert pebbles...........	34.0
Quartzites are fine grained becoming coarser upward with some pebbles of rounded white vein quartz up to 1/4 inch in diameter. Bedding obscure, rocks stained deep rust and black; thin shaly member is dark brown-maroon in color, contains many crushed flecks of mica..	16.5
Transition zone of granite pebble conglomerate, pebbles up to 1 inch in diameter, tan, red, dark brown-black in color, contains rounded to subangular quartz fragments, feldspars and mica, alteration products of sericite and chlorite noted, conglomerate grades upward from coarse grained to finer grained................................	15.0
Precambrian igneous complex................................	0.0

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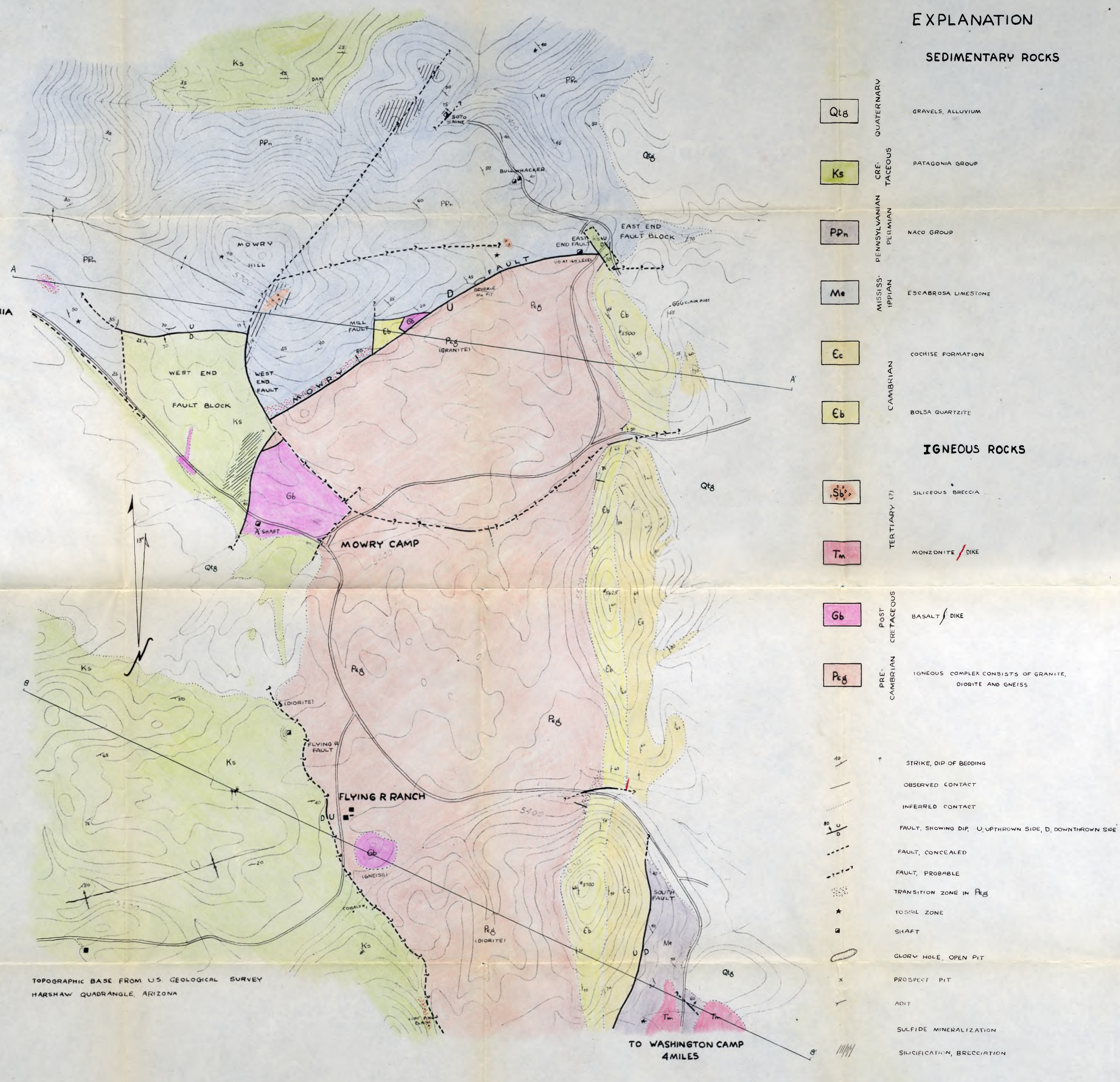
4 pieces

PLATE I



GEOLOGIC MAP OF THE MOWRY MINE AREA, SANTA CRUZ COUNTY, ARIZONA

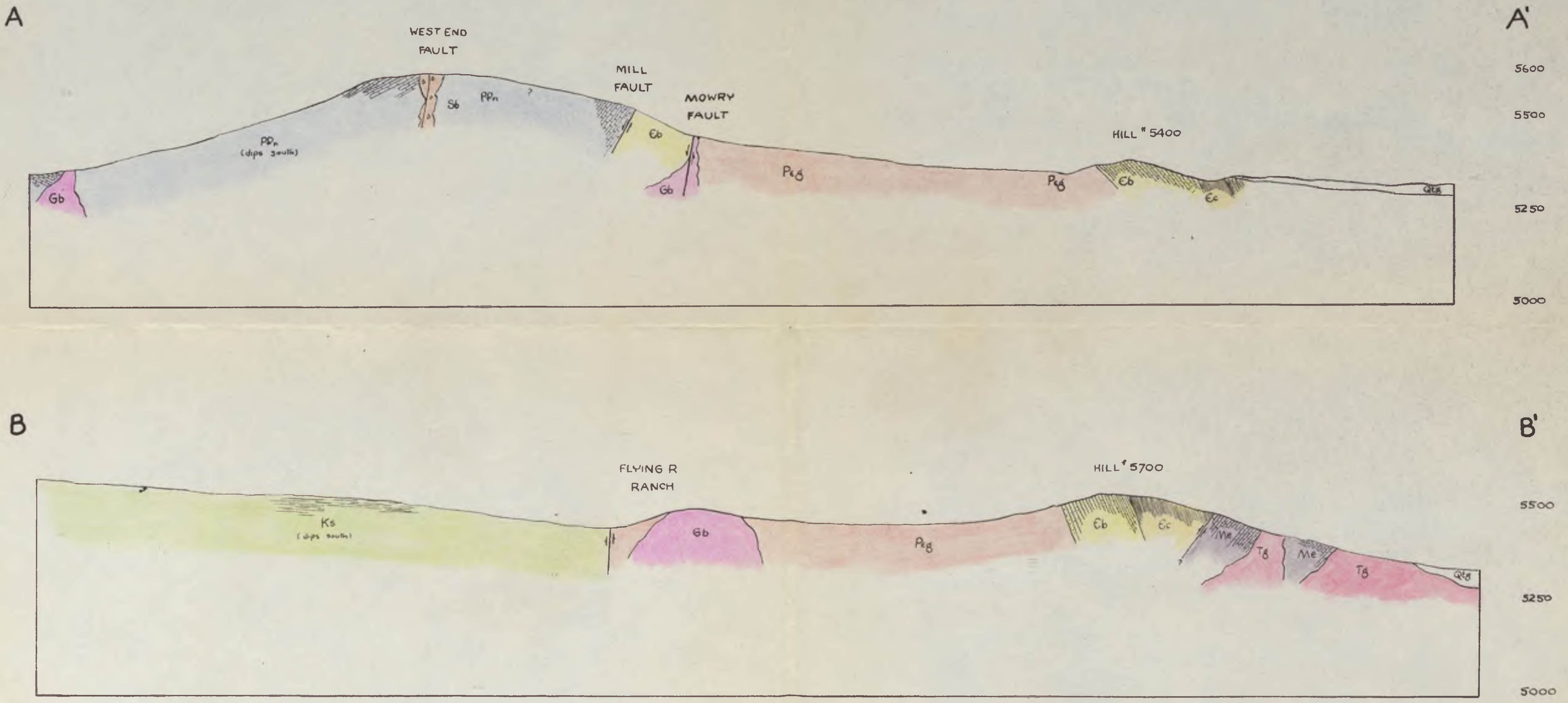
SCALE IN FEET

500 250 0 500 1000 1500 2000

GEOLOGY BY G.E. SMITH, 1955-56

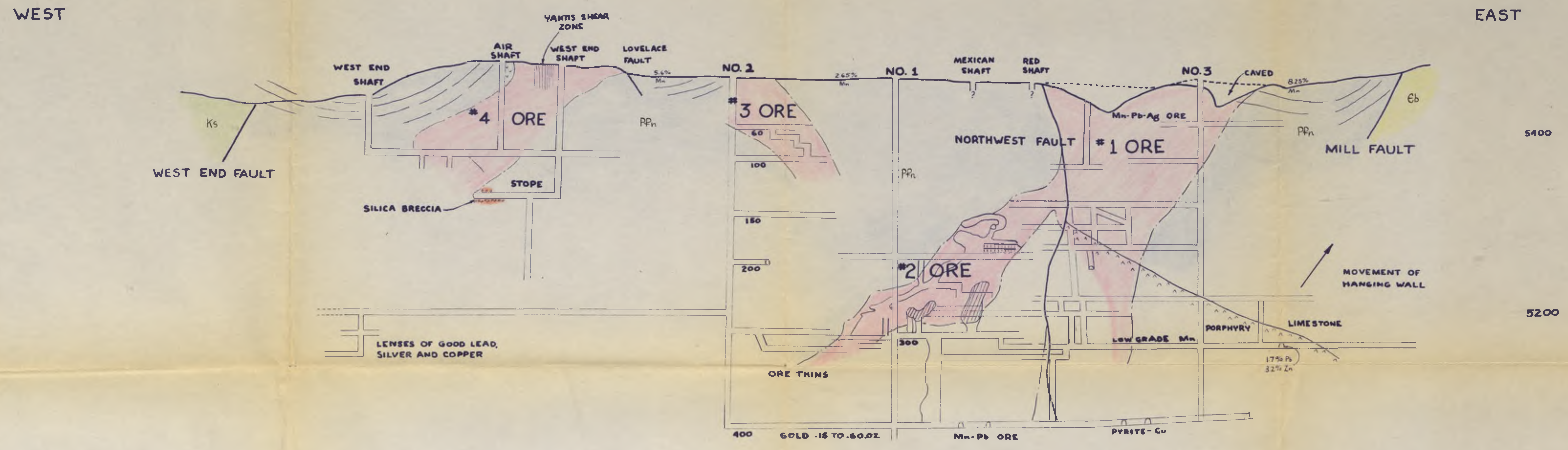
CONTOUR INTERVAL 25 FEET

PLATE II



A-A' = 7500', VERTICAL SCALE DISTORTED

GEOLOGIC CROSS-SECTIONS, MOWRY MINE AREA

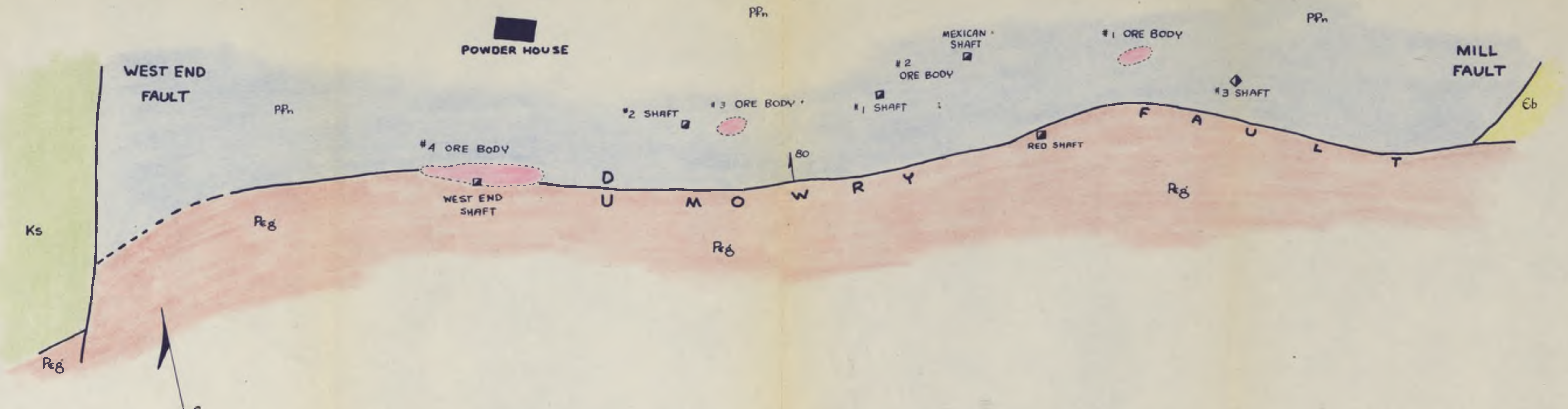


MOWRY MINE

SANTA CRUZ COUNTY, ARIZONA

LONGITUDINAL SECTION THROUGH ORE BODIES

DATA COPIED FROM MAPS BY BILLINGSLEY, LOCKE, MAYO, LOVELACE



LOCATION OF MAJOR ORE BODIES.
MOWRY MINE. SANTA CRUZ COUNTY.
ARIZONA

SCALE: 1 INCH EQUALS 40 FT.

AFTER BILLINGSLEY, LOCKE, MAYO & LOVELACE.

3-56